# RAISING THE LEVEL
# OF
# SCIENCE AWARENESS
# AMONG
# EARLY SECONDARY STUDENTS

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# ABSTRACT

This research develops the concept of science awareness and explores how it can be promoted among early secondary students at school through sustained reflection about one's own beliefs regarding the importance of science, science education, and the engagement with and action on scientific issues. The study consists of two phases: Phase 1 aims at measuring the level of science awareness; Phase 2 pilots a number of activities aimed at raising science awareness among 12-year old students. A survey with a representative sample of 400 Form 2 (year 8) school students, aged 12, in Malta, was used to measure the level of science awareness. This was then followed by focus group discussions. Science awareness was found to be low in particular in the recognition of everyday issues that are related to science and in the recognition of the importance of science education to engage with and act on these issues. Science awareness depended on school type, students' social background, gender and set (track) in science. Students from Independent schools had higher awareness as well as socioeconomic status. School science content is still too detached from everyday life and activities carried out in class are usually teacher-centred. Consequently, early secondary students, do not recognise the relevance of studying science beyond their career prospects. Phase 2 involved the development of a number of learning activities, based on metacognitive reflection and planned to raise science awareness with a small group of Form 2 students. These activties were implemented within the current Integrated Science curriculum. Data were collected through the original questionnaire, students' and teacher's journals. Analysis showed that although an increase in science awareness was observed, in particular with regard to aspects that were originally measured to be low, it can be concluded that beliefs among 12-year olds are already strongly held and for such work to have more effective results, more effort has to be made in earlier years of science education.

KEYWORDS: Science awareness; Metacognition; Scientific Literacy; Beliefs; Science Education; Science for Citizenship

# STATEMENT OF AUTHENTICITY

I, the undersigned, declare that this disseration is based on my original work, and has not been presented in fulfillment of other course requirements  at the University of Malta or any other University.

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Ms. Claudette Azzopardi
*Candidate*

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*This work is affectionately dedicated to my husband Kevin without whose encouragment and moral support it would not have been finalised. I would also like to dedicate this work to my kids Miguel, Alejandro, Jael and Francesco who were a fountain of love and hope when times were challenging.*

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**Preamble**

“I still clearly remember the philosophy of science lecture, as part of my Master in Education degree, during which I was crudely exposed to the subjectivity of science. It felt like a blow. I had just been through a four year intensive Bachelor of Science degree course during which I was alienated with the rigour and details of Physical Chemistry, Analytical Chemistry, Organic Chemistry and the parallel biological areas. I couldn’t quite believe that “the scientific method”, to which I so religously complied or attempted to comply with didn’t actually exist or actually consisted of a number of methods. There were also so many humanisitic factors that could problemitise the objective character of science.

Once I became aware of the complexity of this enterprise called science, I felt that my philosophy had suddenly changed. No matter how hard I tried I could no longer envision myself as a scientist with all the positivist connotations I used to psychologically assign to this role. The word scientist itself became questionable. I felt resentment that no one had shown me this more authentic picture of science before. It almost seemed that I was robbed of a very important piece of knowledge that could have moulded my outlook of science in a different way. It shouldn’t have come to me so late in my education.

By this time I was teaching Integrated Science and Chemistry. Inevitably, at this point, I also started to question the learning that went on in my science classroom. Are we, as science educators, doing a disservice to our students when the main focus of science education is on scientific knowledge and training in the scientific method? Can this be why so many students see science as being too abstract, detached and irrelevant? Weren’t we leaving something amiss by almost ignoring the political nature of science and the skills other than scientific that one needs to deal with science in everyday life? Will a focus on the humanistic aspect of science create the necessary impetus to engage more students with science?

It was then that I started to feel I had to do something to deal with this situation. I didn’t want my students to go through the same educational experience I went through. Teaching science for a science career just didn’t feel adequate anymore because so few students eventually become scientists. What about the rest? Were students studying science simply because it was compulsary? My main personal focus became one of addressing the majority of students rather than the few who want to become scientists, and consequently start teaching science for life. As a teacher, I wasn't in a position to change syllabi but at least I could study ways on how to make students more aware of how science infiltrates their lives, and the skills they need to deal with it as it becomes more important in this day and age. This is the scenario which triggered this study and which gave me the psychological boost to embark on this doctoral journey."

# Chapter 1. INTRODUCTION

This research work addresses the recognition of the importance of science and science education by early secondary students and explores whether it can be enhanced by raising students' awareness of science. This study was based in the Maltese archipelago consisting of three main islands, namely: Malta, which is the largest island and the sister islands Gozo and Comino. Malta, a member of the European Union since 2004, is situated in the middle of the Mediterranean Sea. It defines the southern extremity of the European continent, both geographically and also in cultural terms. Furthermore, it is one of the most densely populated countries in the world and has two official languages: Maltese (a Semitic language) and English.

This introductory chapter summarises the main concerns in science education in Malta that have shaped the research problem addressed. Science education in this study mainly refers to the provision of education and training in science within the compulsory level in Malta (5-16 years) with marginal reference to formal and non formal aspects. Accordingly, a detailed account of science education as embedded in compulsory schooling in Malta is provided for a better understanding of the context. Many changes have occurred in both science education and in the education system in the past decade. The information included is thus correct at the time of writing, i.e. 2017. Additionally, this chapter also presents the rationale of this study. It includes a statement of the research question and provides a brief review of the chapters that ensue.

## 1.1 The State of Science Education in Malta – The Main Challenges

Issues in science education began in Malta in the 1990's, continuing until now, as the careful consideration of the relevance of science education in the quest of scientifically literate citizens gained momentum (MEEF, 2011a; MEEF, 2011b; MEE, 2012). The majority of the school students in Malta like elsewhere in the world do not become science specialists. Thus, the objective of producing citizens with the competencies to deal with issues that have a scientific component has gained more importance than the traditional objective of science education to supply more scientists. However, whether scientific literacy is being achieved is questionable as will be discussed below.

### 1.1.1 Numbers and Level of Student Achievement in and Engagement with Science

The level of science education in Malta is here analysed at two levels. Pencil and paper assessments, both at a national and international level are used to indicate achievement or the final academic performance of the students in science. On the other hand, other data, mainly related to students' attitudes and interests in relation to science and science education are scrutinised to see how the levels of achievement compare to the degree to which students feel they are engaging with science.

A thorough cross-examination of science education in Malta was triggered by the country's participation in worldwide recognised assessments in science education such as: the *Programme for International Student Assessment,* PISA and the Trends *in International Maths and Science Survey*, TIMMS. **Table 1.1** represents a summary of some of the most important results obtained in three sessions of TIMSS and twoPISA audits. These results show that at different stages in their science education, Maltese students lag behind the majority of EU and other countries in mastering: academic science content (Life Science, Physical Science, Earth Science); cognitive skills (Knowing, Applying and Reasoning) (MEE, 2013a); and scientific literacy aptitudes; to address real life challenges (MEE, 2013b). Not only did Malta have fewer students in the upper percentile, but a high proportion of students were at, or did not even achieve, the lowest benchmark in these standardised international assessments. These results were even more worrying since Malta is a small island with very limited natural resources. Human resources are considered to be the pillar of Malta's economy and education is also the vehicle through which to achieve a fair, just and more equitable society (Camilleri, 2013). Any failings in the outcomes of education are thus a great national concern.

**Table 0.1: Comparing TIMSS and PISA results for Malta**

| **Data** | **TIMSS 2007** (Gonzales *et al.*, 2008) | **TIMSS 2011** (MEE, 2013 a) | **TIMSS 2015** (MEE, 2016b) | **PISA 2009+** (MEE, 2013b) | **PISA 2015** (OECD, 2016, MEE, 2016a) |
|---|---|---|---|---|---|
| **Age** | 13 | 9 | 13 | 15 | 15 |
| **Overall ranking in science** | 30th out of 48 countries | 40th out of 50 countries | 22nd out of 39 countries | 40th out of 74 countries | 39th out of 72 countries |
| **Comparison with EU countries** | All EU countries performed better than Malta except Romania and Cyprus | All EU countries performed better than Malta. | All other EU countries performed better than Malta. | All EU countries performed better than Malta except Bulgaria and Romania | All EU countries performed better than Malta except Greece, Cyprus, Bulgaria, and Romania. |
| **Percentage below lowest benchmark** | 29% | 30% | 16% | 14.1% | 31.5% (below level 2) |
| **Gender differences** | No significant gender differences in achievement | Boys performed significantly higher than girls | Girls performed significantly better than boys | Girls performed significantly better than boys. | Girls outperformed boys. |

The results of Secondary Education Certificate (SEC) Exams, the national school leaving examinations for science subjects show similar trends as shown in **Table 1.2**. In the past four years, an average of a third of students who sat for science SEC exams did not achieve a Grade 5 which is the minimum grade needed to further study in this area. Moreover, only 14.5% of the students sit for exams in the three sciences. Most students sit for one science subject, most commonly Physics. Results have shown time and time again that achievement in science is strongly related to the type of school that students attend. Independent Schools perform best, followed closely by Church Schools. Students attending State Schools are faring worse (MEE, 2013b). Another factor is the economic, cultural and social status which influences attainment in science which is in itself related to the type of school (*ibid.*).

**Table 0.2: Comparing percentages of students who did not achieve Grade 5 in SEC science subjects**

| SEC May session (% below Grade 5) | Physics (%) | Chemistry (%) | Biology (%) |
|---|---|---|---|
| 2013 | 32.2 | 25.4 | 34.4 |
| 2014 | 36.6 | 28.4 | 39.5 |
| 2015 | 35.5 | 24.7 | 38.1 |
| 2016 | 30.5 | 23.4 | 34.9 |

Results obtained with respect to adults' scientific knowledge and perception of science also point at shortcomings in this area. Eurobarometers regarding science and technology provide a snapshot of the Maltese citizens' scientific knowledge and perceptions of S&T across the last decade. **Table 1.3** shows that although Maltese citizens believe in the potential of science and are interested in it, they are poorly informed about science and issues that may arise from it.

The shortcomings in achievement identified are related to problems in engagement. An explanatory study amongst 15-year olds in Malta (Azzopardi, 2008), based on *The Relevance of Science Education*, ROSE questionnaire (Schreiner & Sjøberg, 2004) showed that, although students understand the importance of science and science education for their lives, many considered studying a science subject simply because it is an entry requirement for post-secondary courses. They also believe that they should not be forced to study subjects they are not interested in or which they do not need for their careers. Very few students in Malta wish to become scientists. This finding is similar to that of other countries which participated in the ROSE study and which have a high Human Development Index (HDI) (Schreiner & Sjøberg, 2007; Sjøberg & Schreiner, 2005).

**Table 0.3: Comparing Eurobarometer results about S&T for Malta since 2001**

| EU studies | Date | Main result |
|---|---|---|
| Special Eurobarometer 224: *Europeans, Science and Technology* (EC, 2005) | 2005 | Malta was found to have one of the lowest number of people with good scientific knowledge in relation to other EU countries. However, the Maltese are the most enthusiastic about scientific research and what it can achieve in the understanding of the universe and to improve our quality of life. They are also very interested in issues of science in the news. (EC, 2005) |
| Special Eurobarometer 340 *Science and Technology* (EC, 2010) | 2010 | Although Europeans feel that the general public should be consulted by scientists, the majority are not active in issues of science and technology. They also feel that they should be more informed re issues of S&T they are interested in. Again Malta tops the list re science makes our lives easier and more comfortable. (EC, 2010) |
| Special Eurobarometer 419 *Public Perceptions of Science, Research and Innovation* (EC, 2014) | 2014` | More than half Europeans, including the Maltese have studied science and technology. This is more likely if the age is younger and higher up the social ladder. In Malta, health and medical care are considered to be a priority for science and technological innovation in the next 15 years. Respondents agree more that science and technological innovation rather than people's behaviour will have a positive effect in the issues tested. There were several areas for which the Maltese were not able to share an opinion. (EC, 2014) |
| Eurobarometer Qualitative study – *Public Opinion of Future Innovations, Science and Technology* | 2015 | Although optimistic about future innovations, they are also aware of the negative impact these may have on our lives. Malta is one of the group of countries with low interest, less informed about science and less positive about the positive impact of science on society. (EC, 2015) |

The same study (Azzopardi, 2008) has also shown that the content of traditional science subjects tends to instil negative affective attitudes towards science amongst students. This is substantiated by other national (Baldacchino, 2010; Sultana, 2011) and international studies (Lindahl, 2003; Lyons, 2006; Osborne & Collins, 2003). Students refer to: the unnecessary difficulty of school science; the heavy mathematical aspect; the transmissive teaching methods used that leads to what Kessels *et al*. (2006) call a perceived heteronomy of the subjects that does not provide space for discussion and creativity; and the irrelevant, decontextualised content as reasons for their disenchantment with science school subjects.

National studies indicate that dislike towards science seems to increase with age (Baldacchino, 2010; Camilleri, 1999; Gafà & Grima, 2000). The steepest decline in attitudes towards science in Malta coincides with the subject specialisation that takes place at the end of early secondary schooling when the students are 12 years old (Borg, 2013). At this stage, the element of fun associated with the ‘easy’ science taught in primary and early secondary years, is replaced with boredom and fear often associated with difficult science exams (*ibid*.). International studies also show similar trends with age. While interest in science is reported to be high at age 10 (Haworth *et al*. 2008), a steep decrease in attitudes occurs between ages 11 and 14 (Bennett & Hogarth, 2009; Galton *et al.,* 2003; Osborne & Collins, 2003). Some also argue that the decline even starts before secondary school (Harlen, 2008; Pell & Jarvis, 2001).

The disenchantment with school science goes beyond the boundaries of secondary school, to be reflected in the recruitment of students at higher academic levels and ultimately in choosing a science career. Statistics show that the number of students following pure science courses at the University of Malta is less than that in other courses. For the academic year 2015/6, only 447 students were enrolled in courses with the Faculty of Science when compared to 1294 and 1781 reading a course with the Faculty of Arts and the Faculty of Economy, Management and Accountancy respectively. More science students are preferring applied science courses as shown by the high figures attending the Faculty of Health Sciences (1278) and the Faculty of Medicine and Surgery (1122). There is also a high dropout rate among Bachelor of Engineering and Bachelor of Science students in particular due to the difficult transition from post-secondary courses (Vella, 2014).

The shortcomings in primary and secondary science education seem to reverberate at university level. In fact, Vella (2014), called for a need for better communication between postgraduate entities and university, and furthermore called for the restructuring of science courses, such as Bachelor of Science and that of Engineering to become more student–centred, of a less monologue-type, more hands-on and with more support in terms of the development of coping skills strategies for the students.

### 1.1.2 Shortcomings in Science Education in Malta

Shortcomings in the provision of science education in Malta, are found as early as the primary years due to class teachers who are not science specialists and thus who lack confidence in teaching science, present it through didactic methods (Chetcuti, 2009; Falzon, 2003; MEE, 2013a; Vassallo, 2010) and furthermore do not dedicate enough teaching time to the subject (Vassallo & Musumeci, 2012). Although science peripatetic teachers (visiting teachers) are expected to support class teachers, they have minimal contact with them as the latter expect the former to carry out the science teaching when they visit schools (MEEF, 2011b). Some science educators are even calling for an education in science by mothers and carers through basic life processes prior to the initiation of formal schooling (Tunnicliffe, 2013). This area is still in its infancy in Malta.

As stated above, although at secondary level science subjects are usually taught by science specialists, there are still other problems in addition to the boredom and difficulty usually associated with the traditional science subjects. National studies (Buhagiar, 2008; Debono, 2007) have shown that at age 12, students are still too young to make subject choices as they do not yet know what they want to do in the future. At this age, there is a strong influence by their relatives and friends, which might decrease if subject specialisation is deferred to a later stage. Consequently, as things stand, students who are related to someone in a science career are more likely to follow suit (*ibid.*). Many of the rest are encultured to accept that science subjects are difficult and are only for the brighter ones (Hili & Zammit, 1998). The availability of information about the worth of science with respect to employment and the flexibility of science qualifications for career advancement are important for science uptake. In Maltese schools, although guidance teachers are in a position to provide this information, they do not usually provide a full picture and tend to limit information to traditional science careers (Debono, 2006; Debono, 2007).

Following subject choice at the end of the second year of secondary education (age 12), there is still no distinction between science subjects for science specialists and those aimed at basic science literacy for the general student. Although it is recognised that the aim of science education in Malta should be twofold, the same pedagogies and assessment techniques are still used to address both goals (MEEF, 2011b). “Asking the school science curriculum and teachers of science to achieve both of these goals simultaneously places school science in tension where neither goal is served successfully” (Osborne & Dillon, 2008, p.7).

In spite of numerous science education policies that underline the importance of *Scientific Literacy* (AAAS, 1993; NRC, 1996) and more recently *Science for Citizenship* (EC, 2015), in many developed countries including Malta this tension has not yet been resolved. Science education is still viewed by Maltese political leaders from a narrow neoliberal perspective as is promoted by the EU (Zahra, 2013). This implies that even if scientific literacy is the ultimate goal, the driving force to introduce appropriate pedagogies to address this aim is an economical rather than a societal or emancipatory one. This outlook views schools as performative spaces where curricular and teacher reforms are controlled to showcase the economic prowess of the country in international audits and standardised tests.

Carter (2008), argues that this neoliberal perspective is leading to the majority of students being excluded from science. The exclusion of the majority was in fact highlighted by the TIMSS and PISA results. These results have shown that nationally there is a significant percentage of students who are not even achieving the lowest benchmark. The traditional school science subjects still favour the minority of students who wish to specialise in science and in fact attitudes towards science at the end of secondary schooling are recorded to be more positive as the number of science subjects studied increases (Azzopardi 2008). In several Maltese schools, students who do not wish to specialise in science have to succumb to national and school policies to choose Physics when they believe that they should be studying Biology as this would be more practical and relevant to their lives. In addition, it has been shown that students who are less academically-oriented actually have more everyday experiences where they participate in activities in which they interact directly with the natural world or in which they have to deal with technological artefacts (*ibid.*). These interests are not usually addressed through the more academically-oriented science subjects.

Marginalisation from school science is also accentuated by language issues such as English which is the language of instruction for science subjects, where 88% of the students speak their native language (Maltese) at home (MEE, 2013b). According to Mifsud (2012), for Integrated Science, English is used only in high achieving classes while codeswitching is the order of the day in the majority of classes. “Using Maltese during science lessons introduces extensive language mixing, which may be negatively affecting students’ already weak proficiency in English” (p.66). Such language barriers have also been noted in other countries where the first language used by the students is not English (NSF, 2014).

Through traditional teaching of science subjects, the political aspect of science is not addressed and this can be observed through the image of scientists portrayed by students. In Malta, as in other countries, studies have shown that secondary school students embrace a traditional image of scientists (Azzopardi, 2004) which is highly influenced by school science and science teachers (Degabriele, 2008) but also the portrayal of scientists through films and other media (*ibid.*, Borg, 2004; Obidimalor Munro, 2006). Scientists are usually viewed as male, serious individuals, isolated in labs and doing some kind of research. This image emerges from the positivist stance in which science education and the media portray scientists as the producers of knowledge and the students as consumers. It is no wonder that students fail to see the human and political aspect of science which acknowledges the scientists' interplay with other specialists, government bodies, businessmen and society at large.

### 1.1.3 Challenges beyond Schooling

Although, at first glance, low achievement and uptake of science seem to stem primarily from the impact or boundaries presented by school science, issues have shown that the problem is more complex and more strongly influenced by the socio-cultural features of the current youth generation (Boe *et al.*, 2011; Schreiner & Sjøberg , 2007)

A significant international finding in this respect is the philosophy that science is 'important but not for me' (Jenkins & Nelson, 2005) that seems to become more pronounced, the higher the Human Development Index (HDI) of a country. Although students acknowledge the usefulness of science, they, especially girls, tend to prefer other school subjects to science as they allow more space for discussion. This negative relationship between the engagement of secondary students with science and the development of a country was first tracked during data collection of the ROSE project (Sjøberg & Schreiner, 2004). Malta is considered to have a high HDI and the related 2016 United Nations report placed it 33rd out of 169 countries. In fact, as expected this conflict in attitudes was also confirmed nationally in a ROSE-based study carried out in Malta (Azzopardi, 2008).

With their fixation on the self, many students see the *utility* value of science only in relation to the benefit it offers in terms of career goals (Osborne & Collins, 2001). They fail to recognise the utility of science and science education beyond their individual aspirations. In fact, in Malta it was observed that 15-year olds resent the introduction of socioscientific issues in their education, e.g. those related to the environment, and prefer areas that are more related to the self, e.g. health issues (Azzopardi, 2008). There is a need to help students recognise that science is also having an enormous impact on their social and global lives. They have to be shown the need to be prepared to make informed decisions regarding scientific issues such as food and water shortage, environmental degradation, global warming etc. that have an impact that threads beyond the self and which are threatening the sustainability of our planet.

The sociocultural arguments above can be further understood if appreciated in the recent move towards stretching Bourdieu's theory of social reproduction, that was largely arts-based, to encompass the acquisition of science capital. Bourdieu (1984, 1986) sees capital as resources that can result in social advantage within particular fields such as education for those who have them. Bourdieu (1986) distinguishes between four types of capital, namely economic (financial resources), social (social networks), cultural (qualifications, dispositions and cultural goods) and symbolic that work together to determine a person's position in a given field. Archer *et al*. (2015) make a case for the recognition of scientific forms of social and cultural capital that have been given only marginal importance in Bourdieu's original conception of capital. Families with more science-related resources have been found to sustain their children's interest by providing science kits, watching and discussing science TV, discussing science in everyday conversations, visiting out-of-school science-related contexts, etc. (Archer *et al*., 2012). More science capital is also conferred by families who know someone who works in a science job or where the parents have science qualifications.

Right now, school science values reflect those of the dominant scientific elite privileging the production of the next generation of professional scientists rather than seeking to produce scientifically literate citizens (Claussen & Osborne, 2013). Hence science capital can be translated into educational advantage mainly by those who can do science in ways closest to the type of science privileged at school. This leaves many marginalised. In fact, in an attempt to measure the science capital of 11-15 year olds in England (Archer *et al*., 2015), it has been found that science capital aligns with other forms of cultural capital in that only 5% have high science capital while 27% fall into the low science capital category. The latter are considered to have " lower levels of scientific literacy, less confidence in their skills and abilities, less engagement with out-of-school science activities, and whose family/social networks tend to include people in science related jobs" (*ibid.,* p.936). These results are useful to this study in that measures to achieve equity and more participation in science education can go beyond the obvious by providing students with a 'better' science capital. As in this study, they can be channelled to elevating components of science capital, such as scientific literacy to symbolic forms of capital that endow one with social privilege.

## 1.2 The Maltese School System and Recent Reforms

In understanding the context within which this study was conducted, it is considered important to describe the overall structure of the Maltese education system and reforms which have been implemented during the data collection process.

### 1.2.1 The Educational System in Malta

Compulsory schooling in Malta is of a duration of 11 years, consisting of 6 years of Primary Education (ages 5-11; Year 1 – Year 6) and 5 years of secondary (Form 1 – Form 5 equivalent to Year 7-11). Even if not compulsory, the great majority of children receive education prior to the compulsory age in several kindergartens and childcare centres. In Malta, there are three types of educational providers: State (60%); Church (30%); and Independent (private) Schools (10%). State provision includes 67 primary schools which are co-educational and 22 secondary schools which up to September 2014 were single-sex. Co-education in secondary State Schools was introduced in 2015. Church Schools are mainly single-sex both at primary and secondary level although there are some co-educational primary schools. Independent Schools are mainly co-ed.

Following the Church Schools Agreement in 1991, State and Church Schools are presently non fee-paying, yet in Church Schools parents are only expected to give a donation as the government funds staff costs. Independent Schools are all fee-paying. Despite tax rebate benefits, Independent school fees are too expensive for many (Camilleri, 2012) and therefore attract mainly elitist families with a high socioeconomic status (Cachia, 2014). Each year, there is heavy participation in the ballots for entry into Church Schools as this is considered by many parents as the best, cheaper alternative one can get to Independent Schools. Independent Schools are highly regarded due to the good results they attain in several areas (MEE 2013a, MEE 2013b) and as they are known to set innovative trends in education (Camilleri, 2012).

During the course of this study, schooling in Malta has undergone significant reforms concerning the transition from primary to secondary schools. Up to June 2010, just before this study was commenced, all students at the end of primary schooling in State Schools sat for a highly selective Junior Lyceum (JL) exam (the equivalent of an 11+ selection exam). Those who succeeded attended Junior Lyceums (Grammar type schools) which were set up by the State in 1981 to provide a complimentary opportunity for the academically talented and gifted students (MECYS, 2008). Those who did not pass or did not sit for this examination were admitted to an Area Secondary (AS) school in their area.

Although the percentage of students who made it to the JL's increased throughout the years (MECYS, 2008), this system proved to be highly selective, promoted prestige education and led to a lot of pressure on the students, their families and schools themselves (Cassar, 1991). In an attempt *For All Students to Succeed* (MEYE, 2005), in February 2008, all primary and secondary State Schools were clustered geographically in 10 colleges under the direction of College Principals. Additionally, in June 2011, the Junior Lyceum exam was eradicated and the pupils attending State Schools now pass on more smoothly from a primary to a secondary school within the same college. The main target of this reform was to enhance the autonomy of schools so that they could improve their outcomes through the more decentralised college administration (*ibid.*). Today, State and the majority of Church and Independent school pupils at age 11 sit for the End of Primary Benchmark assessments whose function is now more to inform rather than select the learners.

In the Church sector, the issue of non-continuity affected the majority of boys' schools since most of the girls' schools were and are still continuous. Up to June 2010, boys attending primary Church Schools also used to sit for a selective 11+ 'common entrance' exam to secure a place in a secondary Church school. As part of the reform in transition from primary to secondary school, the Common Entrance exam was also eradicated and all children attending a primary Church School now automatically progress to Church secondary schools. Independent Schools were immune to these transitions as most were already continuous and non-selective on basis of ability.

These transitions are very significant to this study as the first part of data collection of this research was collected from a representative sample of Form 2 students in May 2012. This was the last cohort of students who sat for the JL and common entrance exams. The rest of the data were collected after this date and thus from students who did not have to go through the selective process at age 11.

Whatever school type attended, at the end of secondary schooling, students sit for Maltese-set Secondary Education Certificate (SEC) examinations. They can then choose to either do two years of study for entry into University or follow vocational education courses.

During the course of this study, there was also the establishment of a new National Curriculum Framework, NCF (MEE, 2012) that became law in 2012. One of the main outcomes of this endeavour was the proposal of a Learning Outcomes Framework (LOF) as the fulcrum of learning and assessment during compulsory schooling. The aim of the LOF's is to compliment the colleges system and to liberate schools and learners from centrally-imposed knowledge-centric syllabi. Although the LOF's have been drafted for several subjects, to date they have not been implemented in schools.

### 1.2.2 Formal Secondary Science Education in Malta

Science education provision in secondary schooling (ages 11 – 16; Form 1 – Form 5) is more or less uniform across State, Church and Independent Schools in Malta. In Forms 1 and 2, all students have 4 lessons of Integrated Science per week.

The three science subjects studied from Form 3 onwards are Physics, Chemistry and Biology. Students are expected to start specialising in science at this stage by choosing to study one, two, or three science subjects. Although a pass in any science subject is now accepted for further studies at post-graduate level, Physics remained a compulsory science subject for some time in most schools especially State School. Other types of schools usually allow greater freedom in opting for any of the three science subjects (Zahra, 2015).

All secondary school pupils, regardless of their degree of science specialisation study one science up to the end of Form 5. In most schools, the science syllabi, schedules, exams, marking schemes, and textbooks are determined by the Matriculation and Secondary Education Certificate (MATSEC) board and therefore all pupils in Malta have practically the same exposure to secondary science education. Data collected in this study focuses on Form 2, the year before students decide whether to take science specialisation within the science education system described here. The reason for choosing this cohort will be discussed in more detail at in the methodology chapter.

## 1.3 Malta's Vision for Science Education

Of direct relevance to this study are the most recent changes that have resulted or are being proposed in science education in Malta in the light of the National Curriculum Framework NCF (MEE, 2012) in a bid to engage more students in science. The major principle on which the NCF is based is that all children are entitled to quality education in order to reach their full potential as individuals, as well as Maltese and EU citizens.

A new vision for science education within the framework of an updated National Curriculum (MEEF, 2011a) was published in 2011 (MEEF, 2011b). This document argues in favour that as much learning time should be allotted to Science and Technology, as to Maths, in the junior years and the early secondary years. It also commits to inquiry-based competencies needed in the development and application of solutions. The most important change suggested is the introduction of a Core Science Curriculum that starts in Forms 1 and 2, and continues throughout secondary schooling, unless the students go for the science option. The aim is that more students, especially those who do not want to specialise in science, become scientifically literate by providing them with a more balanced content organised in themes that bring together knowledge from different areas. To date (2017), this proposal has not yet become fully implemented even if learning outcomes for the new syllabi have been drawn up. Separate subjects are still taught to all students at higher forms.

In the meantime, a new Integrated Science curriculum (DQSE, 2012) was implemented in schools in Forms 1 and 2 to promote more self-directed and lifelong learning and to meet the different needs of the students (*ibid.*). In contrast to the previous one, this curriculum provides guidance for teachers regarding the learning methods that can be used, any necessary resources, internet links and the time that should be dedicated to the respective topics. The curriculum divides each topic into nine sessions which last approximately forty minutes giving a total of six hours per topic. Each topic is further split up into two: the lower levels of attainment (levels 1, 2, 3 and 4) and the higher levels of attainment (levels 5, 6, 7 and 8). This allows teachers to adapt their lessons according to the achievement levels of their students.

A study carried out to capture students' and teachers' views regarding the new, local Integrated Science curriculum following its first year of implementation (Glynn, 2012), showed that both teachers and students agree that it is an interesting and stimulating curriculum. Students also point out that in general they have no problem in understanding implying that teachers are preparing lessons at the appropriate levels. Methods used include discussions, demonstrations and experiments. Teachers pointed out that one of the main restricting factors is time. The various extracurricular activities organised in schools limit lesson time and in particular the number of student centred inquiry based activities that can be carried out during science lessons. This results in disparities between the intended, planned and the received curriculum (*ibid.).*

Through this curriculum, students are also expected to "develop their competencies to communicate science and link science to everyday life. Science allows students to understand the human impact on the environment, understand and appreciate the natural, social and cultural environment, and gain the necessary skills to become active participants in the process of sustainability through the promotion of community awareness about sustainable lifestyles" (DQSE, 2012, p.9). However, teachers still view this curriculum more as the route to move onto higher levels of academic science at SEC level (Glynn, 2012). In parallel, many students fail to see the relevance of what they are learning in their science classrooms for their everyday life (Borg, 2013; Glynn, 2012). Teachers tend to undermine the role that they have as professionals to instigate change and to transform science into a subject that is essential for everyday life (Chetcuti, 1992; Glynn, 2012). This psychological leap will be specifically addressed in this study.

The curriculum teaching blocks for Form 2 are: *Healthy Living (1): Go for Everest; Healthy Living 2: Life Cycle Challenge; Elements Compounds and Mixture ; Elements, Compounds and Mixtures 2; Separating Mixtures; Light and Sound; Ecological Relationships; Forensic Science; Climate Change 1 (Energy and the Environment); Climate Change 2 (Environmental Chemistry); Earth and Space 1; and Earth and Space 2*. Boys tend to prefer *Earth and Space* while girls prefer *Forensic Science*. *Climate Change* is the least preferred topic (Glynn, 2012).

The textbook most frequently used for the new syllabus is KS3 Science (Collins). It is a textbook with plenty of ICT backup, including an online version of the book and a backup interactive CD featuring also virtual experiments. It also has 'levels', that do not match the syllabus levels, but that allow for some differentiation. It is peppered with a multitude of references to real-life situations, as well as many hands-on activities that stimulate teachers out of the rut of lecturing science and which expose students more to the process of science. A similar textbook used in some schools is *Exploring Science.* (Publisher: EDCO). In addition to several of the features mentioned above, this textbook also includes issues or questions that may be used for debates or discussion as well as timeline boxes to show how the work of scientists developed over time.

### 1.3.1 Science Popularisation Initiatives

In the last decade or so, there have also been several initiatives undertaken to make science more popular amongst the Maltese population. The Malta Council for Science and Technology, (MCST) is the main public body responsible for science popularisation. Initially, e.g. in 2009 and 2010, events were in the form of Science & Technology Festivals usually held on campus at the University of Malta. The main aim was for students to have fun and concurrently learn scientific concepts by interacting with various exhibits and displays. Most of these festivals were very well attended by students and adults alike (MCST, 2010).

More recently, most of the effort for science popularisation by MCST was focused on an Interactive National Science Centre (MCST, 2011), *Esplora,* which was officially inaugurated in late 2016 (www.esplora.org.mt ) and which is intended to teach, entertain and instil interest in science. The centre includes a science communication hub, science shows, hands-on exhibits, a planetarium, interactive workshops and under 7's area. It is also reaching out to schools and other establishments.

An important activity, which has been organised annually by the Malta Chamber of Scientists and the University of Malta for the past few years, is *Science in the City* (www.scienceinthe city.org.mt). This daylong event which takes place in Valletta, the capital city, is a joint collaboration between Maltese scientists and artists. Through a range of science experiments, live shows such as plays, and fun activities, it encourages young people to build on Malta's cultural legacy and to develop the scientific skills to improve their quality of lives.

Science popularisation is also one of the objectives of the National Students Travel Foundation, NSTF (www.nstfmalta.eu). An annual contest and exhibition of science projects was organised annually for different age groups of students for a number of years. The winners usually take part in international events, such as the International Youth Science forum, the International Wildlife Research Week, and the EU contest for Young Scientists.

## 1.4 Rationale

In the light of the scenario described above, this study addresses the challenge of engaging more students in science by focusing on students' science awareness prior to subject choice and their level of motivation to engage with science specialisation at school. Raising awareness of the importance of science and science education in this way will target many of the national problems in science education, namely: poor achievement in science exams and in international science surveys; low participation of students in school science beyond the compulsory level; students' negative personal attitudes towards science; the exclusion of the majority from science through language and socioeconomical background and inaccurate images of scientists amongst students addressed earlier.

Although literature on science awareness is quite limited, one can draw several characteristics that distinguish it from other educational targets. Science awareness is considered to be a precedent in affective engagement to higher educational goals like scientific literacy and science for citizenship (ASTA, 2004; Rusli, 2010; Stocklmayer & Gilbert, 2002). In an age of booming technology, science awareness is considered to be a more realistic goal and which thus may be achieved by a larger number of students (Rusli, 2012; Shamos, 1995). Additionally, the definition of science implied is one that is technologically applied.

The concept of science awareness used in this study also encompasses these features. However, to avoid overlap with other educational targets, it is taken to be more rooted in the psychological aspect of the concept and is thus restricted to beliefs. Science awareness in this research does not include any understanding of concepts or exhibits of particular behaviours which are sometimes expected by other definitions (ASTA, 2004; Rusli, 2010; Shamos, 1995). Although Rusli (2010) uses *science awareness* and *scientific awareness*, the former was chosen as the key word for this study as the latter may imply the acquisition of general scientific skills (Rusli, 2010) as in being observant, logically critical etc. (Rusli, 2012).

The main objective of this study is to gauge and explore the level of science awareness amongst Form 2 students and then to design a number of school-based learning activities that can be used to increase science awareness. In this study, science awareness is understood as: **a personal attentive recognition:**

- **of the increasing impact of science and technology on individual lives and on society;**

- **of the range of competencies, values, knowledge and attitudes that are essential to be able to engage with and act upon issues having a science/technological component; and**
- **that science education can contribute to the development of these competencies, values and attitudes.**

This definition of science awareness was derived from a thorough literature review regarding science education for the general student and that of the psychology of awareness. The concept of science awareness is discussed in greater depth in the literature review chapter. According to the expectancy-value model of achievement-related choices (Eccles *et al.* 1983), augmenting the strength of beliefs in the value of science can lead to more students opting to engage, persist and perform better in science. Fishbein (1963, 1967) also relates beliefs to the formation of attitudes. Since science awareness is based on beliefs that students have about science and science education, it is thus considered to have the potential to provide the appropriate cognitive base for the formation of positive judgemental attitudes towards science; scientific literacy; as well as science for citizenship. If efforts are made to strengthen students' beliefs of the importance of science, technology and science education, or of the *utility of science* in their everyday life at all its levels, more students can be expected to have the predisposition to learn enough science to become scientifically literate and to attain the values to act as responsible citizens (George, 2006). Raising science awareness in this sense may also target relevance as it makes science education and youth identity construction more compatible. It can offer students a new vision of why science matters and that science education can open the door to a multitude of possibilities for self-realisation that go beyond the attainment of a career. This can also hopefully result in a shift in those components of science capital that result in more prestigious symbolic capital. It is for these reasons that it was considered worth exploring and investigating 'science awareness' in this study.

## 1.5 Research Question

The main focus of this research was to obtain an insight into the level of science awareness among Maltese secondary students in Form 2 (age 12, Year 8), and based on this knowledge, then developing and trialling some learning strategies and suitable assessment techniques to augment ***science awareness*** at this stage.

In fact, the main research question was the following:

**WHAT IS THE LEVEL OF SCIENCE AWARENESS AMONG FORM 2 STUDENTS AND CAN IT BE AUGMENTED THROUGH SCHOOL SCIENCE?**

This question was firstly targeted through a thorough literature review to shape the definition of science awareness that guided this study. Next, mixed methodology was used to gauge the level of science awareness of Form 2 Maltese students. Based on the findings from the prior stages of the study, six activities related to the sections of a slightly modified version of the Integrated Science curriculum (DQSE, 2014) originally launched in 2012 were then planned. These were trialled by the teacher/researcher with a group of Form 2 female students in a Church school during the scholastic year 2015/2016. Various data collection instruments such as the original questionnaire and students' and teacher's journals were used during this stage of the research.

The main reason why Form 2 students (average age 12) were chosen is that this group presents an age where research has shown that students' attitudes towards science are on the decline but have not yet become established (Bennett & Hogarth, 2009; Galton *et al.,* 2003; Osborne *et al*., 2003). At this age, science awareness can therefore be used to target attitude formation. Although attitudes towards science would probably have started to form much earlier (Lindahl, 2003), a younger age group was not considered so as to ensure that all the students in the study had received a regular exposure to science education as when this study commenced, science lessons were still quite scant in some primary Maltese schools (Azzopardi, 2008). Form 2 is also the school year at the end of which Maltese students opt whether to specialise in science in secondary schooling. This initiative will give students at this critical stage, a more authentic exposure to the relevance of science and science-related opportunities than the solitary ones provided by guidance services.

In Malta, there is as yet no distinction between science education for science specialists and that to achieve general scientific literacy. Thus, this study will also explore the possibility of targeting science awareness in parallel to the acquisition of traditional science concepts in science classrooms. Although some may see this approach as creating a tension in the objectives of science education (Osborne & Dillon, 2008), one cannot ignore the fact that the experience of school science is more influential on students' beliefs than their perceived importance of science in society (Azzopardi, 2008). This supports the argument of using school science to pursue science awareness. Cech (2014) also argues that focusing on the social awareness in science curricula is important and should not be treated separately in ethics courses or given tangential treatment (Cech, 2014). Depoliticisation of science curricula and the assumption that technical competencies have more value than social ones are leading to disengagement. Cech (2014) stresses that such learning objectives should also be addressed in marked homework and exams.

It is believed that teaching for science awareness will also lead to the development of learning strategies and assessment techniques specifically designed for the general student in the journey to achieve scientific literacy. Although work has been done to achieve scientific literacy (Roth & Lee, 2004; UNESCO, 2000), very little work has focused specifically on science awareness which may help students have a better disposition towards engaging more deeply with personal and social scientific issues later on in their life.

The story of this research will unfold in the following chapters. **Chapter 2** provides a critical account of the theories and studies that were used in shaping the definition of science awareness. **Chapter 3** includes an outline of the methodology employed to measure science awareness in this study while **Chapter 4** is the analysis of the quantitative and qualitative results obtained in the quest to gauge the level of science awareness amongst Form 2 students. The framework used to design the learning activities aimed at raising science awareness is then described in **Chapter 5**. This chapter also includes a description of how they were implemented in a particular setting and any challenges that had to be addressed in the process. **Chapter 6** provides an analysis of the piloting of the learning activities described in the previous chapter. The final chapter, **Chapter 7** takes into account all the feedback obtained in order to discuss the implications of this study.

# Chapter 2. THEORETICAL PERSPECTIVES

## 2.1 A Cultural Overview

Science education in today's world can only become relevant if seen within the cultural context in which students are growing up. This section considers education from current cultures in Western, modern societies that are increasingly being shaped by: the impact of world media; globalisation and neoliberal philosophies; democratic principles and active citizenship; and scientific and technological advances. The qualities expected by individuals experiencing these driving cultural forces are also delineated.

### 2.1.1 A Media-Driven, Participatory, and Reflexive Culture

The culture of 21st century societies traverses beyond conventional definitions of the concept of a "concrete world of beliefs and practices" (Sewell, 1999, p.39). These traditional characterisations provide quite a limited and static idea of culture (Roth, 2007) as here cultural components are considered to be internalised *de facto* as the word of the father is transmitted via unchallenged *authoritative discourses* (Bakhtin, 1981). They are passed on from 'old-timers' to 'newcomers' as the latter move along a trajectory that guides them from peripheral to core participation in cultural practices (Lave & Wenger, 1991). Analysis of late modern societies shows that cultures and identities can no longer be visualised as inherited, given and established but have become a complex reflexive project (Bauman, 1992; Beck, 1992; Giddens, 1991), free from authority and tradition.

> "The disturbing consequences of weakened authorities and tradition are diversity and cultural liberation. Young people are free from conventions and unrestricted of traditional values and norms. Who they are, what they believe in, right or wrong, future occupation, social class, friends and even their own body are all matters of their own choice." (Beck, 1992, p.28)

In contrast to prior conceptions of culture, neophytes or newcomers are no longer considered apprentices. They are the ones who contribute most to cultural change as they are more likely to diverge from the established (Roth, 2007). Their participatory actions can be envisaged as being simultaneously marginal and central and leading to learning and to new cultural forms (Goulart and Roth, 2006; Roth *et al.* 2005).

Identities and cultures are becoming more dynamic, collective, emergent and dialectical (Roth, 2007) as they are constantly shaped and reshaped by dialogue in the social fabrication of meaning. As individuals contest authoritative discourses, they engage in dialogic relations with others in the quest of *internally persuasive discourses* (Bakhtin, 1981). What a person becomes and his decisions are determined by whom he meets, and the ways and in which contexts he interacts. This everlasting recontextualisation of ideologies has flourished in moral public cyberspaces or the *mediapolis* (Silverstone, 2007). Computers, iphones, radios, tablets etc. allow new forms of civic engagement and exchange of information, which can be exemplified by memberships in online communities such as *Facebook*, fan videomaking, working in teams to complete tasks such as *Wikipedia* and shaping the flow of media as in blogging. Passive audiences have been transformed into active publics as they get entrenched in this *participatory culture* (Jenkins, 2006).

Potential benefits of these forms of participatory culture include opportunities for peer-to-peer learning (Black, 2005a,b; Gee, 2004), more respect to the intellectual property of others, the diversification of cultural expression (Lenhardt & Madden, 2005), the development of skills valued in the modern workplace (Beck & Wade, 2004), and above all a more empowered conception of citizenship (Buckingham, 2000). These qualities distinguish the current generation from previous ones.

These benefits are not attained automatically. Although there are now endless possibilities for expressing preferences and making decisions, handling the responsibilities this entails, such as respecting other people's tastes and cultures is not an innate consequence (Beck, 1992; Hermes, 2006). This rapidly evolving society calls for radical changes in the way we teach and educate current and future generations. The promotion of cultural citizenship and conversations across difference requires an educational framework and should be in itself an educational goal (Hull *et al.* 2010; Jenkins, 2006). Everyone involved in preparing young people for the world has contributions to make in helping students "cultivate as richly as possible their intellectual, moral, political, and aesthetic being" (Hansen 2010 p.8).

There is a call for education to become more multidimensional leading to the inculcation of a range of competencies, values, knowledge and dispositions (Hull *et al.* 2010; UNESCO, 2009). These taken together can be thought of as *habits of mind* or *sensibilities* because they all relate to a person's perception on knowledge and learning and associated ways of thinking and behaving. One of the most acclaimed habits of mind is cosmopolitanism (Appiah, 2006; Hansen, 2010; Hull *et al.,* 2010). This is an educational orientation with aesthetic, moral and ethical dimensions that is built on respect for legitimate difference, a determination to participate and the recognition that openness to dialogue is one of the suitable means to resolve opposing values. Cosmopolitanism and analogous habits of mind are rooted in sociocultural views of learning (Vygotsky, 1986; Wertsch, 1991). They are acquired, not simply as individualised skills to be used for personal expression, but as ways of interacting with the larger community in the social production of meaning.

### 2.1.2 The Increasing Impact of Science and Technology

While scientific and technological development has led humanity to a better quality of life, individuals increasingly face science-based issues where the benefits in question are less obvious. This is a result of two parallel phenomena. Firstly, science and techno-economic development are heavily interfering with natural systems (Collucci-Gray *et al.,* 2006; Wackernagel *et al*., 2002) generating a number of risks, many times with uncertain repercussions (Beck, 1992; Giddens, 1991; Jenkins, 1999). The second phenomenon is the parallel advance of digital media that has increased the scepticism of scientific knowledge (Beck, 1992). New information technologies give people access to large amounts of information and opinions and they are therefore experiencing first-hand the untrustworthiness of scientific calculations and predictions.

Since knowledge is now literally in the hand of individuals, the responsibility of decision-making and action in the face of contradictions and conflicts presented by scientific and technological matters has also shifted from the experts to individual citizens (Beck, 1992). Decentralisation of decision-making is not simply a natural consequence of the introduction of digital media but is considered by some to be an essential component of 'post-normal science' (Funtowicz and Ravetz, 1993; Ravetz, 1997). In contrast to traditional science, the consequences of scientific implementation have become intricate, uncertain and of a very high stake. Decisions have been rendered so value-laden that they cannot simply be based on mathematical models and risk assessments produced by technocrats. Political, social and ethical considerations have become linked to the extent that 'citizen thinking' (Jenkins, 1999) and support of individuals making up the extended community are essential to clarify scientific issues and make rational choices when experts have conflicting points of view. This openness and democratic participation also ensures that scientific development does not serve sectional interests but leads to worldwide progress (Fensham, 2008).

Life situations involving science and technology are diverse and can be compartmentalised according to the context in which they arise or in relation to the impact they have on humanity. Contexts frequently named in literature include health, resource management, energy efficiency, hazards, the conservation of the environment and all issues of modern science that raise ethical questions such as biotechnology or genetic engineering (Bybee, 2008; OECD, 2006; OECD, 2013; Ratcliffe & Grace, 2003; Sadler & Zeidler, 2004). Some issues, as in the choice of a particular treatment over another for a life-threatening disease are personal and the consequences are limited to the self, family and peers. At other times, as in deciding the location of a landfill, the impact of the decision or action is at a societal level. Some other issues, especially those related to environment and resources are so complex that they also have worldwide repercussions. Studies have shown that people are less ready to accept the highly unpredictable risks associated with global issues, such as ozone depletion, in contrast to situations where the risk is self-based and has a more immediate impact (Jenkins, 1999). A comprehensive classification of these issues is shown in **Table 2.1**:

A number of the most complex scientific issues are related in some way or another to sustainability, combining aspects of environmental protection with social equity and the quality of human life for current and future generations (Dani, 2011). Sustainability has been given importance in relation to scientific issues not only because of its political and economic relevance, (UNESCO 2003) but also because it is regarded as a model on which our thinking should be based in resolving sustainability issues (Colucci-Gray *et al*., 2006). Understanding how different ecosystems can co-exist harmoniously in nature can help us move to the desired global systems of thinking that can lead to a heightened awareness of multiple points of view, an ability to establish relationships that are not so obvious and the resolution of complex issues in non-violent ways. In fact, some authors are even calling for a new relationship between science and subjects such as religion (Ezeh, 2015) to forge a more sustainable environment.

**Table 0.4 Classification of scientific/technological issues (OECD, 2006, p.26). A similar classification is presented in the Draft Framework for PISA, 2015 (OECD, 2013).**

| | **Personal** (Self, family and peer groups) | **Social** (The community) | **Global** (Life across the world) |
|---|---|---|---|
| Health | Maintenance of health, accidents, nutrition | Control of disease, social transmission, food choices, community health | Epidemics, spread of infections, diseases |
| Natural resources | Personal consumption of materials and energy | Maintenance of human populations, quality of life, security, production and distribution of food, energy supply | Renewable and non-renewable, natural systems, population growth, sustainable use of species |
| Environment | Environmentally friendly behaviour, use and disposal of materials | Population distribution, disposal of water, environmental impact, local weather | Biodiveristy, ecological sustainability, control of pollution, production and loss of soil |
| Hazard | Natural and human-induced, decisions about housing | Rapid changes (earthquakes, severe weather), slow and progressive changes (coastal erosion, sedimentation), risk assessment | Climate change, impact of modern warfare |
| Frontiers of science and technology | Interest in science's explanation of natural phenomena, science-based hobbies, sport and leisure, music and personal technology | New materials. devices and processes, genetic modification, weapons technology, transport | Extinction of species, exploration of space, origin and structure of the universe |

For this study the issues in which humans interact with science and technology in their lives will be considered to be ones which:

- arise at the forefront of scientific and technological research characterised by high levels of societal application, complexity, uncertainties and possible risks;
- involve a decision or action at a personal, social or global level;
- are value-laden and cannot be solved by simple reference to scientific knowledge; and
- have given rise to a multiplicity of competing and sometimes biased perspectives especially in the media

### 2.1.3 Neoliberalism, Globalisation and Neoconservatism

One cannot consider science education today in isolation of neoliberalism that is the logic that dominates social and cultural Western life. Neoliberalism, derived from the work of Austrian economist Hayek, underlines that all form of human conduct is driven by economy (Beck, 2000). Wealth is no longer tied to industrial resources and the manufacture of products but to human capital development and hence to educational systems (Spring, 2008). It is based on reduced governance, the rule of markets, free trade and more individual freedom to pursue economic self-interests. The government assumes more the role of a regulator and auditor rather than one that ensures social justice (Carter, 2008; Carter, 2016).

One can see several other elements reflected in this neoliberal competitive component. Neoliberalism opens economic and political bodies to globalisation. Globalisation is quite a nebulous phenomenon (Bencze & Carter, 2011) but can be viewed as the "intensification of social relations which link distant localities in such a way that local happenings are shaped by events occurring many miles away and vice versa." (Giddens, 1990, p.64). Although globalisation may take many forms as in cultural, biological, economic and political (Stiglitz, 2003), capitalist globalisation is considered to be the foundational category of this phenomenon (Harvey, 2010). Here people increasingly base their fulfilment on economic exchanges and as such help to foster the ideology of neoliberalism.

It is clear that neoliberalism does not favour everybody. Global, Western economic elites are often in power and act in a way that they maintain their status and stratification at the expense of the rest of the population (Hall *et al*., 2013). There exists a hidden neo-conservative agenda (Carter, 2008; Carter & Dediwalage, 2010), that is "morally denuded" (Hall *et al*., 2013, p. 16), that promotes hostility towards collective responsibility and to more democratic and alternative approaches (Hall *et al*., 2013). Although people may think they are free, the messages they receive, especially from a business-controlled media limits this agency and aids to serve and conserve the purposes of the business elite (Bencze & Carter, 2011). Although everybody seems to be eligible to integrate in this global phenomenon, some may be achieving this eligibility through exclusion (Santos, 2001).

Following the financial downfalls of 2007/8 in several Western countries, and the concurrent democratic Arab uprising, some authors are arguing that the system of neoliberalism has imploded and that we are moving towards a new political era. Measures, such as extreme austerity measures targeting the welfare state to combat this crisis, yet still neoliberal in nature, have further enhanced social stratification and may only offer short term solutions. (Hall *et al*., 2013).

## 2.2 Science Education for the General Student in the 21st Century

Following a description of the cultural factors and ideologies that may be influencing our society today, this section firstly outlines how the philosophy of science education for the general student is being influenced more by the democratic rather than the neoliberal school of thought described above. Pragmatic initiatives in this area are also discussed. This is succeeded by a critique that is aimed at providing an explanation for the huge gap that exists between the democratic visions of science education philosophers and the actual day to day proceedings in science classrooms.

### 2.2.1 Theoretical Aspects of Scientific Literacy

Scientific Literacy (Bybee, 1997; Hurd, 1998), Science Literacy (UNESCO, 2009; OECD, 2006), Scientific and Technological Literacy (UNESCO, 2001, Holbrook & Rannikmae, 2007), Science Technology Engineering and Mathematical Literacy (Bybee, 2010), Sustainability Literacy (Colucci-Gray et al., 2006), Citizen Science (Roth & Lee, 2004; Jenkins, 1999), Science Education for Citizenship (Ryder, 2002) etc. have all been used as headings to cap the objectives of a general science education to empower students to assume a participatory role when confronted with issues and problems of a scientific nature.

Beyond these technicalities, the overarching attribute that is considered to be indispensable for individuals to engage with life situations involving science and technology is that of scientific literacy (OECD, 2009). Although there is agreement regarding its importance as an educational goal, there is lack of consensus about its meaning (Bybee, 1997; De Boer, 2000; Fensham, 2008; Laugskch, 2000). In fact, science education research is peppered with definitions of scientific literacy (AAAS, 1993; Bybee, 1997; Holbrook & Rannikmae, 2007; Hurd, 1998; OECD, 2006; OECD, 2009; NRC, 1996; Shamos, 1995). Several authors have attempted to review these definitions and to synthesise common or differing elements of the concept (Holbrook & Rannikmae 2009; Kemp 2000; Laugskch, 2000; Norris & Phillips, 2003).

Earlier perspectives of scientific literacy were based on the acquisition of a whole repertoire of scientific knowledge and skills for their intrinsic worth (AAAS, 1993; Millar & Osborne, 1998; NRC, 1996). The inherent assumption was that if an individual knows enough science, or is apt to think scientifically, he or she will be able to apply that knowledge in life contexts involving science (Bybee & McCrae, 2011; Jenkins, 1999). The achievement of such a wide-ranging and logical positivistic interpretation of scientific literacy was seriously questioned. Shamos (1995) was among the first to doubt the achievement of what he called ambitious definitions of general science education of wide and deep content knowledge. He promoted instead, a view of science education that prepared students to be competent consumers of science with the ability to gain knowledge from experts as and when appropriate.

The underlying assumption of the type of general science education promoted in the nineties was that through knowledge in and about science one will be able to function better in society. Nonetheless, one could still find people who have made it to the top of their professional ranking with very limited understanding of knowledge in and about science. The personal and social qualities required to function in response to real life science-related situations go beyond logic and rationality. In several instances, "citizen thinking" or everyday thinking, characterised by uncertainty, contingency and adaptation appears to be more applicable to decision-making in everyday life than rational thinking (Jenkins, 1999; De Boer; 2000). Here, one can consider the work of Symington & Tytler (2004) who investigated the views of community leaders, most of whom were not science specialists in this regard. They provided an out-of-school perspective on the matter. They see science learning in the context of lifelong learning and an obligation for everybody to keep up with the progress of science and technology and science-based issues. Thus, school science should be a beginning not an end, a 'launching pad' (*ibid*. p.1415) that should expose students to a range of fields, provide them with skills to be lifelong learners and strengthen them with the belief that science is there to support them not hinder them. This challenges the importance given to knowledge in several curricula.

This criticism led to definitions of scientific literacy that included the personal and social domain with an emphasis on the ability to functionally use knowledge in relation to scientific issues (Goodrum *et al*., 2001; Hurd, 1998; OECD, 2006, 2009). This applied perspective of scientific literacy rendered it as a competency as it went beyond knowledge and skills to the capacity to mobilise cognitive and non-cognitive resources in any given milieu (OECD, 2003; OECD, 2009). Despite being highly situational, a competency also draws on and is regulated by a number of individual attributes that are of a less circumstantial nature, such as attitudes. A summary of the attributes reviewed in literature that are considered to be expected of a scientifically literate individual is given in **Table 2.2.**

**Table 0.5: A summary of the attributes expected by a scientifically literate individual**

| Attributes | Definitions |
|---|---|
| Scientific competencies (Hurd, 1998; OECD, 2006, 2009) | Identifying scientifically-oriented issues<br>Explaining phenomena scientifically<br>Using scientific evidence |
| Generic Competencies (Graber *et al*. 2001), Cognitive processes (OECD, 2006, 2009), Habits of mind (AAAS, 1993) or Higher-order Thinking Skills (UNESCO, 2001) | Inductive and deductive reasoning<br>Critical and integrated thinking<br>Transforming representations<br>Thinking in terms of models<br>Using mathematical processes, knowledge and skills |
| Knowledge of science (McClune & Jarman, 2010; OECD, 2006; UNESCO, 2009) | Understanding of physical, living, earth and technological systems |
| Knowledge about science, procedural understanding of science (Duggan & Gott, 2002), Ideas-about-science (Millar, 2006; Millar & Osborne, 1998) knowledge of the Nature of Science (Fensham, 2008) or of the scientific method (UNESCO, 2001) | Understanding components of scientific enquiry and how scientists use data<br>Awareness how science pervades our lives<br>Recognising the power and boundaries of the influence of science |
| Attitudes/Dispositions (Bybee, 2008; Bybee and McCrae, 2011; OECD 2006, 2009) | Interest in science<br>Readiness to support scientific enquiry<br>High level of motivation to act responsibly |

This idea, featuring science as a means to an end rather than an end in itself is reflected in terms, such as *education through science* (*ibid.*) and *learning through science* (UNESCO, 2009), as opposed to *science through education.* The differences between these two approaches have been summarised by Holbrook & Rannikmae (2007) and shown in the **Table 2.3.**

Another shift in perspectives occurred when scientific literacy started to be embedded in the scenario of responsible citizenry to go beyond simple engagement with socio-scientific issues to participation and activism (Barton & Tan, 2010; Hodson, 2003). Activism implies taking action to bring about change. In this respect, scientific literacy is less conceptualised in terms of received individual abilities to assume a more contingent, collective and socially embedded character based on division of labour and dialectic participation (Goulart & Roth, 2006; Roth & Lee, 2004; Roth, 2007). This type of scientific literacy for action, also called *scientific*

**Table 0.6: A comparison of similarities and differences in philosophical emphases between "science through education" and the alternative "education through science" (Holbrook & Rannikmae, 2007, p.1354)**

| **Science through education** | **Education through science** |
|---|---|
| Learn fundamental science knowledge, concepts, theories, and laws | Learn the science knowledge and concepts important for understanding and handling socio-scientific issues within society |
| Undertake the processes of science through inquiry learning as part of the development of learning to be a scientist | Undertake investigatory scientific problem-solving to better understand the science background related to socio-scientific issues within society |
| Gain an appreciation of the nature of science from a scientist's point of view | Gain an appreciation of the nature of science from a societal point of view |
| Undertake practical work and appreciate the work of scientists | Develop personal skills related to creativity, initiative, safe working, etc. |
| Develop positive attitudes towards science and scientists | Develop positive attitudes towards science as a major factor in the development of society and scientific endeavours |
| Acquire communicative skills related to oral, written and symbolic/tabular/graphical formats as part of systematic science learning | Acquire communicative skills related to oral, written adn symbolic/tabular/graphical formats to better express scientific ideas in a social context |
| Undertake decision-making in tackling scientific issues | Undertake socio-scientific decision-making related to issues arising from the society |
| Apply the uses of science to society and appreciate ethical issues faced by scientists | Develop social values related to becoming a responsible citizen and undertaking science-related careers |

*capability* (SCCC, 1996) or *critical-responsible scientific literacy* (Sperling & Bencze, 2010) can only be measured in terms of agency. An individual can have knowledge of and about science, possess scientific competencies, possess the right attitudes, etc., but if s/he lacks the ability to put all this into political action to bring about change then all this is futile for responsible citizenship. Knowledge and experience should work in tandem (Goulart &Roth, 2006).

Scientific literacy for this type of citizenship entails the strengthening of value positions and ethics as most of the socio-scientific issues today are linked with sustainability and social justice, both of which are highly value-laden (Graber *et al*., 2001). There should be a heightened recognition that decisions about scientific and technological development benefit some at the expense of others thus bringing about moral-ethical dilemmas. Malnutrition, famine, inadequate sanitation and diseases, such as cholera, are not consequences of climatic harshness and overpopulation but are mainly the result of oppression of the developing world by the Western countries (Colucci-Gray *et al.,* 2006; Hodson, 2003). This view upholds the need for scientific literacy to be far more than knowledge. It should interrelate with the goals of Peace Education (Hicks, 1998) and Global Education (Selby, 1995) that start from fostering the self-esteem and well-being of the individual to extend to human rights, tolerance, gender equity, co-operative decision-making and creative resolution of conflict between individuals. The term *Sustainability Literacy* was coined by Colucci-Gray *et al*. (2006) to refer to this amalgamation of scientific literacy with values education.

In the same way, if education is to lead to socio-political action, then it should result in a recognition that the environment is a social construct. This renders environmental degradation a social problem that can be resolved by adopting sustainable lifestyles based on values such as conservation, prudence and stewardship. There is a need to replace anthropocentrism, where people justify their continued exploitation of natural resources and absolve themselves of any moral responsibility to protect nature, with a biocentric ethic. According to this moral belief, humans make an effort to live their life in a way that respects the welfare and worth of all living creatures.  Laszlo (2001) even elevates this set of principles to a universal, planetary ethic.

Once people have a clear feeling of what is right or wrong, what is just and what is immoral then they should also gain the knowledge and competencies to safeguard these ideals in the best interest of the biosphere as well as to refashion society along more socially-just lines. This knowledge pertains an element of political literacy and includes a clear understanding of where power is located and the mechanisms through which decisions are taken at a local and national level as well as in industry and commerce (Hodson, 2003; Murray, 2007). Competencies for responsible action are socially laden and thus can only be developed in relation to others. Through science education students should learn the skill of co-operative learning,  presenting their views, listening to the views of others having different levels of and forms of expertise, to argument and to weigh evidence and to negotiate possible solutions through democratic mechanisms for effecting change (Davies, 2004; Holbrook, 1998; Holbrook & Rannikmae, 2007; QCA, 1998; Roth, 2007; UNESCO, 2001; UNESCO, 2009).

These competencies empower the individuals not only to care about an issue but also to own it and do something about it (Hodson, 2003; Marks & Eilks, 2008).

The ideas discussed above helped to shape the nature of science education for the general student that guided this study based more on activity theory rather than logical positivism. Such an education in science encompasses achievement of targets in the personal milieu, in particular intellectual and communication skills, as well as the development of character and positive values. It also features achievement of targets in the social domain, underlining cooperative learning and socio-scientific decision-making. In this scenario, aalthough the nature of science is seen as an important part of science education, the over-riding target of science education for the general student is seen as responsible citizenry.

### 2.2.2 Pragmatic Initiatives Addressing Scientific Literacy

Just as the philosophy of scientific literacy has evolved and has become more geared towards sociopolitical action, so too have the pedagogies developed to address this educational target as will be discussed in the following two sections. The first section focuses on the chronological development of pedagogies in response to the progressive transformation of the meaning of scientific literacy to assume its more sociopolitical character. The second section targets argumentation and the use of discourse as these attributes transcend most of the initiatives taken to promote scientific literacy and thus is also highly relevant for this study. The students are not only expected to become more aware of the importance of this attribute but the use of discourse/language play also a significant role in the use of metacognition and self-directed learning that were used to raise science awareness in phase 2 of this study.

- **Addressing scientific literacy in the classroom.**

Before the new millennium, initiatives to address scientific literacy generally meant the attainment of a general science background by all students (AAAS, 1993; Millar & Osborne, 1998; NRC, 1996). It was necessary for attaining society's aspirations to advance individual development within the context of science and technology (Bybee, 1997). The main objective was to transform the student into a little scientist, through a thorough understanding of the "big" ideas of science, the nature of science and the applications of science to society (Millar & Osborne, 1998). The discussion revolved around what content should be included and what methods could be used to cater to these three dimensions (Bartholomew *et al*. 2004; Lederman & Lederman, 2004; McComas & Olson, 1998; Rocard*,* 2007). This line of thought was operationalised in projects like *Twenty First Century Science* (Millar, 2006) for which a number of content modules were chosen to teach *Ideas about science* established through a previous Delphi study (Osborne *et al.,* 2003b) and *Science Explanations.*

Other initiatives started to move beyond the focus on science to an emphasis on skills and habits of mind that the individual may need in order to engage with science in society. Initiatives promoting such skills were mainly based on social constructivist Vygotskian approaches. Here, science is considered to be a social construct and students should be encultured into this enterprise and develop their skills to do so. This target is usually addressed through authentic learning experiences or place-based science learning (Adams *et al.*, 2012; Aikenhead *et al*., 2006; Bulte *et al*., 2006; Pilot & Bulte, 2006) especially those in collaboration with out-of-school settings. Less experienced community members learn from more experienced ones by engaging in common activities, e.g. pairing students with mentor scientists (Adams *et al*., 2012) or through community projects such as REAL (Restoring Environments and Landscapes), a project where youth were expected to convert an empty space into a community garden (Aikenhead, 2006). Everyone is expected to contribute to the solution and to be respected in this build-up of knowledge. In such a scenario, there is an emphasis on language and other shared traditions.

Beyond cultivating habits of the mind, scientific and social skills, some authentic learning experiences, such as the curriculum project *Sustainable Living by the Bay* (Carter & Dediwalage, 2010) also encouraged the strengthening of ethics and morals. While Year 8 students, with the assistance of several social organisations were encouraged to visit Port Phillip Bay in Melbourne and conduct experiments, another important goal was to enhance students' ethical and moral values as twenty-first century global citizens in relation to issues such as energy, water use, recycling, etc. Improvement in students' attitudes towards science were recorded for such projects (*ibid*., Adams *et al*., 2012).

The inculcation of ethical and moral values is also the target of pedagogies tackling socioscientific issues (SSI) (Hodson, 2013; Lee *et al*., 2013; Sadler, 2009). SSI have ousted previous Science-Technology-Society, (STS), approaches that used to simply provide a context to studying science content (Zeidler *et al*. 2005). In SSI, the aim is not only to recognise the effect of science on society, but to provide a pedagogical tool to develop skills through discourse and interaction (Zeidler & Keefer, 2003) and to take decisions that also entail moral and ethical aspects on what is right or wrong to do. A typical SSI was addressed in a British study by 12-13 year olds students "Should we kill the grey squirrel to save the red?" (Evagorou *et al*., 2012). SSI methods consider the psychological and epistemological development of the child as well as development of character and virtue in the quest to achieve a functional level of scientific literacy. Hodson, (2013) suggests that for education through socioscientific issues to be effective, it should include a choice of SSI from a mix of categories, relevant technical knowledge, group discussions to debate arguments and the use of future wheels to direct attention to ethical concerns.

Hodson went even further to provide a more radical conceptualisation of SSI (Santos, 2009) that includes sociopolitical action as the ultimate aim of an education in science literacy. The students have to be shown that they can contribute to society. This can be done at different levels of agency. Some initiatives are based on *modelling* (Hodson, 2013) or *learning about action* (McClaren & Hammond, 2005), e.g. using a digital game called *Citizen Science* (Gaydos & Squire, 2012) to help students develop identities as citizen scientists in the setting of a lake ecology. Some move beyond learning about action to *guided practice* and *application* (Hodson, 2013) as in *learning through* and *learning from action (*McClaren & Hammond, 2005). Participation of students in citizen science projects helps give students a tangible experience to engage with science during their life (Jenkins, 2011). There are several examples including one from New Zealand where primary students tackled a unit on butterflies, learning about them, hunting, tagging and releasing them and publishing results on a national website (Chen & Cowie, 2013). Citizen science may also offer an opportunity for youth to connect critically with their community in relation to scientific issues and to enhance their sense of place (Calabrese Barton, 2012).

Meuller *et al.* (2012) argue for citizen science projects that go beyond featuring students as simple collaborators or helping out scientists in the collection of data but such participation should also involve some form of political action, e.g. lobbying governments, writing in newspapers etc. Here one can refer to the distinction made by Jensen (2004) between *activity* and *action* in relation to environmental education, e.g. investigating the amount of oxygen in a lake is an activity. An action must go beyond that to address solutions. Roth, (2007), for example, reports on students not only collecting data about local citizens' access to municipal water but also the students' subsequent lobbying actions. For students to take such measures, they must become politically literate. Thus, the political nature of science should be made visible. Students have to be specifically taught skills of how to identify bias and uncertainty, how to reflect on science reports, etc. (Fensham 2014; Santos, 2014). They should also have a thorough understanding of the nature of science coupled with critical reading skills and media literacy (Hodson, 2013). In such approaches, the knowledge and procedures of science are not blueprints to which students are compared but reduced to a resource to be chosen from. The science education pyramid model, starting with the basics to more specialised knowledge, should become inverted starting with broad issues and choosing specialised, need-to-know knowledge to address such issues. Consequently, interdisciplinarity and cross-curricular approaches are necessary to achieve such targets (Levinson, 2010; Mc Farlane, 2013; Prain, 2012; Senchina, 2010; Taylor *et al*., 2006; Taylor, 2007). Several have argued that the most difficult part of such projects is the narcisstic behaviour of the younger generation who struggle to demonstrate willingness to participate (Chang & Lee, 2010; Lee *et al*., 2013).

All of the approaches above can be capped under Aikenhead's term *humanistic* (Aikenhead, 2006) perspectives of science as they refer to the values, the nature of science, the social aspects of science, the culture of science and the human character of science as revealed through its history, sociology and philosophy.

- **Dialogic learning/language/argumentation.**

Since the late nineties, there has been a growing emphasis on student participation through the careful use of dialogues, language and argumentation in science education. Based on Vygotsky's sociocultural framework, such activities mimic the linguistic interactions and social structure of a practicing science culture. Like scientists and engineers, students use language to design, test, critique, re-design and work towards a particular goal. As in a truly collaborative community, language is also a tool to mediate individual roles in order to reach the goals of the collective (Goulart & Roth, 2006). Dialogic learning is necessary for emerging scientists to be mentored into the science culture. Simultaneously, the more experienced members must also listen to and be open to the ideas of the less experienced so that progress can be achieved (*ibid*.).

In this field, there has been a growing appreciation of the use of argumentation and the acquisition of good argumentative skills in the science classroom. An argument can be considered to be a subset of discussion and can be defined as 'the intentional explication of the reasoning of a solution during its development or after it' (Krummheuer, 1995, p.231). Argumentation skills are the ability to contextualise knowledge for the purpose of justifying a decision. Argumentation skills can be demonstrated through one's ability to analyse information, evaluate evidence, and generate and present an argument in making an informed decision (Foong & Daniel, 2013).

The importance of argumentation stems from the publication of documents that set the process of enquiry as an essential aspect of scientific literacy (Minstrell & Van Zee, 2000; NRC, 2000). Due importance should be given to the processes of critical reasoning and argument that enable students to understand science as a way of knowing (Driver, Leach, Millar, & Scott, 1996; Driver, Newton, & Osborne, 2000; Millar & Osborne, 1998; Osborne *et al*. 2004). This requires the discourse in the classroom to shift from being authoritarian to become more deliberative or dialogic (Mortimer & Scott, 2003). Simon *et al*. (2006) identify this competence to understand and follow arguments of a scientific nature as an essential component of scientific literacy in its fundamental sense. From this perspective, scientific literacy is viewed as the ability to understand, interpret and analyse scientific texts (Norris & Phillips, 2003).

Most of the time, the development and assessment of this quality in science education research is monitored through Toulmin's Argument Patter, TAP (Toulmin, 1958). The main components of Toulmin's argumentation model are: claims, the conclusion, proposition or assertion; data, the evidence that supports the claim; warrants, an explanation of the relationship between the claim and the data; backings, basic underlying assumptions to support the warrants; qualifiers, specific conditions under which the claim is true; and, rebuttals statements which refute alternative or opposing claims, data and warrants.

An iconic researcher in argumentation, Kuhn (1991), states that this attribute is not innate but is acquired through modelling and practice. Thus, it has to be specifically taught (Driver *et al*., 2000; Osborne *et al,*. 2004). There is a lot of learning that needs to be done, both by the teacher and by the student before they can actually debate (Simon *et al*., 2006). Thus, there have been several development programmes aimed at the professional development of teachers in this regard, e.g. IDEAS, Ideas, Evidence and Argument in Science , a professional development package for teachers as they worked to enhance the argumentation skills of high school students. Other projects, such as Argument Driven Inquiry (ADI) laboratory activities (Sampson *et al*., 2010), are more targeted at the students. Here, laboratory practices are moulded to develop the knowledge and skills students need to participate in scientific argumentation and to craft written arguments. Other educators have focused on the structured instruction of particular scientific communication skills (Spektor-Levy *et al*., 2009), such as information retrieval, scientific reading, information representation, etc. The importance of discourse in science education has been accentuated through the actual funding of such projects e.g. CISIP (Communication in Science Inquire Project) (Baker *et al*.,2009).

Science is not an isolated entity especially because of the moral and ethical implications of its applications. The focus on and use of language therefore has been stretched to target more progressive and functional levels of scientific literacy (Zeidler *et al*., 2005). Kim *et al.* (2014), have actually made a distinction between scientific argumentation which is usually taught within closed situations where there are right procedures and conclusions and socioscientific argumentation where problems are more open and unpredictable making argumentation more presumptive.

This increased focus on argumentation skills and decision-making related to ethical dilemmas and controversies has been achieved mainly through the field of socioscientific issues (SSI) (*ibid*.) both at college and high school level (Albe 2009; Evagorou, 2011; Jiménez-Aleixandre & Pereiro-Munoz, 2002), and also on younger students (Evagorou *et al*. 2012; Foong & Daniel, 2013). Such studies, many of which were related to environmental education have shown that decision-making related to real –life situations does not only entail conceptual understanding but includes also value judgements (Jiménez-Aleixandre & Pereiro-Munoz, 2002) and also a high degree of emotional loading (Ziedler *et al.* 2002).

Several programmes have been implemented to aid pre-service teachers and teachers in their professional learning as they use argumentation in addressing socioscientific issues (Dawson & Venville, 2013; Iordanou & Costantinou, 2014). Results have shown that this training should not be sporadic but should be sustained and intensive (*ibid*.). Some also argue that more multidisciplinarity and co-teaching are crucial in the development of argumentation skills as social sciences students have been shown to be more competent in this regard than science students (Christensen *et al*., 2014).

Even technology is being employed to help in the development and assessment of argumentation skills. A case in point is Argue-WISE (Web-based Inquiry Science Environment) platform (Linn, Bell & Davis, 2004) which is an online learning environment designed in order to engage students with the socioscientific problem and provide all the evidence to help them construct their arguments. Evagorou and Avraamidou (2008) argue that the design of such a technology-enhanced environment provides scaffolds for argument construction, by making thinking visible, making the structure of argument construction explicit, and by structuring both peer to peer and group discussion. Debates are also promoted in the development of argumentation and to spark and maintain interest in science (Osborne *et al.*, 2001).

### 2.2.3 A School in Tension

As described above, the philosophy of science education is moving towards a more humanist, democratic tradition with the main emphasis of the last few years on scientific literacy (Roth, 2004). From this point of view, scientific literacy is viewed as the means to produce individuals who have the skills such as critical thinking, teamwork, and using information and ICT in order to make decisions as future citizens on scientific issues related to the environment and other areas. "The best way forward is to provide the highest grade of 'science education for citizenship' for all students" (Kaptan & Timurlenk, 2012, p.765).

One cannot expect these elements to come to fruition when undemocratic structures are still the pillars of many schools (Weinstein, 2012). In several countries, curriculum change is top-down and ignores the specificities of particular situations. Consequently, teachers are regarded as technicians who implement the curriculum, which is a far cry from being viewed as agents of change (Gough, 2011). Other factors of schooling that may actually complicate the logistics include: compartmentalized subjects taught by teachers isolated within and across departments, the large numbers of students in class, the informational education orienting students only towards exam achievement, insufficient physical conditions of school and the more intensive curriculum with less time allocated for science education (*ibid.*)

Resistance may also be expressed by the various stakeholders inside and outside schools. School administrators may resist any perception of political controversy linked in any way to their school (Mueller *et al*., 2012). Teachers, scientists, students and parents (Hodson, 1994; 2010) may all oppose or remain passive when facing such changes. Science teachers may also argue that sociopolitical action has no place in schools as they see themselves as concerned more with facts rather than with values (Lakin and Wellington, 1991). For a long time science has been taught and learned as a mono-methodological, dogmatic branch of knowledge where objectivity and empiricism are given priority while creativity and subjectivity were downplayed and sometimes even penalised (Kaptan & Timurlenk, 2012; Mc Farlane, 2013; Reiss & Tunnicliffe, 2001).

Students see themselves more as receivers rather than constructors of knowledge. Students also struggle with their own identities and by the uncertainty in crossing gender, language, cultural, religious, and other borders in their quest to consider themselves as scientists (Aikenhead, 1996; Birr Moje *et al*., 2007; Kaptan & Timurlenk, 2012). In addition, not all students have the same disposition to act (Hodson, 2010). They have different levels of the attributes required such as knowledge, self-esteem, values, commitment, etc. Parents may be reluctant to accept such humanised approaches to science education as they regard them as a ‘soft’ option to the ‘proper’ science taught and assessed by conventional means (Hodson, 1994). There may also be resistance from beyond schools, by scientists who feel that their work will lose its credibility as it is scrutinized by students and the general public (Cooper, 2012; Gray *et al.,* 2012). Members of the wider community, such as politicians may regard students who are scientifically and politically literate as a threat to the established order of power and control (Hodson, 1994).

Although this resistance to a philosophy that allows a more egalitarian approach to science education has been documented for several years (Aikenhead *et al.,* 2006), it is only recently that it started to be articulated in ideological terms. In the last few years, there have been several publications discussing the effects of neoliberalism, together with globalisation and neoconservatism, on science education (Bazzul & Siatras, 2011). Even whole issues of journals such as *Cultural Studies in Science Education* and *Journal of Research in Science Teaching*, have both been dedicated to this area on 2011.

At first glance, the quest of scientific literacy seems to be based on democratic principles and is supported by science educators who value the democratic provision of science education (Carter, 2008). However, pedagogies employed to address this target that are usually learner-centred, may also be acting as "fodder for the global knowledge economy" (Carter, 2010, p.230). This implies that emphasis on skill acquisition may be acting more to feed individualism, competition and better success rates in international testing such as PISA, rather than to serve its collective emancipatory function of promoting citizenship (Carter, 2010; Tobin, 2011). . In line with this economic imperative, some authors broaden this target by suggesting that undergraduate science degrees should be advertised also as a means by which non science students can gain a repertoire of competencies which are useful in the workplace especially at managerial levels where decisions are made (Rodrigues *et al*., 2007, Symington & Tytler, 2004).

Effects of neoliberalism have also meant less control by the state, having schools mimic businesses and, thus, seemingly depoliticise education (Apple, 2011). This transforms the political aspect of democracy into an economic or consumerist concept with stronger control of curricula and rigorous accountability at all levels (Apple, 2006). Tests conducted by IEA and OECD have transformed the meaning of scientific literacy to quality of science teaching, access to resources and equal opportunities for students to succeed in science courses. In some countries, like the US, this has also taken the form of better pay for teachers whose students perform better in standardized tests. Such neoliberal perspectives which celebrate individualism are further reinforced when educators encourage students to celebrate achievements of individual scientists like Nobel Prize winners.

Although equal opportunities seem to be provided, there are still many who are failing their science education, especially from the lower strata of society because they are expected to change their life realities in order to succeed in science. Although there is increased choice, it does not mean that there is equity. PISA 2006 results showed that socioeconomic status is the most significant factor that affects students' performance. An outcomes based education mirrors lack of inclusivity (Smith, 2011) as it challenges the ideals of democracy in a three-fold manner: by giving a strong focus on the individual competitiveness rather than the collective good; by promoting a false idea that there is a common Western, Eurocentric knowledge for all the different cultures and nations; and by assuming that only that which is measurable is important (Apple, 2011; Gough, 2011). To this end, some scholars (De Boer, 2011) are even proposing the outline of an international document laying down these standards in science education for all citizens.

The entrepreneurial scholarship of neoliberalism has also infiltrated the processes of science with the ultimate aim of transforming this knowledge into a production of commercial commodities for the market (Carter, 2008). Scientists dedicate a lot of effort and time competing for funding, completing accountability forms with a lot of input from non-scientific personnel to control budgets, quality and user outcomes etc. (*ibid.*) Scientists thus now experience a lesser degree of autonomy and responsibility. Eligibility to participate in science has also declined with fewer nations and fewer individuals working on more narrowly defined problems of Western science, controlled by a limited number of economically related interests. From open knowledge, scientific results have become privatised, scarce, heavily applied knowledge not given away for free (Carter, 2016). If the number of scientists needed in such a scenario has declined, then the ultimate aim of science education should not be vocational but to prepare the majority to understand the processes and the political nature of science and to engage them to work for a more socially just and sustainable world.

This study can be considered to be a response to the call of authors like Bencze and Carter (2011) who are advocating a science education that goes against this neoliberal philosophy to treat what McMurty (1999) calls “the cancer stage of capitalism”. ‘Radical science educators’ or this ‘critical pedagogy movement’ (Apple 2011) pertain to the ideology articulated by Lather, 2012 as “post-neoliberalism”. If we do not take a political role to bring about change, it means we are being involved by default and supporting the dominant ideology (Hodson, 2013). This ideology provides an alternative to neoliberalism where the political nature of science and science education are not masked and where the negative effects of Western science are put into the open (Carter, 2008; Carter, 2011; Smith, 2011) with the hope of achieving a more just education related to the cultures and lives of our students. This will see education not only as reproducing but also as challenging dominance.

‘‘Scientists firmly believe that as long as they are not conscious of any bias or political agenda, they are neutral and objective, when in fact they are only unconscious’’ (Lather 1991, p. 106).

An education to ensure the common good for all rather than individual excellence for the economic gain in the market is one that is based on principles of holism, altruism, realism, egalitarianism and cosmopolitanism. Pragmatically, this can be achieved through a transdisciplinary, holistic, creolised approach (Bencze & Carter, 2011; Carter, 2011) where clearly business as usual cannot do to combat the ‘wicked problem’ (Carter, 2011) of neoliberalism. Bencze and Carter (2011) propose the STEPWISE framework for science education to achieve this end. In this blueprint, sociopolitical action for the collective good is not an add-on but is at the centre of science education.

Apple (2011) argues that democratic principles, although highly valued by educators, have not filtered into schools because they have remained too theoretical, too rhetorical and disconnected from the actual realities of the daily lives of educators, students, social movements in schools and classrooms. Only when this connection happens, only when science education philosophers start providing answers for questions that teachers have in the classroom, can a democratic education succeed.

## 2.3 Science Awareness

This section will focus on the main concept being addressed in this study, its meaning and how it confers the basis of cognitive engagement in the achievement of the currently proposed educational targets for the general student in science.

### 2.3.1 Awareness and Education

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Awareness refers to a particular state of mind in which an individual has undergone a specific subjective experience of some cognitive content or external stimulus (Tomlin & Villa, 1994). Practically, awareness is often gauged either through the subject reporting about an experience (meta-awareness) or can simply demonstrate the experience directly through a behaviour (*ibid.*). Commonly suggested synonyms of awareness in everyday life include examples such as: knowledge of; understanding of; appreciation of; recognition of; attention to; perception of; consciousness of; acquaintance with; enlightenment with; sensibility to; realization of; familiarity with; mindfulness of; cognizance of; and sentience of (Free online dictionary by Farlex, Macmillan dictionary, Oxford Dictionaries). These hint at an overlap of awareness with other important constructs of consciousness that can be more clearly distinguished from awareness in psychological terms.

In fact, the concept of awareness used in this study does not stand alone as a psychological construct of *consciousness*. While awareness is the background "radar" of consciousness continually monitoring the inner and outer environment (Brown & Ryan, 2003, p.822), *attention* is also needed to be given to conscious awareness. Attention "continually pulls 'figures' out of the 'ground' of awareness holding them focally for varying lengths of time" (Brown & Ryan, 2003, p.822). When attention and awareness are actively and regularly cultivated, then one reaches a conscious state of *mindfulness.*

The concept of awareness in this study goes beyond being a passive, cognitive process, such that it can be deliberately and consciously sustained in wilful decisions of the self to learn in order to reach particular goals (Roeser & Peck, 2009). In this scenario, awareness can also be viewed as a continuum (*ibid.*), based on the much acclaimed psychological distinction of the self made by James (1890). Its margins are set by the Me-self which provides a fast automatic feedback and the I-self which is the consciously experiencing subject (Galen, 2003; James, 1890) sometimes described as the "vehicle of choice" (James, 1890; Leary & Tangney, 2003).

Although it is possible to learn something new without being aware, learning is more likely to occur if the learning process is personally significant (Krapp, 2003). Educators may thus attempt to enhance a more active and alert awareness, meta-awareness - the phenomenon of being aware of being aware (Lutz, Dunne & Davidson, 2007). The enhancement of awareness and mindfulness has also been linked to the promotion of autonomous motivation (Ryan and Deci, 2008) as opposed to controlled motivation which is externally regulated.

Despite this mental component, at this level of consciousness, the level of understanding of the object required by the mental state of awareness is minimal. E.g. a person may still have an awareness of HIV and its prevention even if her or his understanding of the virus and the disease are minimal. An important distinction which will guide this study is the difference that exists between perceptions resulting from awareness and conceptions. The latter may take years to form and draw upon deep knowledge. In contrast, in order to be useful, perceptions have to be formed fast, and thus employ a rapid but not deep intelligence with a small data base (Gregory, 1987).

### 2.3.2 Defining Science Awareness

The definition of science awareness that guided this study arose from a fusion of the psychological reference to awareness made above with a philosophical vision of a science that emphasises its usefulness, at a personal and social level mainly through technological applications.

**Thus, *science awareness* is the personal attentive realization that:**

- **science and technology have an increasing impact on individual lives and society**

- **a range of competencies, values, knowledge and attitudes are essential to be able to engage with and act upon issues having a science/technological component**
- **science education can contribute to the development of these competencies, values and attitudes and thus makes one more able to function in society.**

Although not studied in depth as scientific literacy, some definitions or references to science awareness have been identified in literature, and some common features can be isolated. Generally, science awareness is featured as a chronological precedent to some higher form of achievement in being educated in science. In his book, *The Myth of Scientific Literacy*, Shamos (1995) stresses that though the majority of students will become scientifically aware, relatively few would become scientifically literate. This suggests that science awareness is of a lower ranking in the list of educational objectives than scientific literacy. The proponents of ASTA's (2004) *Science Awareness Raising Model* also emphasize this sequential progression as illustrated by the statement "Raising people's awareness of science means helping them to become more scientifically literate" (p.2/8). No direct reference is made to the association between science awareness and scientific literacy by Stocklmayer & Gilbert (2002) in their explanation of the acronym PAST (Personal Awareness of Science and Technology). Nonetheless, they still state that the realisation of PAST will lead "at some time" (p.853) to understanding and evaluation of scientific ideas and their significance for personal and social life.

Another common feature that threads across these studies is the emphasis placed on having an awareness of science that does not exist in isolation but which is technologically applied, with a strong effect on personal and social lives. The focus is therefore on *societal science* as distinguished from views towards traditional *school science* that have already been the subject of investigation of several widely known studies (Cerini *et al.,* 2004; Osborne & Collins, 2001). Correspondingly, Shamos (1995) suggests that any education for science awareness should start from technology not from abstract scientific knowledge. Stocklmayer & Gilbert (2002) include technology as part of the acronym PAST used in their work. Another common component of science awareness verbalisations is the promotion of the perception that science and science education are essential for their usability and functionality in everyday life. The

Science Awareness Raising Model developed by ASTA (2004) was, in fact, based on this principle to the extent that the target audience was not students but the general community.

In contrast to other studies, the definition of science awareness outlined in this work is more rooted in the psychological definition of awareness and consequently will be restricted only to beliefs or mental components students have about science, technology and science education. This approach sets the concept at the very base of the structure of the affective domain as proposed by Klopfer in relation to science education. Klopfer (1976) identifies awareness as the minimal level of the process of internalization whereby science successively and pervasively becomes part of the individual. In this continuum, the individual is first merely aware of the phenomenon or is able to perceive it before he is willing to attend to it, develops positive feelings towards it and eventually goes out of his way to respond.

Thus, science awareness will be articulated in terms of beliefs that students have about science and science education. The word 'belief' implies a personally held idea, different from formal knowledge, and which involves personal value in contrast to being correct or incorrect. In science education research, the term is not used to describe conceptual understanding of science topics but rather to students' ideas of what science is like as a field, what counts as science, etc. Beliefs can change over time and with experience (Fenstermacher, 1994).

Such a definition of science awareness, based solely on beliefs or perceptions, intentionally excludes general attitudes and behaviours, or intended ones that have been directly used to signify science awareness in other studies (ASTA, 2004; Stocklmayer & Gilbert, 2002). In this research, these will be considered to be achieved following the stage of becoming scientifically aware.

### 2.3.3 A Psychological Distinction between Science Awareness and Other Common Educational Targets in General Science Education

In reviewing scientific literacy and science for citizenship, it has been argued that a range of competencies and attitudes are needed for individuals to become committed to attend to or to engage with socio-scientific issues. In addition, it has also been shown that in order for this engagement to lead to political action, these competencies must be supported by strong value systems as well as enhanced social skills. So what is the role of science awareness in this scenario?

In science education literature, science awareness has been related to convincing students, and in some cases the general public, of the importance of science and science education (ASTA, 2004; Castagno, 2005; Good rum *et al.,* 2001; Mathews, 2007; Stocklmayer & Gilbert, 2002). The ultimate goals may be various: e.g. public understanding of science, scientific literacy, etc., but science awareness is consistently described as a step towards the achievement of these differing targets. In marketing terminology, science awareness can be described as an advert calling attention to science and science education. The students can be regarded as consumers who have to be convinced 'to buy' science education as it will improve their quality of life, now, and in the future. As argued by Good rum *et al.* (2001), there is "little point in learning about science unless it is of benefit to people in their everyday life" (p. 165).

In the conceptualization of intrinsic motivational processes it is stated that awareness must precede engagement (Deci & Ryan, 1985; Ryan & Deci, 2000). Although science awareness implies a cognitive component, it does not entail understanding of scientific concepts, the nature of science and acquisition of competencies as desired by proponents of scientific literacy. "This project is about increasing the community's awareness of science, what science is and what science can do. It is not about teaching scientific facts to the community" (ASTA, 2004, p. viii)

Science awareness excludes the ability to engage with or act upon issues pertaining a scientific component but can be considered to endow individuals with a set of beliefs or perceptions regarding science and science education that predispose them to do so. The individual must first realize the relevance of science to his/her level of satisfaction before he or she will be motivated to engage with it and to participate democratically in relation to issues with a scientific/technological component.

A diagrammatic illustration of this relation between science awareness, scientific literacy and science for citizenship as it is being proposed in this study is shown in **Figure 2.1**. The base of the diagram is wider as more students are expected to achieve science awareness than the other two goals. This is mainly because less cognitive input and competency attainment are expected when compared to the other two objectives. This may renderscience awareness as a more appropriate goal for lower secondary and possibly primary students. Fensham (2004) also proposes *Science for Citizenship* as an educational target of curricula more appropriate for the higher secondary years. Hodson (2010), in the issues-based curriculum he proposes, also sets recognition, awareness and appreciation of the societal impact of science at a more basic level than preparing for and taking action in relation to these issues.

**SCIENCE FOR CITIZENSHIP – ACTION FOR CHANGE**

If a scientifically literate individual also has strong values regarding scientific/ technological issues, coupled with an element of political literacy, then he or she will also be more likely take action to bring about change. This is the ultimate goal of science education for all.

**SCIENTIFIC LITERACY -**
**ENGAGEMENT – COGNITIVE AND ATTITUDINAL COMMITMENT**

Once the individual recognises the importance of science and science education, then he or she is more likely to become willing to engage with scientific issues. This attitudinal disposition serves as a trigger for the individual to make an effort to understand and to apply scientific knowledge to scientific/technological issues. A number of scientific competecies based on a knowledge of and about science are essential in this regard.

**SCIENCE AWARENESS:**
**RECOGNITION OF THE IMPORTANCE OF SCIENCE AND SCIENCE EDUCATION**

A preliminary step to the acquistion of scientific literacy is an acknowledgment of the importance of science and science education. Strengthening this belief may result in the formation of attitudes that make the in..dividual more disposed to engage with science.

**Figure 0.1: A diagrammatic model of the relation between science awareness, scientific literacy and science for citizenship.**

This model is parallel with the psychological distinction made between beliefs, attitudes and behaviour. Beliefs are considered to be the psychological foundation of attitudes. Attitude is defined as 'a learned predisposition to respond in a consistently favourable or unfavourable manner with respect to a given object' (Fishbein & Ajzen, 1975 p. 6). Examples of responses reflecting attitude are approval or disapproval of a policy, liking or disliking of a person or group of people, and judgments of any concept on such dimensions as enjoyable – unenjoyable, desirable – undesirable, good – bad, or pleasant – unpleasant. According to the most popular conceptualization of attitude, the expectancy-value (EV) model (Fishbein 1963, 1967), this overall evaluative meaning about an object results spontaneously and consistently from the summation of the person's accessible beliefs or cognitions about the object, where belief is defined as the subjective probability that the object has a certain characteristic (Fishbein & Ajzen, 1975). Accessibility on the other hand is dependent on the likelihood that a belief will be emitted in a free response format (Ajzen *et al*., 1995).

Attitudes and beliefs, together with other factors, can be used to predict whether a person will engage in a particular behaviour. The most popular theory for the prediction of behaviour is the theory of planned behaviour (Ajzen, 1985, 1988, 1991). Briefly, according to this theory, human action is guided by three kinds of reasoned considerations: beliefs about the likely consequences of the behaviour (behavioural beliefs), beliefs about the normative expectations of others (normative beliefs), and beliefs about the presence of factors that may further or hinder performance of the behaviour (control beliefs). Behavioural beliefs produce a favourable or unfavourable attitude toward the behaviour, normative beliefs result in perceived social pressure and control beliefs give rise to perceived behavioural control, the perceived ease or difficulty of performing the behaviour. Like attitudes, subjective norms and perceptions of behavioural control are assumed to emerge spontaneously as people form beliefs and in combination lead to the formation of a behavioural intention. As a general rule, the more favourable the attitude and subjective norm, and the greater the perceived control, the stronger should be the person's intention to perform the behaviour in question. Finally, given a sufficient degree of actual control over the behaviour, people are expected to carry out their intentions when the opportunity arises. A diagrammatic representation of the theory is shown in **Figure 2.2.**

Once an individual becomes scientifically aware, then s/he is assumed to have formed beliefs based on realistic information through several sources about the importance of science and science education to his quality of life. These beliefs can in turn lead to the formation of positive attitudes to science and science education and a better likelihood that students will indulge in the much desired behaviour of engaging with and acting upon issues with of a scientific/technological nature.

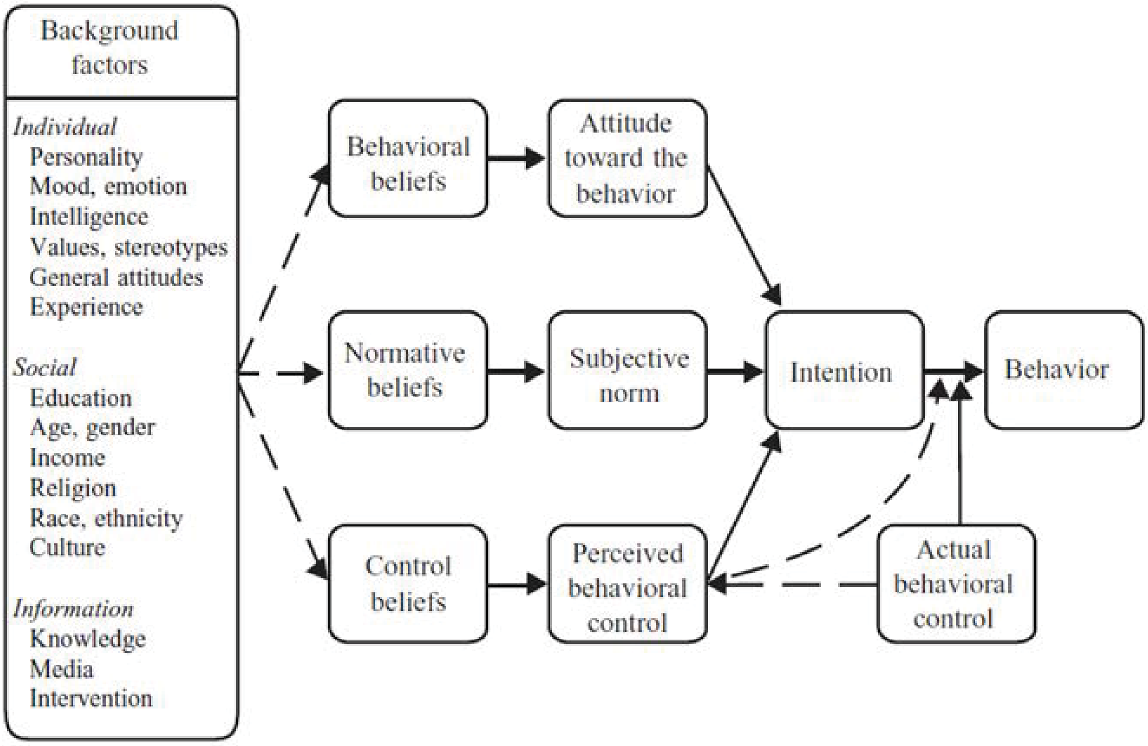



**Figure 0.2: The theories of reasoned action and planned behaviour (adapted from Ajzen & Cote, 2008, p.301)**

### 2.3.4 Raising Science Awareness – A Trasformative Experience

Raising science awareness implies transforming beliefs students have about the usefulness of science and science education in their everyday lives. An attempt is made to help students change/widen their beliefs regarding the importance of science and science education such that they become more willing to engage with and act upon scientific issues at a personal, social and global level. In this sense, this study assumes the form of a *transformative* experience (Jackson, 1986) as it focuses on changing perceptions. Embedded in a realist epistemology (Wong *et al*., 2001), a transformative experience not only emphasises the social and cultural aspects of context and participation, but also the individual's interactions with the real world. A transformative experience contrasts with a *mimetic* (Jackson, 1986) one which focuses on transmitting information to the students.

Transformative experiences fill a gap by targeting a form of engagement that extends beyond the classroom. A lot of effort to address engagement in science education was mainly focused in the classroom or structured out-of school contexts such as museums (Falk, 2001). Transformative experiences extend beyond the barriers of classroom walls and can be said to be a form of in-school to out-of-school engagement (Pugh *et al*., 2009). Any science awareness raised is expected to diffuse into the students' routine lives as they transform into mature adult citizens.

Pugh (2002, 2004) defined a transformative experience in terms of three interdependent features: *Motivated use* which is a type of transfer that refers to the application of learning in a context in which such use is not required (Pugh & Bergin, 2006); *Expansion of perception* which refers to seeing and understanding aspects of the world in new ways. It is the cognitive aspect of the motivated use. *Experiental value* refers to the valuing of content for its usefulness in immediate everyday experiences. Raising science awareness targets the last two factors as it implicates expanding the perceptions that students have of the importance of science in their lives and valuing science education more due to the attributes it endows for one to be able to engage with and act upon scientific issues in everyday life.

In science education, tranformative experieces have been employed in the use of science concepts to see and experience the world in new ways. Rather than focusing on the understanding of concepts, the emphasis is on whether the concepts are making a difference in the students' out-of-school lives (Pugh & Girod, 2007). This study expands the notion of transformative experiences in science education further as it is mainly focused on perceptions rather than concepts.

Transformative experiences do not occur spontaneously. Research suggests that transformative experiences are rare, unless they are specifically fostered by instruction (Girod, Rau & Schepige, 2003; Pugh, 2002). It may well be that most students do not think about science ideas once they leave the classroom (Pugh *et al*. 2009) and this is probably why many cannot see the relevance of science education to their everyday lives. Such findings further underline the importance of specifically targeting awareness in science classrooms rather than expecting it to occur naturally through *mimetic* experiences.

## 2.4 Targeting the Rudimentary Cognitive Component of Engagement to Science and Science Education

Since science awareness is based on beliefs, this section will focus on constructs of engagement that are largely cognitive rather than affective in nature, and how they were or can be addressed in schools. In particular, the students' image of science and scientists and what interests them in relation to this subject area will be reviewed. Metacognition, a relatively new tool in science education and which in this study was adapted to help students think about their science awareness is discussed in the last part of this section.

### 2.4.1 Students' Mental Models of Scientists

Mental models may be viewed as representations of an object or an event and is the person's knowledge of a phenomenon (Tunnicliffe & Reiss, 2000). The process of their formation is a mental activity. Children come to school with pre-existing mental models of science and scientists. Several international studies, both in Western and Eastern developed countries have investigated students' image of science and scientists (Fung, 2002; Newton & Newton, 1998). Most were based on the Draw-A-Scientist Test, (DAST), (Chambers, 1983) and quite a number were supported by writing statements or by interviews.

Students' mental model of scientists is usually stereotypical depicting a Caucasian elderly man, wearing a lab coat and working indoors, mainly on chemistry-based experiments. More stereotypical symbols are included the older the students are. The image held about scientists also seems to be culturally related as it was found that Arabic students tend to exhibit a more unique image with a strong ethnic trait (Koren & Bar, 2009). Furthermore, underdeveloped countries have a higher tendency to regard scientists as intelligent, brave and heroic, helping other people, and trying to improve the standard of living for everybody (Sjøberg, 2002).

A lot of research regarding students' image of scientists has also been carried out in Malta. Results reflect international findings with the image becoming more stereotypical the higher the stage of education to the extent that secondary students see people presented in photographs doing work outside the lab and wearing casual clothes as non-scientists (Azzopardi, 2004). Although younger students (5-7 year olds) also see scientists as working in labs, they use fewer symbols such as lab coats and glasses (Obidimalor Munro, 2006). As in other countries (She, 1995; 1998), these symbols become more common as primary students become older (Spiteri, 2006). It may be that classroom science and textbooks actually reinforce these popular perceptions of science and scientists (She, 1995; Newton & Newton, 1998). Images of astronauts as well as mythic figures and mad/evil scientists working with weapons and inventing robots are also common in the late primary years, especially amongst boys (*ibid.*). Many primary students also identified the science teacher as a scientist (Obidimalor Munro, 2006; Spiteri, 2006).

Studies show that for both primary and secondary students, the image of scientists is largely based on what is portrayed in the media (Azzopardi, 2004; Borg, 2004; Obidimalor Munro, 2006). This was also found to be true beyond Maltese borders (Jane *et al.,* 2007; Turkmen, 2008). This distorted image of scientists also influences subject choice, and students are presented with unrealistic images of scientists and their job. More recent studies (Degabriele, 2008) have indicated that science lessons and science teachers are perhaps also a strong influence.

It is suggested that students' image of scientists, and consequently the development of their scientific identities begins to form when they are 6 to 7 years old (Birr Moje *et al.*, 2007; Newton & Newton, 1998). In fact, it was found that attempts to alter the students' perceptions of scientists through direct encounters with scientists and their work, through videos or interviews with STEM professionals (Wyss *et al.*, 2012), and even by presenting scientists' lives from the past are more successful the younger the age of the students (Flick, 1990; Howitt & Rennie, 2008), in particular in their primary years (Cakmakci *et al.*, 2010; Sharkawy, 2012). Through these means, students gain a more complete image of the scientific enterprise not limited only to its products and instruments but also to its relation to the social and environmental context (Solbes & Traver, 2003).

### 2.4.2 A Focus on Interest

Although there is a lot of work on important elements of engagement such as motivation and attitudes, a greater focus on interest is essential for this study since like science awareness it is a more basic psychological variable and is considered to be a subordinate of other important affective constructs (Hidi *et al.*, 2004; Krapp, 2003; Osborne & Collins, 2003). Interest varies from other affective variables as it is content specific (Schiefele, 1991) and is conceptualised as residing in the relationship between the person and the environment. This implies that interest can be triggered and is not simply a case of a person having or not having interest. Although interest has a neurological basis (Renninger & Hidi, 2011), a person is not always aware of his or her interest during engagement.

Interest has both cognitive and affective emotional components (Hidi *et al.*, 2004; Hidi & Renninger, 2006), with the former becoming more important the more advanced the stage of interest development. A distinction is usually made between *situational* and *individual interest.* The former is specific to a particular scenario; mainly consists of positive affect and focused attention; and is highly scaffolded and transient in nature. The latter entails a more enduring pre-disposition to re-engage with the domain. Here the individual becomes more active and committed cognitively through the accretion of knowledge and values (Hidi & Renninger, 2006; Krapp, 2003). Individual interest seems to be relevant when it comes to students' study and career choices (Dierks *et al.,* 2014).

Enjoyment is central in the equation between interest in science, value and knowledge and future desire to acquire further knowledge and understanding (Ainley & Ainley, 2011). Fredrickson (2001) refers to both joy (enjoyment) and interest as complementary emotions with the playfulness of the former combining with the exploratory and information seeking of the latter. The importance of generating both enjoyment and interest for learning was also made by Dewey back in 1933 as according to him learning is at its best when an activity is both playful and serious.

A low interest in science amongst students and young people has been repeatedly reported (OECD, 2006; Fensham, 2004) especially for the subjects of physics and chemistry (Oon &

Subramaniam, 2011; Osborne & Collins, 2003) and in countries where S&T education is the strongest (Schreiner & Sjøberg, 2004). This has been attributed to the lack of quality of science instruction, explanations from the field of developmental psychology as well as the so-called differentiated hypothesis that assumes that this decline in interest stems from the fact that when young people are searching for their identity, anything that is not compatible with their self-concept is simply excluded from their interest. The extent to which students believe they are confident and successful in science or their level of self-efficacy is also relevant in this respect (Potvin & Hasni, 2014; Renninger & Hidi, 2011) as studies and careers in S&T are still considered to be destined for high achievers. Teachers also attribute the decline in interest in science to the low career and salary prospects of physics graduates compared to the prospects of finance and business vocations (Oon & Subramaniam, 2011).

However, it is significant to note that interest in science is very rich and includes several aspects (Yang, 2010). College students who said that they were not interested in science were actually found to be very interested in some areas of science in some contexts (*ibid.*). They were actually not interested in the learning of science facts at school for the usual reasons commonly quoted in literature. Therefore, the negative general perception that students have of science is due to the perception they have of 'school science'. School does not seem to be able to preserve the initial strength of students' interest for S&T (Potvin & Hasni, 2014).

Several studies, in fact, differentiated between interests in particular subjects, subject areas, and different aspects of science or activities (Krapp & Prenzel, 2011; Prokop *et al.,* 2007; Schreiner & Sjøberg, 2004; Yang, 2010). *Hands-on* experiences were found to evoke interest and to motivate students to learn science (Bergin, 1999) although later Holstermann *et al*. (2010) underlined that this is not so straightforward and differentiated between different types of practical work and their relation to interest. Community partnerships or out-of-school experiences (Jianzhong *et al*., 2012; Watters & Diezmann, 2013), e.g. with industries, have also been found to enrich the learning experiences of students, especially those from minority groups and who experience cultural dissonance when school science is taught. The interaction with animate, natural objects was also found to increase interest in science amongst primary children (Tomkins & Tunnicliffe, 2007), further underlining the importance of out of school first hand discovery experiences. Summer camps, competitions, science fairs, field trips were considered to improve interest, motivation and attitudes (Potvin & Hasni, 2014).

It is relevant to note that most research on interest focused on the students' disposition to continue engaging with science for studying purposes or as a science career, e.g. whether one acquired a Ph.D. in physics and chemistry (Maltese & Tai, 2010). In fact, it was only lately (OECD, 2006) that interest in science was included as an important component of scientific literacy. Perhaps the focus should be shifted from underlining the importance of science for science careers to enhancing and measuring interest in science that is important for our personal and social lives. Yang (2010), in his conceptual framework, did not consider interest in science to be manifested through a career choice but one that is exhibited as individual interest in science that leads to lifelong learning even outside of academic settings. The intellectual knowledge gained from a study of science should also be given its due importance (Oon & Subramaniam, 2011). Fensham (2004) presents a model which shows that the qualities needed by future scientists (creativity, willingness to enquire, etc.) should be enhanced in a science for all course and given importance in selection processes apart from static knowledge. More students would respond to this richer sense of science and pursue it as a career while it helps the majority to gain a lifelong interest in science and its social value.

Interest in science is developed from a very young age, even before middle school (Maltese & Tai, 2010). Interest in science plays a crucial role in learning and choosing science-related careers (Tai *et al.*, 2006) and the teacher is very important in promoting science interest (Aschbacher *et al.,* 2010; Potvin & Hansi, 2014). In particular, teachers can promote science interest when they are themselves interested in science, value this interest and show that they care. In addition, they should scaffold this interest by providing new experiences, encouraging students to take part, encouraging diverse standpoints including hands-on activities, technology, different forms of expression and involving the community (Jianzhong *et al.,* 2010; Maltese & Tai, 2010; Yang, 2010) .

Since women seem to be less engaged with science than men (EC, 2008) and the interest of girls in science seems to decline drastically between the ages of 12 and 16 (Lindahl, 2007), research has also focused on initiatives aimed at engaging girls more with science. Student-centred instructional strategies, careful attention to the formation of groups, provision of appropriate role models, early science instruction (in kindergarten), relevant curriculum that addresses girls' interests, initiatives that build self-efficacy, etc. have all been suggested to be appropriate pedagogical strategies for girls (Baker, 2013).

### 2.4.3 The Meta- Approach

Science awareness includes elements of conscious awareness, mindfulness, and active thinking with attention about one's own awareness. It is thus relevant to review meta-approaches that attempt to raise awareness about the importance of science and science education.

While it is difficult to find specific references to meta-awareness approaches in science classes, a few examples have been found for other areas of education. Following a thorough analysis of classroom conversations between mathematics teachers and students during her doctoral thesis (Kleve, 2007), Kleve (2013) promoted teaching that intentionally leads to meta-awareness of the secondary discourse (the discourse that results from schooling) in Mathematics, in contrast to its assumed acquisition through academic content. Together with another Norwegian author, she also promoted meta-linguistic awareness as a cross-curricular tool amongst early secondary students to support literacy in Mathematics and Norwegian. The intention is to make similarities and differences in rules, language and the nature of arguments in both subjects more explicit to the students (Kleve & Penne, 2012).

These two propositions (Kleve, 2013; Kleve & Penne, 2012) of the possible usefulness of meta-awareness, intentionally enhanced by the teacher, are believed to combat social inequalities by bridging the gap between the primary and secondary discourse of students (Kleve, 2013). Primary discourse, which refers to the prior understanding of an educational field with which students start school (Gee, 2003), in some cases, does not match the secondary discourses in the subject that result from schooling. Thus, while many students start school with already acquired secondary discourse, others still have to learn it. Teaching based on assumed as opposed to intentional acquisition of this secondary discourse may actually enhance the differences that already exist. Gee argues that meta-awareness is a pre-condition to literacy in the learning process incorporating contextual understanding and interpretation. Bruner (1996), in fact, underlines that learning takes place through the use of language and our awareness of the learning situation - "thinking about thinking' has to be a principal ingredient of any empowering practice of education." (p.19)

Despite the lack of studies on the use of meta-awareness in science classes, there has been an interest in a related, but a deeper and more complex concept, namely *metacognition and self-direction.* This concept is recognised (Choi *et al*., 2011) as an important integrating common component threading across all the levels of sophistication of scientific literacy as shown by the framework represented in **Figure 2.3**. "Metacognition and self-direction is the element that allows an individual to know if they are aware of an issue and if they are or are not acting responsibly or taking action" (Choi *et al*., 2011, p.689). In this respect, metacognitive skills are essential to understand one's level of comprehension and reflect whether more knowledge is needed to understand large amounts of new information of critical and complex scientific issues. With respect to habits of the mind, metacognition allows one to be more flexible and to come up with different thinking strategies and more flexible plans in order to solve problems presented by science and technology. In the realm of character and value, metacognition and self-direction help one to see in what way perspectives of others are similar or different from one's own and in considering whether one is being ecologically, socially and morally conscious in his or her pursuits.

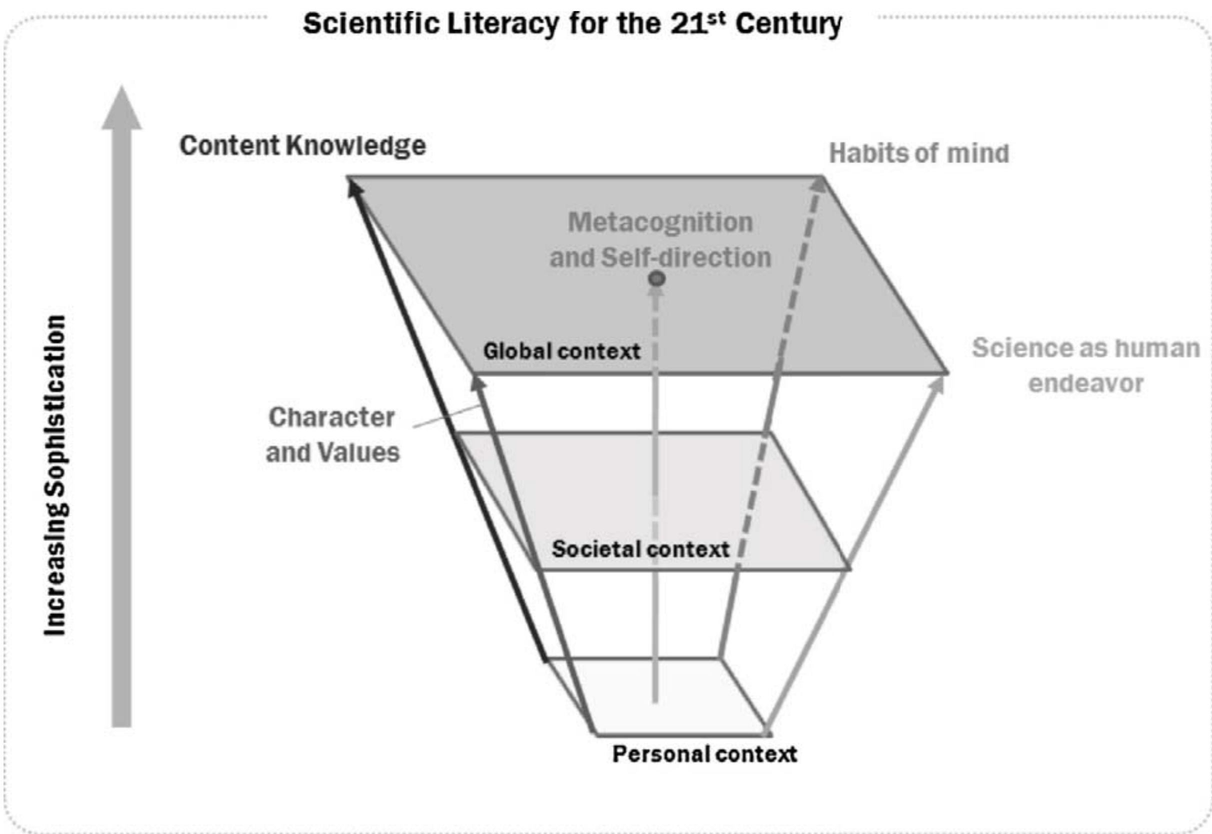



**Figure 0.3: A framework for scientific literacy as developed by Choi *et al*. (2011), p.682.**

The concept of science awareness targeted in this study does not entail the depth of metacognition required by Choi's model as the ultimate aim is not scientific literacy. As described by the Norwegian authors (Kleve, 2013, Kleve & Penn, 2012), meta-awareness involves mere consciousness of the setting through which one learns, which in this research includes the science enterprise, its reciprocal association with society, and the attributes one needs to gain through science education to engage with this field in everyday life. This will in turn enhance literacy (Gee, 2003). In this study, however, awareness is being featured as a phenomenon that can be developed and sustained, as opposed to one that can suddenly be switched on by the educator. Since metacognition involves thinking about your understanding and the mastering of skills you need in a particular field, then metacognitive approaches can be employed to raise this level of meta-awareness in the realm of science education, by helping students intentionally reflect and develop their beliefs of the importance of science in their everyday life, the political nature of science and how science education can help them to acquire the competencies to engage with and act upon such issues.

One of the problems of metacognition is the lack of agreement among psychologists with respect to its meaning. It was mainly described as regulation of one's own cognitive system (Flavell, 1976). Later, as the concept was further elaborated, a distinction was made between *metacognitive knowledge* and *metacognitive monitoring and self-regulation* (Flavell, 1979). *Metacognitive knowledge* (knowledge of what you know) comprises implicit or explicit ideas, beliefs and theories of person/self, tasks, strategies, goals, cognitive functions (memory, attention), validity of knowledge and theory of mind. On the other hand, metacognitive monitoring and self-regulation, also referred to as *metacognitive skills* (Efklides, 2006), focus on procedural knowledge, e.g. planning, monitoring, etc., required for the actual regulation of one's own learning activities. There is also reference to *metacognitive experiences* that also include the affective aspect of learning such as feelings, moves, motives, etc. While metacognitive knowledge and experiences manifest the *control* function of metacognition, metacognitive skills are manifestations of its *monitoring* function (Flavell, 1979).

A review on the use of metacognition in science education by Zohar & Brasilai (2013) shows that this field is in state of growth with most current metacognitive research largely focused on the understanding of scientific concepts. The most commonly used method is the employment of metacognitive prompts and cues. Since this field is still in its infancy, several research gaps identified included: lack of causal evidence of the effectiveness of metacognitive instruction in science education; few studies among pre-school and elementary learners; as well as lack of understanding of the professional development of teachers regarding the use of metacognition (*ibid*.).

The use and effectiveness of metacognition in science education has been shown to improve through student and teacher training. Teachers tend to resist the implementation of metacognition as a pedagogical tool before they have some kind of instruction in it (Adi & Nir, 2013). However, following training, teachers acknowledge that the experience can improve the affective element of the relation between teaching and learning and are willing to continue learning about it. However, they still identify lack of support, time and learning materials as major obstacles in the traditional classrooms (*ibid*.). Students also tend to resist metacognition, as they are used to being rewarded for being mindless and passive (Thomas, 1999). Teaching metacognitive skills were shown to be more effective among low achievers (Ben-David & Zohar, 2009) as the high achieving students tend to construct these metacognitive skills themselves without the need for support.

The review regarding meta- approaches has shown that they have a significant role in promoting science awareness. Metacognitive reflection about one's own beliefs can actually lead to a heightened meta-awareness, an increase in the recognition and appreciation of the milieu in which one is learning science, or in the conceptual terms of this research, a higher level of science awareness.

**Conclusion**

This literature review provided a critique of current theories in general science education, which lead to the development of the conceptual framework of science awareness that guided this research. These theoretical perspectives also served as a background for the development of research tools to measure science awareness in Phase 1 of this study and for the planning of the learning activities piloted to raise this educational objective in the second and final phase of this research.

The two chapters which follow include the methodology implemented and analysis of the data collected in Phase 1 of this research. Chapters 5 and 6 describe the methodology and analysis of Phase 2.

# Chapter 3. METHODOLOGY – PHASE 1

This chapter describes the methodology used to address the first part of the research question in this study: that of measuring science awareness and obtaining insight into the factors that affect early secondary students' beliefs on the importance of science, the attributes needed to engage and take action in relation to scientific issues and the role that science education plays in this regard. It describes the need for a 'mixed methods' model to obtain both a broad snapshot of students' level of science awareness in Malta as well as to why they hold this view of the role of science. The chapter also provides details about the tools used, their validity and reliability, the samples, ethical issues, and how the data were collected. The results of this phase will be analysed in the next chapter and contextualised in the theoretical perspectives discussed earlier to plan the second and final phase of this study where a framework for learning strategies aimed at raising the level of science awareness of early secondary students was designed.

## 3.1 Research Design

The first part of this study was aimed at gauging the level of science awareness and in identifying the factors that affect these beliefs, recognitions and perceptions regarding science and science education. This required an exploratory and an explanatory nuance and thus both quantitative and qualitative data were considered to be essential. A mixed method strategy, which will be discussed in the next section, was necessary to achieve this end.

### 3.1.1 Mixed Methods – An overview

Mixed methods research is a recent development, and a historical overview of its emergence is important to understand its strengths. Several researchers made significant contributions to mixed methodology research since the 1950s (Creswell & Plano Clark, 2011). In the 'formative period' (Campbell & Fiske, 1959), multiple methods were used in quantitative methodology to obtain multiple forms of data to validate psychological traits. This led to several detractions from purists, who stressed the incompatibility of qualitative and quantitative methods. In the 'paradigm debate period', Bryman (1988) advocated mixed methods by identifying connections between the qualitative and quantitative methodologies. In the 'procedural developmental period', Bamberger (2000) provided an international policy focus to mixed methods research. A comprehensive handling of many aspects of mixed methods research was later presented by Tashakkori & Teddlie (2003).

Mixed methods research was still in its 'adolescence' (Tashakkori & Teddlie, 2003, p.3) at the beginning of the 21st century, but is becoming established as the third methodological movement (Doyle *et al*., 2009), which aims to help in the understanding of complex research problems. Since the late 1990's, particular forms of mixed methodology have been developed and are now in use (Creswell & Plano Clark, 2011). Considerable in-depth texts aimed at guiding researchers in the field of mixed methods have been compiled (Creswell *et al.,* 2004; Tashakkori & Teddlie, 1998; 2003), and the *Journal of Mixed Methods Research,* was launched in 2007.

Many different terms have been used to refer to mixed methods research over time. These include 'multitrait/multimethod research' (Campbell & Fiske, 1959), 'integrated/combined' (Steckler *et al.,* 1992), 'triangulation' (Morse, 1991), 'hybrid' (Ragin *et al*., 2004), 'mixed methodology' (Tashakkori & Teddlie, 1998) and finally, the term most in use today is 'mixed methods research' (Tashakkori & Teddlie, 2003). A common definition of mixed methods research in use is that by Creswell & Plano Clark, (2007, p.5), who define it as:

> "a research design with philosophical assumptions as well as methods of inquiry. As a methodology, it involves philosophical assumptions that guide the direction of the collection and analysis of data and the mixture of qualitative and quantitative approaches in many phases in the research process. As a method, it focuses on collecting, analysing and mixing both quantitative and qualitative data in a single or series of studies. Its central premise is that the use of quantitative and qualitative approaches in combination provides a better understanding of research problems than either approach alone."

The research contributions that have strengthened the rationale for the establishment of mixed methods as a separate research paradigm are mainly twofold. Firstly, research methods should be chosen to provide the best opportunities for answering research questions (Tashakkori & Teddlie, 2003). In some studies, the nature of questions allows them to be answered by either quantitative or qualitative research methods while others require methods that make use of the strengths and complementarity of both methodological frameworks (Niglas, 2004; Onwuegbuzie & Leech, 2005). In fact, mixed methods research has several purposes and can specifically address many types of research questions. It can be used to: inform the development of one method from another for the purposes of increasing construct validity; elaborate, crosscheck or corroborate results; increase the range or scope of inquiry; develop the basis of instruments; discover inconsistencies; and check reasons for unexpected effects (Greene *et al.,* 1989; Krathwohl, 2009). These purposes are not mutually exclusive and may be combined in any given study (Schifferdecker & Reed, 2009). Secondly, from a philosophical point of view, mixed methods research helps to overcome the subjectivity and value-ladeness of the researcher's often lop-sided thinking as well as the theory-ladeness of results (Johnson & Onwuegbuzie, 2004). Thus, through the establishment of this new paradigm, there is no longer a need for a sharp demarcation between qualitative and quantitative research (Newman & Benz, 1998).

Of course, mixed methods research is not devoid of challenges. These comprise: the requirement for the researcher to be familiar with both quantitative and qualitative forms of research; the time-intensive nature of collecting and analysing both text and numerical data; access to tools and programs in which to store and integrate qualitative and quantitative data; and the difficulties in publishing mixed method studies, given the word limit and the amount of data resulting from such studies (Creswell, 2002; Schifferdecker & Reed, 2009).

### 3.1.2 Measuring Science Awareness: A Sequential Explanatory Strategy

This phase of this research involved measuring early secondary students' level of science awareness, as well as obtaining some insights into why students hold this level and in which aspects of science they are interested. Several approaches to applying mixed methods designs have been identified in literature (Creswell & Plano Clark, 2011; Creswell & Zhang, 2009;

Teddlie & Tashakkori, 2003). These different classifications are based on the implementation sequence and priority that is given to quantitative and qualitative data collection, as well as on the stage at which the two types of data are integrated. The design that was considered as appropriate in implementing this first phase of the research question set was *explanatory sequential* which means that "the investigator first gathers and analyses quantitative data, and then uses a qualitative follow-up data collection and analysis to help explain the quantitative results" (Creswell & Zhang, 2009, p.614). The choice of this model was based on several criteria:

The approach of this research study was sequential as it was designed to be implemented in two separate steps, with one following the other. The first step in this phase involved collecting quantitative data through a survey based on a questionnaire aimed at measuring the level of science awareness among Maltese early secondary students. In order to obtain insights into reasons for the statistical trends identified, and to further understand what aspects of science and science education students are interested in, the second step of this phase then proceeded with collection of qualitative data through focus group discussions;

The research design was explanatory in nature as the qualitative results from the focus groups were used to explain and interpret the results obtained in the quantitative study. Priority was given to the quantitative data which provided trends in level of science awareness held by students in the second year of secondary education. The focus groups' data was used to supplement and explain the trends obtained.

Integrating the quantitative and qualitative methods only during the interpretation phase is another characteristic feature of the sequential explanatory design. The steps of this strategy are presented in the visual model (**Figure 3.1**) below based on the notations adapted from Morse (1991) and Tashakkori & Teddlie (2003). More detailed descriptions of each stage are given in subsequent sections:

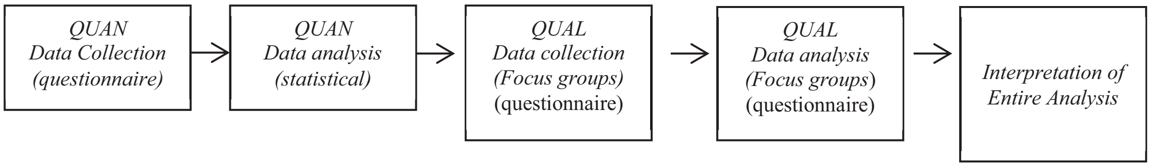



**Figure 0.4: A visual model, based on the notations adapted from Morse (1991) representing the explanatory sequential design used in the first phase of this research study.**

This design was easy to carry out as the stages were clearly separate. This made it manageable for a single researcher. The main weakness was the duration of the data collection, with the two separate phases (Creswell, 2002; Creswell & Zhang, 2009). In fact, data collection was carried out over two scholastic years and therefore the students participating in the quantitative phase of this study were not available for the qualitative phase.

## 3.2 The Indicators of Science Awareness

Science awareness is a relative concept and its measurement is aimed at placing students along a continuum of personal beliefs according to the extent to which they recognise the impact of science and technology on their lives, the range of competencies, knowledge and attitudes needed to engage with and act upon science issues, and that science education is the route to achieve these abilities. In the quest to distinguish between low and higher levels of science awareness, specific indicators were formulated for each of the three aspects that defined science awareness. Each characteristic was also described in a bi-polar way representing a low level of science awareness at one end against a higher level at the other end according to the definition of science awareness used for this research study.

These contrasting extreme positions were used to direct the development of the items in the questionnaire. These positions are elaborated below:

1. **Recognition that science has an impact on individual lives and society**. The bi-polar description of the list of indicators that was used to measure this first attribute of science awareness is shown in **Table 3.1**

**Table 0.7: Characteristics that define science awareness in terms of the extent to which students are able to recognise the impact of science on their lives.**

| *A student with a low level of science awareness is more likely to believe that:* | *A student who has a higher level of science awareness is more likely to recognise*: |
|---|---|
| personal, social and global issues are related to science only if they have a direct link to scientific factual knowledge. | the science component in personal, social and global issues even when these have high political and social connotations. |
| recent scientific and technological advances are utterly beneficial and have no negative implications. | recent scientific and technological advances as more uncertain and risky than ever before. |
| only scientists control the progress and research in science and technology. | that citizens, Governments and industrialists all influence the progress and research in science and technology. |
| morals and values are detached from science and technology. | science and technology are relevant to maintain social justice and sustainability of the planet. |

2. **Recognition of the range of competencies, values, knowledge and attitudes essential to be able to engage with and act upon issues having a science component**. These competencies were identified from literature as explained in **Table 2.2**. They are here diagrammatically listed as a ladder (See **Figure 3.2**) according to the extent to which they prepare the individual to reach the pinnacle of science education of the general student as it is featured in the triangular model given in **Figure 2.1**. This model relates science awareness to two much acclaimed educational goals for the general student, namely scientific literacy and science for citizenship. Once the students recognise that science and science education are important through enhanced science awareness, then they are more likely to gain the attributes such as knowledge in and about science, explaining phenomena, higher order thinking skills etc., that characterise scientific literacy and to become more engaged with the science around them. Beyond engagement, achievable results and action are only possible if the individual has strong morals and values, good argumentation skills, an element of political literacy and the ability to resolve conflict. A student who has a high level of science awareness is more likely to acknowledge that in order to attend to and act upon personal, social and global scientific issues, one needs to espouse a range of attributes that go beyond knowledge and skills to those that make one move beyond understanding to taking action. Such students climb higher up the ladder of recognition of necessary attributes than their counterparts.

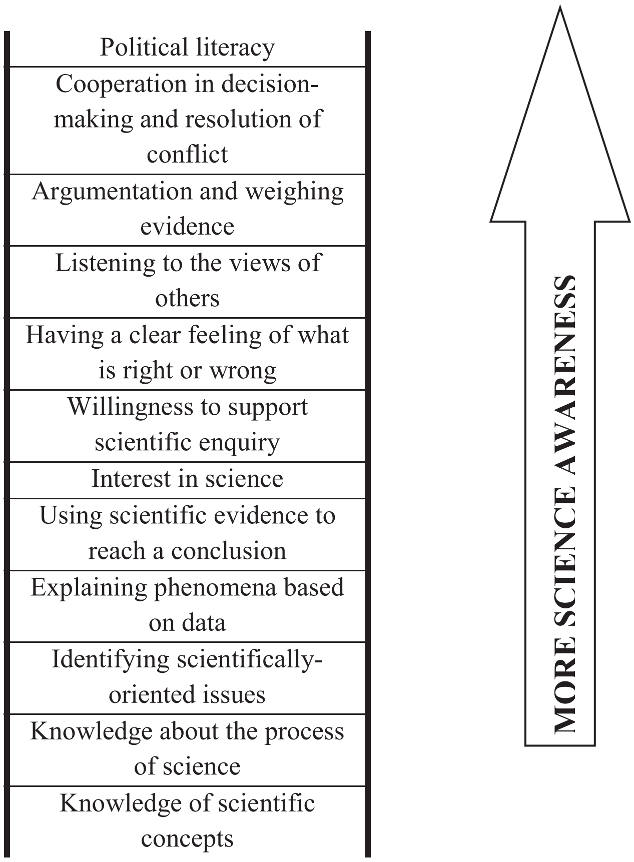



**Figure 0.5: Hierarchical attributes to profile a more scientifically aware student**

At this point, it is also important to underline that this study was aimed at measuring the degree to which students are aware that the above competencies are important to engage with and act upon scientific issues and in no way a measure of the extent to which students have actually acquired these attributes.

**3. Science education can contribute to the development of these competencies, values and attitudes**. More specifically, a person who is more scientifically aware is more likely to acknowledge that all the attributes mentioned in (2) above can be achieved through science education. A person who has a lower level of science awareness is more likely to see science education only fit to impart knowledge and explanations with the rest of the attributes further up the ladder as achievable through the humanities.

The indicators above were derived from the theoretical perspectives discussed in Chapter 2. They were compiled by putting together the philosophy underlying and the competencies required by documents advocating or actually measuring scientific literacy and science for citizenship. The yardsticks specified above were used to design the questionnaire used to measure science awareness of early secondary students and which is discussed in more detail in **Section 3.3.2 (p.72 )**.

## 3.3 Quantitative data collection

This section describes the key quantitative methodology in answering the first part of the research question targeted at measuring the level of science awareness of early secondary students (Form 2 – at age 12). It first includes a detailed description of the research tool –the questionnaire used to capture students' level of science awareness, the sampling of students in their second year of secondary education, and the method for data collection.

### 3.3.1 A Survey Design to Gauge the Level of Science Awareness

A survey strategy was used to obtain a general picture of the students' beliefs about science and science education and thus to answer the first part of research question. This strategy was chosen to gauge the level of science awareness as "a survey design provides a quantitative or numeric description of trends, attitudes, or opinions of a population by studying a sample of that population. From sample results, the researcher generalises or makes claims about the population" (Creswell, 2002, p.153). Data can be collected relatively quickly and economically, and attributes of the student population can be identified from a small sample.

This survey was *cross-sectional* or *correlational* (De Vaus, 1995; Fink, 1995) as data were collected from the student sample over one month. Cross-sectional studies are designed to capture a still picture of population characteristics such as values, beliefs and attitudes. Measuring how science awareness changes over time was not an issue, and therefore *longitudinal* (*ibid.*) models were not considered. The survey instrument used was developed based on the elaborate definition of science awareness provided in the previous section.

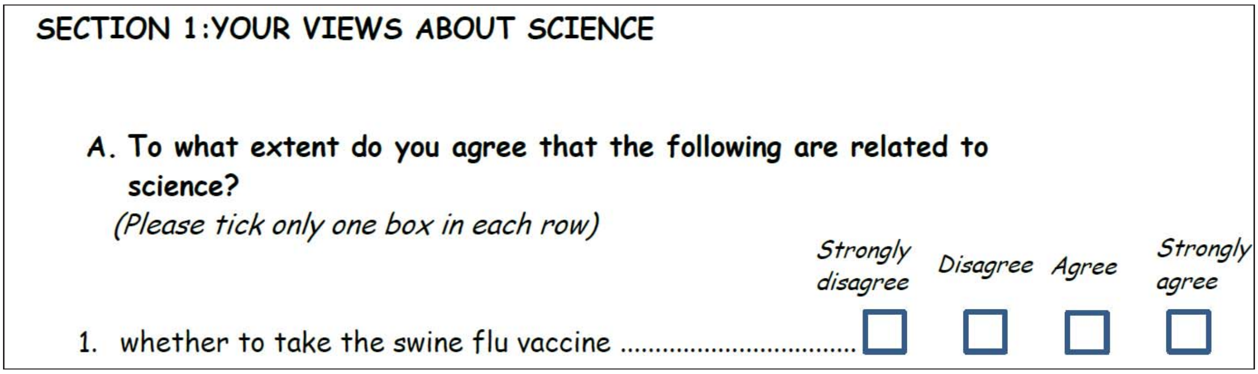
It was decided that it was best to carry out the survey with Form 2 students (students in their second year of secondary education). At this stage, students would have experienced one full year of core science in their first year of secondary education, and are about to make subject specialisation choices for their next academic year. They are thus at a crucial point where they decide whether or not they want to engage more with science by choosing it as their specialisation.

### 3.3.2 The Instrument

A questionnaire (see **Appendix A**) was used as the instrument for the collection of quantitative data for the survey. The tool was designed by the researcher to measure the level of science awareness amongst Form 2 (Year 8, age 12) students according to the definition of science awareness specified for this study and the operational indicators derived from it. In this study, science awareness is understood in terms of beliefs that students espouse about science and science education. Since beliefs are the cognitive component of attitudes, Likert scales were chosen to gauge these beliefs. Likert scales have been used in major instruments targeted at measuring attitudes to science e.g. ROSE (Schreiner & Sjøberg, 2004). Compared to Thurnstone scales, Likert scales are easy to construct and easy to give response and scores to. Likert scales are also found to give data with relatively high reliability (Gable & Wolfe, 1993; Oppenheim, 1992).

The questionnaire thus consisted entirely of closed, pre-structured questions that by their format offered the respondents fixed, alternative responses. Advantages with closed questions are that they are relatively low cost as the data are rapidly collected and coded. They also give clear data that are easy to compare. Because closed questions do not require extended writing, they are also quickly and easily answered (Oppenheim, 1992). The drawbacks usually associated with closed questions, such as loss of spontaneity and expressiveness will be counteracted by additional qualitative data as part of a mixed methods design.

Most items in the questionnaire followed the same basic logic as shown in **Figure 3.3**. A statement was presented, and the students were asked to give their response by ticking the appropriate box in a fixed scale. Likert scales with four categories were used for such items. Further categories were avoided as this could lead to confusion and frustration amongst the respondents (Gable & Wolfe, 1993). The responses were presented in ascending order: Strongly Disagree to Strongly Agree, or Never to Very Often, e.g.


SECTION 1:YOUR VIEWS ABOUT SCIENCE

A. To what extent do you agree that the following are related to science?
(Please tick only one box in each row)

| | Strongly disagree | Disagree | Agree | Strongly agree |
|---|---|---|---|---|
| 1. whether to take the swine flu vaccine ................................ | ☐ | ☐ | ☐ | ☐ |

**Figure 0.6: Typical Likert scale items included in the questionnaire.**

The instrument used in this survey, was divided into three sections which were used to collect information about:

- the students' views about science and science education **(Section 1);**
- themselves and their general attitudes towards science/science education **(Section 2);** and
- their family and home respectively **(Section 3).**

The distribution of items in the respective sections of the questionnaire is given in **Table 3.2.**

- **Awareness of the science component in personal, social and global issues.**

**Sections 1 A, B** and **C**, tackled students' awareness of personal, social and global scientific issues. Students were asked to respond to the following instructions:
*To what extent do you agree that the following are related to science? (Please tick only one box in each row.* This was followed by 36 items, each with a 4-point Likert scale from *Strongly Disagree* to *Strongly Agree*. A five-point Likert scale, with a middle neutral point was avoided in this study as research has shown that the meaning of the middle box can be complicated to interpret (Oppenheim, 1992). Respondents do not necessarily regard the middle category as the neutral point between the two extremes. They can choose the middle

box to indicate a lack of knowledge or understanding, indifference, lack of motivation for taking a stance or refusing to answer (Gable & Wolfe 1993). This may cause complexities in the data analysis. Additionally, the term science used in the question was not defined as its interpretation, in itself, would give information regarding the extent that school science has on the early secondary students' interpretation of science. In fact, during the piloting, as well as as during the actual data collection process, there was not a single instance when students asked for a definition of the word science as used in the questionnaire..

The items in these three sections represented issues or decisions, pertaining a science component that people might face in their personal and social lives. Issues were divided into three sections according to whether they had a personal, social or global dimension as is further shown in **Table 3.3**.

The list of issues is by no means exhaustive. The choice depended on the extent to which 12-year olds can easily relate to the issue and on encompassing a wide range of contexts as identified in literature (Bybee, 2008; OECD, 2006; Ratcliffe & Grace, 2003; Sadler & Zeidler, 2004). Although the Maltese early secondary science curricula do not include topics such as cloning and abortion, these items were still included in the questionnaire as their awareness might indicate the extent to which students are exposed to out-of-school experiences in science.

**Table 0.8: Distribution and number of items in the questionnaire used to measure science awareness.**

| Section | Sub-Section | Main area | Number of items |
|---|---|---|---|
| Your views about science | 1A, B, C | To what extent do you agree that the following are related to science? (personal, social, global issues respectively) | 36 |
| | 1D | To what extent do you agree with the following statements? (re the process of science) | 17 |
| | 1E | State the extent to which you agree that the following are/were important for Paul* to improve his quality of life. (context-based question) | 10 |
| | 1F | Citizens who do not agree with this decisions should: (context-based question) | 7 |
| | 1G | To what extent do you agree/disagree that school science has been helping you in the following area? | 13 |
| About you | 2A- F | Background information | 6 |
| | 2G | How often do you carry out the following during your science lessons? | 9 |
| | 2H | How often you carry out the following out-of-school activities? | 7 |
| | 2I | To what extent do you agree with the following statements about science? | 8 |
| | 2J | To what extent do you agree with the following statements about your science lessons? | 6 |
| Your Family and your home | 3A | What is the highest level of schooling completed by your mother/female guardian? | 1 |
| | 3B | Is your mother/female guardian active in any one/or more of the following? | 1 |
| | 3C | What is the highest level of schooling completed by your father/male guardian? | 1 |
| | 3D | Is your father/male guardian active in any one/or more of the following? | 1 |
| | 3E | Which of the following are in your home? | 1 |
| | | **Total number of items** | **124** |

**Table 0.9: Examples of items from the respective sub-sections of Section 1 of the questionnaire.**

| Questionnaire Section | Number of items | Examples |
|---|---|---|
| Section 1A – Personal issues | 8 | Whether to breast-feed or bottle-feed a baby.<br>Choosing between a number of treatments for a deadly disease such as cancer<br>What type of food to buy<br>The type of transport to use |
| Section 1B – Societal issues | 16 | Whether an area should be built or developed<br>The laws to control hunting of birds<br>Where to build a landfill<br>Whether alcoholic drinks should be prohibited for young people |
| Section 1C – Global issues | 12 | Greenhouse gases and their effect on the climate<br>Abortion<br>Cloning<br>Exploration of space. |

- **Acknowledgment of the science - society association**.

In **Section 1D**, the extent to which students acknowledge the reciprocity of the science-society association was studied. The students were asked to respond to the following question: *To what extent do you agree with the following statements? (Please tick only one box in each row.)* This was followed by 17 items, each with a 4-point Likert scale from *Strongly Disagree* to *Strongly Agree*.

The more scientifically aware students are expected to show higher agreement/disagreement with items that feature/do not feature:

- the risk and uncertainty characterising recent scientific and technological advances (Items D1-D7) e.g. *The latest scientific applications are more risky than ever before;*
- a realisation of the effect that society may have on the progress of science (Items D8 – D13) *e.g. what scientists research is determined by politicians and industrialists;* and

- a relation between science, social justice and sustainability of the planet (Items D14-D17), e.g. *Science serves the rich at the expense of the poor.*

Several other attitude instruments used in similar studies include items related to 'real word science' (Pell & Jarvis, 2001), 'the utility of science' (George, 2006), 'importance of science' (Barmby *et al.,* 2007) or 'value of science to society' (OECD, 2006). However, typical statements characterising such questionnaires included generic items such as *Science is beneficial to society* or *Science makes our lives easier and more comfortable* that depict science as an isolated entity, inflicting its technological applications with their pros and cons on society. In this sense, this study is more in line with *A Study of Values and Beliefs in relation to Science and Technology amongst 11-21 year olds* (Haste, 2004). While in this study carried out as part of the Nestlé Social Research Programme, students were asked to express a value position with regards to science, e.g. *I always make sure that I buy cruelty-free products*, in this research study only items that show students' beliefs that science is highly value-laden are included.

- **Recognition of the range of competencies, values, knowledge and attitudes essential to be able to engage with and act upon issues having a science component**

Another important component of science awareness is the recognition of the attributes that determine functionality in relation to issues having a scientific component. This was gauged through the items included in **Sections 1E** and **1F** that were both context-based. Cases based on real stories were presented here because it made the identification of related attributes much easier than if simple generic, detached questionnaire items were used.

**Section 1E** referred to the case of Paul* (identity was withdrawn), who was rendered paralysed following an accident. This case was chosen because it happened in Malta, and as it provided an excellent example of an individual who had to engage with the frontiers of medical science in order to decide which treatment is best to regain his walking abilities. Although stem cell treatment might probably be alien to Form 2 students, detailed knowledge of this therapy was not necessary to answer the questions related to science awareness that were included in this section. Following a short extract to introduce this case, the questionnaire respondents were given the following instructions: *State the extent to which you agree that the following are/were important for Paul to improve his quality of life. ? (Please tick only one box in each row).* This was followed by 10 items each with a 4-point Likert scale from *Strongly Disagree* to *Strongly Agree* as shown in **Figure 3.4.** The students were asked to what extent they think Paul needed knowledge in and about science (e.g. *knowing how his body works*), scientific competencies (e.g. *comparing and evaluating the results obtained by different doctors/researchers*), and attitudes (e.g. *showing interest in scientific research*) in order to engage with his particular life situation. The aptitudes included in the questionnaire were adapted from the latest documents that attempt to define the attributes required for scientific literacy or science for citizenship (Bybee & McCrae, 2011; Fensham, 2008; Hurd, 1998; OECD, 2006, 2009; UNESCO, 2009; etc.) and which were already discussed in Chapter 2. A higher level of science awareness is expected to be shown by those students who indicate a higher agreement with all the statements included in this section.

**Section 1F** addressed a socio-scientific issue of national importance related to the decision of the Malta Environment and Planning Authority, MEPA, to approve the use of heavy fuel oil in favour to the less polluting gas oil in an extension of the main power station in Malta. Following a short introduction, the students were given the following instructions: *State your level of agreement with the following statements. Citizens who do not agree with this decision should: (Please tick only one box in each row.)* This was followed by 7 items each with a 4-point Likert scale from *Strongly Disagree* to *Strongly Agree* as shown in **Figure 3.5**. The questions were aimed to gauge the beliefs of respondents in relation to values (e.g. *only speak up if the decision affects them personally)* and actions (e.g. *take part in demonstrations to stop the project*) the Maltese citizens who do not agree with such a decision are expected to have and carry out respectively.

**The following question refers to this case based on a true story:**

*Paul* was recently paralysed when a heavy structure fell on him. Since then, he has been receiving stem cell treatment overseas to help him regain the use of his legs and he is getting better. Stem cell treatment is quite a new research area, is not available worldwide and not all experts agree about its benefits.* *(*Real person's identity has been withdrawn)*

**E. State the extent to which you agree that the following are/were important for Paul* to improve his quality of life:**
*(Please tick only one box in each row)*

| | *Strongly disagree* | *Disagree* | *Agree* | *Strong agree* |
|---|---|---|---|---|
| 1. knowing how his body works.......... | ☐ | ☐ | ☐ | ☐ |
| 2. knowing about the curing effects of stem cells.......... | ☐ | ☐ | ☐ | ☐ |
| 3. knowing where to look for reliable information about stem cell research .......... | ☐ | ☐ | ☐ | ☐ |
| 4. comparing and evaluating the results obtained by different doctors/researchers.......... | ☐ | ☐ | ☐ | ☐ |
| 5. analysing why different doctors/researchers obtained different results.......... | ☐ | ☐ | ☐ | ☐ |
| 6. evaluating whether the risks of the treatment outweigh the benefits.......... | ☐ | ☐ | ☐ | ☐ |
| 7. being able to listen to the views of others.......... | ☐ | ☐ | ☐ | ☐ |
| 8. showing interest in scientific research.......... | ☐ | ☐ | ☐ | ☐ |
| 9. being willing to take action to collect money for his treatment.......... | ☐ | ☐ | ☐ | ☐ |
| 10. his school science education.......... | ☐ | ☐ | ☐ | ☐ |

**Figure 0.7**: **Insert from the questionnaire showing the items included for the case study tackled in Section 1E.**

**The following question refers to this case:**

*The Malta Environment and Planning Authority on Monday, 5th December 2011 approved the use of heavy fuel oil over gas-oil as the main fuel for the Delimara power station extension. The people who live in the South of Malta did not agree with this decision as they argue that in contrast to gas-oil the burning of heavy fuel oil causes a lot of air pollution especially soot emissions.*

**F. State your level of agreement with the following statements:**
*(Please tick only one box in each row)*

Citizens who do not agree with this decision should:

| | *Strongly disagree* | *Disagree* | *Agree* | *Strong agree* |
|---|---|---|---|---|
| 1. accept such a decision as good and final as it was taken by experts | ☐ | ☐ | ☐ | ☐ |
| 2. only speak up if the decision affects them personally | ☐ | ☐ | ☐ | ☐ |
| 3. write about the issue in newspapers, blogs etc. | ☐ | ☐ | ☐ | ☐ |
| 4. take part in demonstrations to stop the project | ☐ | ☐ | ☐ | ☐ |
| 5. take part in television debates regarding the issue | ☐ | ☐ | ☐ | ☐ |
| 6. collect useful data from different sources to understand the issue better | ☐ | ☐ | ☐ | ☐ |
| 7. collect signatures for a petition and present it to the relevant authorities | ☐ | ☐ | ☐ | ☐ |

**Figure 0.8: Insert from the questionnaire showing the items included for the case study tackled in Section 1F.**

- **The extent to which science education has contributed to the development of the competencies, values and attitudes that make us more able to function in society.**

In **Section 1G**, the respondents were expected to express the extent to which they believe that science education has helped them to gain the knowledge (e.g. *understanding the world around you*), competencies (e.g. *negotiating possible solutions through democratic ways*), attitudes (e.g. *willingness to participate in political action as a reflective citizen*) and value positions (*strengthening your values, e.g. human rights, tolerance, prudence towards the environment, etc.*) they need to be able to engage and take action upon issues of a scientific/technological nature. The students were presented with the following question: *To* *what extent do you agree/disagree that school science has been helping you in the following areas? (Please tick only one box in each row.)* This was followed by 13 items each with a 4-point Likert scale from *Strongly Disagree* to *Strongly Agree*. The question that guided this section has a retrospective stance and responses reflect the outcomes of the science education to which the students were exposed. A more prospective outlook, figuring what students expect to gain through their science education was derived from the focus group discussions as will be explained further on.

- **Background information**

In **Sections 2 and 3** of the questionnaire, the students were requested to give some information about themselves and about their lives at home. These sections were presented as the last two sections of the questionnaire so that students could be more focused when answering items in Section 1 that were more cognitively demanding and which were specifically aimed to gauge science awareness. As shown in previous sections, the beliefs characterising science awareness are components of the general attitude towards science and science education that is usually measured in typical attitude studies (Barmby *et al*. 2008; Francis & Greer, 1999; Schreiner & Sjøberg, 2004). Consequently, the personal and domestic aspects probed were those identified through extensive literature reviews to be predictor variables of affective attitudes towards science and attitudes towards the utility of science (George, 2006; Osborne *et al.,* 2003). These factors include:

- gender (Question 2A);
- type of school (Question 2B);
- language spoken at home (Question 2C);
- exposure to science during the primary years, measured through the number of science lessons in the last year of primary schooling (Question 2D);
- achievement in school science, measured through the mark obtained in the last Integrated Science exam (Question 2E);
- future plans to specialise in science, gauged through the number of science subjects to be studied in Form 3 (Question 2F);
- pedagogical styles characterising science lessons. This was gauged through question 2G for which students were given the following instructions: *How often do you carry out the following during your science lessons? (Please tick only one box in each row.)* This was followed by 9 pedagogical styles each with a 4-point Likert scale from *Never* to *Very Often*. The pedagogical styles included varied from those that are

highly teacher-centred e.g. *listening to the teacher* to those that encourage more student participation e.g. *field work*. Some students asked for a definition of the term *community work*. In such instances, the same example was given throughout. The students were told that an example of community work is when the school takes part in a science project in collaboration with the local council;

- out-of-school engagement with science (Question 2H);
- parent education and participation in political action (Questions 3A to 3D); and
- home resources, measured through Question 3E where students were asked to tick whether they have each of the following educational resources at home: *computer, an internet link, an atlas or globe, more than 50 books, a microscope, a telescope*.

- **Attitudes to science**

**Sections 2I** (8 items) and **2J** (6 items) were included to gauge the affective attitudes or general favourableness of the students towards science (e.g. *science is important for society*) and science education (e.g. *I would like to do more science at school*). These items therefore contrast with those included in **Sections 1D** and **1G** which were only aimed at gauging the beliefs of and not the degree of preference for science and school science. It is anticipated that the results from Sections **1D** and **1G** will lead to the extraction of beliefs that are contributing to the attitudes that are measured in Sections **2I** and **2J** included in the questionnaire.

### 3.3.3 Population and Sample

In order to gauge the level of science awareness of the Form 2 student population through the questionnaire, a representative sample of students were chosen according to gender, school type attended and geographical distribution. The most recent education statistics at the time, regarding the Form 2 (year 8) student population in Maltese schools were requested from the Directorate of Quality and Standards in Education. Numbers quoted in **Table 3.4** are for school year 2010/11 when the target group were in Form 1.

**Table 0.10: Target population based on unpublished education statistics 2010/11.**

| | **State Schools** | | **Church Schools** | | **Independent Schools** | |
|---|---|---|---|---|---|---|
| | No. of students | % of total population | No. of students | % of total Population | No. of students | % of total Population |
| **Boys** | 1215 | 27.5 | 795 | 18.0 | 175 | 4.0 |
| **Girls** | 1293 | 29.3 | 711 | 16.0 | 229 | 5.2 |
| **Total** | 2823 | 56.8 | 1506 | 34.0 | 404 | 9.2 |

For a target population of 4733 students, a sample of 355 students would be representative of the whole population at a confidence level of 95% and a confidence interval of 5%. A total of 422 questionnaires were collected from the respective schools. 22 copies were cancelled when most of the questionnaire was left empty or when the majority of the questionnaire items were filled in the same category of the Likert scale.  These numbers were then converted to percentages of students in Church, State and Independent Schools respectively. The percentages of the actual samples from the different types of school are given in **Table 3.5**.

This table also shows that the student sample was derived from 28 schools. To ensure good geographical distribution, the sample of students from State Schools was representative of the 10 colleges in Malta and Gozo. Students from 10 out of 19 boys 'schools and 10 out of the 12 girls' schools were included. Choice of Church and Independent Schools was limited by those who granted access. Boys from three out of ten boys' Church Schools took part in this study. The same applied for girls. Two out of the seven Independent co-ed secondary schools allowed access.

Quite a number of significant changes in the distribution of students, in particular in State Schools have taken place since this research study was carried out. The students who took part in this study were the last cohort of students who sat for the Junior Lyceum exam (the equivalent of an 11+ exam) in State Schools and who were therefore assigned to a Junior Lyceum or an Area Secondary school during their secondary schooling. The next group of students went through a smooth transition from a primary to a secondary school irrespective of their academic abilities. In the meantime, co-education started to be introduced gradually in State Schools in 2013.

**Table 0.11: Distribution of student sample**

| | Number of students | | | % of Sample |
|---|---|---|---|---|
| | Boys | Girls | Total | |
| *State College 1* | 11 | 13 | 227 | 56.8 |
| *State College 2* | 11 | 11 | | |
| *State College 3* | 9 | 11 | | |
| *State College 4* | 19 | 12 | | |
| *State College 5* | 11 | 12 | | |
| *State College 6* | 12 | 16 | | |
| *State College 7* | 7 | 13 | | |
| *State College 8* | 12 | 8 | | |
| *State College 9* | 11 | 8 | | |
| *State College 10* | 7 | 13 | | |
| *Church School 1* | 22 | 0 | 136 | 34.0 |
| *Church School 2* | 22 | 0 | | |
| *Church School 3* | 24 | 0 | | |
| *Church School 4* | 0 | 24 | | |
| *Church School 5* | 0 | 13 | | |
| *Church School 6* | 0 | 27 | | |
| *Independent School 1* | 7 | 11 | 37 | 9.2 |
| *Independent School 2* | 9 | 10 | | |
| **Total** | **198** | **202** | **400** | **100.0** |

### 3.3.4 Piloting and Data collection

Once finalised, the questionnaire was reviewed by two science education experts and was then translated in Maltese (see **Appendix B**) by a qualified translator. The instrument was piloted with twenty one Form 2 students who then did not take part in the actual data collection. The researcher read through the questionnaire with the students while they ticked their answers. The reader read out some of the scientific items e.g. *l-estinzjoni ta' l-speċi* – extinction of species both in Maltese and English as some students may have been more familiar with the English version of these terms. It was also noted that some students had to be reminded intermittently of the original question as they were answering through a set of statements. Although some commented about the length of the tool, the majority said that it was of acceptable length and preferred it being read to them rather than having to read and fill it on their own. They were also satisfied with the font and with the questionnaire being in the Maltese language. A general comment was that they couldn't see the connection between science and politics that featured in this research tool. Administration and completion of the questionnaire took half an hour indicating that this part of this study could easily be carried out in a typical 40 to 45 minute lesson period.

Once finalised, the questionnaire was used to measure the level of science awareness of a representative sample of 400 Form 2 students attending Maltese schools. Following minor changes to the questionnaire, permissions were sought from the DQSE and The Secretariat for Church Schools to carry out the research in State and Church Schools respectively. Once these permissions were granted (see **Appendix C** and **Appendix D**), informed consent was also sought from the respective Heads of State, Church and Independent Schools who were willing to allow their school to participate in the study. One of the schools also requested a parental consent form (see **Appendix E**). These permissions, together with the questionnaire in Maltese (see **Appendix B**) and English (**Appendix A**) were presented for approval by the Faculty Research Ethics Committee (FREC) and subsequently by the University Research Ethics Committee (UREC) in March 2012. Clearance by the Ethics committee was given in mid-April (see **Appendix F**) and research was carried out during the last week of April and throughout May 2012. Data were collected from 28 schools in Malta and Gozo. These included a boys' and a girls' State School from each of the ten colleges, 3 boys' Church Schools, 3 girls' Church Schools and 2 Independent mixed-sex Schools.

Schools were contacted and an appointment was made in each case. The questionnaire was read to the students and filled in. The instrument was administered in Maltese in all schools except for the Independent Schools and one Church School where an English version of the questionnaire was requested. Where possible, the schools were visited and the questionnaire was read by the researcher. When the students did not understand the term in Maltese, the term used in the English version of the questionnaire was given. However, the students were instructed not to answer the question if they do not understand or have not heard of any scientific terms used. This missing data were then used as one of the indicators of a lack of science awareness. Three schools specifically asked for copies of the questionnaire to be distributed in class by the school staff during a free period. In these cases, written instructions were given to the readers (see **Appendix G**). The questionnaire was not completed by the few

English-speaking students who were present in the classes where the questionnaire was administered in Maltese. It would have been practically impossible for the reader to explain in both Maltese and English and to still fill in the questionnaire in 40 minutes. However, they were still given an English version of the questionnaire so that they could follow and not feel left out.

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### 3.3.5 Data input and coding

An empty IBM SPSS (Statistical Programme for Social Sciences) data file was developed for the coding of responses to the questionnaire items. In the SPSS file, the variables were given names with a maximum length of eight characters. Most variable names were composed of the section, subsection and item number in that order (e.g. SecQA1 for the first item in section 1A). Each variable had a corresponding label with the questionnaire item text. For the Likert scale items, the position of the respondents' tick in one of the of the four response categories, was the value to be entered: a tick in the first box was coded as '1', a tick in the second box was coded as '2', etc. When the respondent gave no response or multiple responses to one item, it counted as missing, and was coded as '9'. The missing code '9' was also used in cases when it was obvious that the respondent had not answered the question seriously, e.g. when the ticks on one page or in one question were all positioned in the rightmost boxes.

All questionnaires were numbered and data were entered. Following data input, it was ensured that data were properly cleaned for coding errors and illegal values. These were uncovered through frequency and crosstab tests. All illegal values were modified by referring to the original questionnaire responses.

### 3.3.6 Issues of Validity and Reliability

Two of the problems in all statistical measurement instruments relate to validity and reliability. This is especially pronounced for studies that aim to measure attitudes. Since this research study is aimed at measuring beliefs or the cognitive component of attitudes most of these controversies surrounding measurement of attitudes also apply to this work.

Validity is a key concern in research as it refers to the truth of the inferences drawn from the results. Research that is invalid is by definition of no value. Validity has many aspects (Cohen *et al*., 2000) and the measures taken to ensure the establishment of the ones particularly applicable to this study will be discussed.

First of all, the development of the instrument required a precise definition of the concept to be measured, namely science awareness. It took approximately a year of thorough review of literature, and discussions with researchers in developing a clear definition of the concept and its indicators. Such definitions are also the backbone of international comparative quantitative studies, e.g. PISA test instruments are based on a clear definition of ‘scientific literacy’ (e.g. OECD, 2006). It was also made sure that the rationales of the study were clearly identified and a good explanation of the intentions behind the choice of item was also given.

‘Face validity’ was ensured by following accepted rules from research methodology literature for designing a good questionnaire – using simple, clear wording, not assuming too much knowledge, avoiding double negatives, and avoiding leading and double-barrelled questions (Oppenheim, 1992). The content of the questionnaire was also validated by two experts who pointed out items to be deleted especially those that had double meaning, may convey gender and culture balance as well as items that may be unknown to Form 2 students. This ensured ‘content validity’.

For further validation once the first draft of the instrument was designed, it was piloted with a class of Form 2 students. The purpose of the pilot was to gain experience on the logistics of questionnaire administration as in establishing contact with the school, instructions needed, the duration of the test run and spontaneous reaction of the students to the questions. Students were requested to indicate the items they did not understand and to comment whenever they feel like it. It is significant to note that the sample of students with whom the questionnaire was piloted was not representative of the whole population.

Items were also validated by clearly explaining the intention behind them. Furthermore the validity of this questionnaire was enhanced by comparing data to that from a qualitative research method, namely focus groups.

Reliability also generates considerable controversy. Most statistical measures of reliability are simply measures of *internal consistency* and offer more or less no evidence on test-retest reliability (Gardner, 1995; Reid, 2006). Such measures are completely inappropriate for attitude measurement (*ibid.*) If the questionnaire used in this study asks different questions about different aspects of science awareness, internal consistency is meaningless. It might offer evidence that, if a student scores high levels of science awareness in one area, he might do so in another, but does not say anything about the reliability of the test. Genuine reliability is really only assessed by using the questions on more than one occasion. This questionnaire was administered again to a sample of students during Phase 2 of this research.

The researcher herself visited schools and administered the questionnaires whenever possible. The questionnaire was read and filled in with the students. When necessary, terms were translated but not explained. When the researcher was not allowed to enter the classrooms, instructions (See **Appendix G**) were provided to the teacher responsible, to administer the questionnaire in the classroom as it would have been done by the researcher. It is here assumed that the teachers followed the instructions provided although one can never be absolutely certain. However, the questionnaires were filled in diligently and completely in all of these cases.

The master version of the questionnaire was developed in English. Although English should be the language of instruction for Integrated Science, 12-year olds in State Schools were being taught science predominantly in Maltese interspersed with technical terms in English (Mifsud, 2012). The questionnaire was thus translated to Maltese with the help of a translator. Although one may here identify translation issues, it is significant to note that such practices are common even in highly quoted comparative international studies such as PISA and TIMSS.

In the questionnaire there were questions about science in general and science lessons. Not a lot of emphasis was made about specifying further as the responses obtained would then also convey a better idea of what students actually recognise as science and the extent to which science education is having an effect on their thinking.

Another important point is that in the analysis, only means and separate scores for the separate items will be considered. Items in a group will not be considered as clusters with each cluster constituting a composite variable. Scores for clusters will not be calculated because the items forming one construct may not be the best possible selection from the universe of indicators relevant to the name of the variable. They will rather be considered as a relevant grouping of items. This has also been done in well-known studies of attitudes to science such as ROSE (Schreiner & Sjøberg, 2004).

*Descriptive Statistics* (SPSS IBM20) were employed on the numerical data collected from the questionnaire to obtain a general measure of the level of science awareness of the sample of students analysed in this study. The analysis first provides means and percentage distributions for the responses obtained for Likert scale items in Sections 2 (*About You*) and 3 (*Your Family and your Home*) of the questionnaire. The *Agreement Index* was also used in some cases to represent the difference in the percentage of *Strongly Agree* (Likert Scale 4)/*Agree* (Likert Scale 3) and *Disagree* (Likert Scale 2) / *Strongly Disagree* (Likert Scale 1) for the Likert items. This measurement was used in the analysis of data obtained from the ROSE (Relevance of Science Education) questionnaire in the United Kingdom (Jenkins, 2005). The students were considered to have a neutral opinion about a particular item when the mean was very close to 2.5 or when the Agreement Index was very close to 0. Otherwise, the students were considered to agree or disagree with the items, the extent of which is indicated by the difference from a mean of 2.5 or by the positive or negative values of the indices.

## 3.4 Qualitative data collection

Data collection through the questionnaire was aimed at providing a broad measurement of science awareness amongst Form 2 (Year 8) Maltese students. The results indicated the extent to which students recognise the indicators that were used to describe science awareness. This research study had to lead to learning activities that can be used to raise science awareness in schools. Beyond a quantitative establishment of the level of science awareness, it was therefore also significant to investigate why students have particular beliefs and to identify possibilities of how they can be changed. This was achieved through the second part of the sequential explanatory methodology used where focus group discussions were carried out for a deeper analysis of the factors that influence the beliefs that characterise science awareness.

### 3.4.1 Why focus groups?

Focus groups are group discussions organised to investigate a particular set of people's views, in particular attitudes and cognition (Kitzinger, 1994, Morgan, 1988). Focus groups surfaced mainly in the mid 1980's. The group is 'focused' in the sense that it usually involves debating a particular set of questions. Focus groups are particularly distinguished from group interviews by the 'explicit use of the group interaction' as research data (Morgan, 1988, p.12). This 'group effect' (Carey, 1994), is what makes it different from individual interviews as the group members both question and have to explain to each other.

There are several advantages that characterise focus groups (Kitzinger, 1994). The fact that group participants provide an audience for each other encourages a greater variety of communication including non-verbal cues and enthusiastic outbursts. Anectodes, jokes or loose word associations may actually enrich data collection. In this sense, focus groups reach beyond reasoned responses usually tapped by questionnaires and reveal other dimensions of understanding. In addition, focus groups facilitate the collection of data about group norms and may also 'break the ice' for the shyer participants, facilitating the expression of taboo experiences.

Usually focus groups are not used in isolation (Morgan, 1996). In this study, focus groups are being paired with the survey as a follow-up study. This corresponds to the third combination in Morgan (1993)'s conceptual framework for how to combine focus groups and surveys. Although the results from focus groups and surveys usually converge (Morgan, 1996), they are also usually complementary as the former allows more extensive responses than the latter.

Survey data is sometimes limiting especially when close-ended questions are used. Surveys, on the other hand, gather data from a wider range of topics than focus groups that are more concerned with depth.

Segmentation (Morgan, 1996) is used to consciously vary the composition of groups to create particular categories of participants. This offers advantages as it builds a comparitive dimension into the study in particular data analysis of the transcripts. It also facilitates discussion by making the participants more similar to each other allowing more free-flowing discussions (*ibid.*). Wide gaps in lifestyle and academic background may limit this interaction. In this study, segmentation was carried out according to gender and type of school.

During planning, several other decisions had to be takenwith respect to the moderator's role, the size of each group and the number of groups in the study. A number of 'rules of thumb' to capture the most common choices that researchers have made have been outlined by Morgan (1992). Focus group studies most often used homogenous strangers as participants, rely on a relatively structured interview with high moderator involvement and have six to 10 participants. Below six, it may be difficult to have a discussion while above 10 it may be difficult to control. Another rule of thumb is to have a total of three to five groups per project. In this study, the students were chosen from the same school and therefore were at least acquaintancies. This made it more convenient than having to recruit strangers from different schools as this would have lead to more disruption of lessons due to the time needed for students to travel to a common location. The number of participants was eight in line with the suggested group size. More groups than recommended were carried out to cover all the segments that emerged from analys of the questionnaire data.

Groups in which the moderator exercises a higher degree of control are said to be 'more structured' (Morgan, 1992). The focus groups in this study was more structured in the two ways identified by Morgan (1992). The moderator chose several questions to be asked during the focus groups directing attention away from what are considered to be less important issues, especially due to time limits. It was also more structured in relation to group dynamics as the moderator tried to ensure that all the participants gave their input during the discussion

### 3.4.2 Limitations of focus groups

Studies have shown that the behaviour of the moderator has consequences on the group data collected (Agar & Macdonals, 1995; Saferstein, 1995). In this study, the researcher tried to keep her participation to a minimum so as not to alter the quality of the data. She tried to be a good listener, observer and facilitator by being mentally alert at all times, patient as participants respond to questions (or not respond) and avoiding head nodding or other responsive body language. At the same time, however, the researcher tried to maximise interaction and debate beyond the stage it would have otherwise ended and to discuss inconsistencies both between participants and within their own thinking. Sometimes this interaction was difficult to achieve and some of the focus groups, especially with students who were not very apt at discussing and debating ended up more like group interviews.

It is also significant to note that while analysis of quantitative data through the survey started after all the data was collected, analysis of the data collected through the focus groups started with the first interview. Through the information and cues gathered, both formally and informally, the philosophy of the researcher moderating the interviews might have changed during the process of data collection itself.

Another weakness or ethical issue usually attributed to focus groups is that they cannot be used to discuss very sensitive topics as it involves disclosure (Morgan, 1996; Smith, 1995). However, this was not considered to be a very serious ethical issue in this study since the topic being tackled was not one of a very delicate nature and did not require participants to disclose any personal and sensitive opinions.

An additional downside of focus groups is that the group may actually deter any deviation from group standards and 'censure certian types of information' (Kitzinger, 1994) by inhibiting people who are in minority to talk about certain things. However, this does not invalidate data collected from a group because in real life people do not exist in a social vacuum as is assumed in one-to-one interviews (*ibid.*). Group data is based on the premise that all discourse that generates meaning is contextual.

Altthough the groups were chosen with a particular set of characteristics, in particular in relation to gender, school type and achievement, one cannot assume that the research participants in any one group were homogenous. The facilitator took advantage of this diversity and encouraged the participants to think why such diversity exists, and to identify aspects of their personal experience which made them alter their opinions. A focus group allows the exploration of such differences 'in situ' with the help of other research participants in contrast to one-to-one interviews which would lead to simple theorising on why such differences exist. This difference between participants also serves as a check and people are forced to explain their reasoning (Kitzinger, 1994).

Focus groups are also very expensive and time consuming. The researcher had to rely on the senior management team of the respective schools to choose the participants. In some of the cases, the researcher also had to return to the schools several times until all the consent forms were collected and for the focus groups to be carried out. Transcript typing is also very slow and transcript analysis is also time-consuming, especially when one considers that this study was carried out single handedly.

### 3.4.3 Focus group questions

A total of 14 questions were compiled in order to structure the focus group discussions. The questions are presented in **Table 3.6** and classified according to the issues tackled by each set of questions.

**Table 0.12: Table showing classification of focus group questions**

| Questions | Issues tackled |
|---|---|
| Do you like science? Why?<br>Do you think science is important? Why? | **Students' general attitudes to science.** |
| To what extent do you think that the following are related to science? (*whether an area should be built or developed or exploration of space*). Why? What do you understand by science? | **Relation of issues to science** |
| Do you think that all scientists are responsible people? Why?<br>Do you think that everyone benefits equally from scientific progress?<br>To what extent do you think that common citizens may influence decisions taken by politicians in relation to scientific issues? | **Reasons behind students' beliefs regarding science, scientists, the scientific process and the science-** |

| | |
|---|---|
| Which qualities does one need in order to do this? | **society association.** |
| Do you ever participate in a conversation related to science? If yes, with whom, about what?<br>Do you ever participate in out-of-school activities related to science? What type? With whom? | **Out-of-school science** |
| Do you consider school science to be difficult? Why?<br>How many science subjects do you plan to choose in Form 3? What influenced your decision?<br>What type of learning activities do you have during your science lessons? Which kind of teaching methods do you find most attractive? | **Retrospective outlook towards science education** |
| Do you think that science education can help you to become more active citizens? Why? How? By what means?<br>Imagine that your science lessons would include activities that feature issues or decisions with a scientific background, such as: debates, community-based projects; media analysis; mentoring in lobbying policy makers; sharing of personal experiences, etc. Do you think that through such activities science education would be more attractive? Why? | **Outlook towards science education for scientific literacy and science for citizenship.** |

The first two questions targeted in the focus groups were used to probe students' general attitudes to science. Questions were then targeted to derive the criteria used by students to classify an issue as being/not being related to science. The reasons behind students' beliefs about scientists, the scientific process, and the benefits of scientific progress as well as the influence of common citizens and politicians on the science enterprise were also probed. Students were also asked to provide details of the out-of-school activities they attend and with whom they usually engage in discourse about science. In addition, they were also asked to analyse retrospectively the learning activities commonly used in their science lessons and to voice their beliefs regarding ones that are perhaps more suiting to achieve scientific literacy and science for citizenship.

### 3.4.4 Data Collection

Eight semi-structured focus group discussions were carried out during the last term of the scholastic year 2012-2013 to validate the trends seen in questionnaire results as well as to further insights into why certain trends resulted. The permissions necessary to carry out this part of this study are given in **Appendix H**. Aspects considered in further detail at this stage were gender differences and school types across the different levels of awareness as shown in **Table 3.7.** Discussions were carried out separately for boys and girls coming from State and Church Schools and for two mixed-gender focus groups from Independent Schools.. No distinction was made between students from Junior Lyceum and Area Secondary State Schools, as this difference no longer existed at Form 2 in 2013. Instead, a group of high achievers and low achievers, as chosen by the Schools' Management Teams were interviewed from two different boys' and girls' State Schools. This resulted in a total of eight focus groups.

**Table 0.13: Focus group characteristics**

| Focus group | School type | Gender | Academic ability |
|---|---|---|---|
| **1** | State school | Male | High achievers (equivalent of Junior Lyceum) |
| **2** | State school | Male | Low achievers (equivalent of Area Secondary) |
| **3** | State school | Female | High achievers (equivalent of Junior Lyceum) |
| **4** | State school | Female | Low achievers (equivalent of Area Secondary) |
| **5** | Church school | Male | Mixed |
| **6** | Church school | Female | Mixed |
| **7** | Independent school | Mixed | Mixed |
| **8** | Independent school | Mixed | Mixed |

Following clearance by the University Research Ethics Committee, the schools were contacted again to set up the focus group interviews. Choice of individuals was left up to the school administration as long as the students chosen corresponded to a particular set of criteria namely; age, gender and their level of achievement in the case of State Schools. To ensure optimal group dynamics, a group size of six to eight students is often considered to be optimal (Folch-Lyon and Trost, 1981). In this research the average group size was seven.

In most schools, the discussions were carried out in a quiet, empty classroom and typically lasted for the duration of a single lesson. After a period of making the pupils as comfortable as possible by introducing myself, asking them about their school, and briefing them about my research study, the discussion began. All interviews were recorded as MP4's after each subject had granted permission. However, notes were also taken in case the digital equipment failed.

### 3.4.5 Processing of Data

All the focus group discussions were transcribed. Responses to each question were then coded reflexively to identify emergent themes. Codes were then tested against the data to produce a set of major codes and sub-codes. For examples the codes that emerged from the responses to the focus group question, *To what extent do you think that the following are related to science?* were:

**Major code: Relation of different issues to science**

**Subcodes**:

- Related as it contains a lot of information/detail/explanations.
- Related as it could be identified with a school science topic.
- Related as it is currently still unfolding.
- Related slightly due to its impact on the environment.
- No relation as item is related to other school subjects or other entities.
- Not related as science equals experiments.

A reliability check was conducted by coding agian the same transcript which gave over 90% level of agreement..

Preliminary analysis was then carried out to identify the frequency of certain codes, differences between sub-groups and to pull out quotations that may be used to consolidate quantitative data from the survey. This was done through a Scissor-and-Sort technique using Word documents. Although a limitation of this method is that it lends room for subjectivity and potential bias, it is not that time consuming, and potential bias tends to be also characteristic of more time-consuming and rigorous methods (Stewart *et al*., 2007).

### Conclusion

In this chapter, the mixed methodology used to gauge the level of science awareness amongst secondary students, to single out factors that affect these beliefs, and to characterise their interest in different school science pedagogies were described. The results of this first phase will be discussed in the next chapter and will be used as a baseline for the second phase of the research study where a number of learning activities were piloted in an attempt specifically to enhance science awareness.

# Chapter 4. ANALYSIS – PHASE 1- MEASURING SCIENCE AWARENESS

This chapter provides an analysis of the data collected from the questionnaire, supported by that from focus group interviews to obtain a measure of students' level of science awareness. It includes the general characteristics of the sample who responded to the questionnaire in particular their gender, type of school attended and their home and family background. A more complete profile of Form 2 students is given through further analysis, of numerical and even qualitative data, in relation to the type of science education they received and their attitudes towards science and science education, both factors of which are highly relevant to this study.

Following this profiling, the results were then used to gauge the level of science awareness of the students studied in relation to the three indicators used to measure this concept: their level of recognition of science in personal, social and global scientific issues; the extent to which they are able to recognise the attributes needed to engage with and act upon these issues; and the degree to which they believe that science education is important in the acquisition of these attributes. The factors that were found to make a significant statistical difference in the science awareness of the students are also discussed.

The chapter ends with an argued discussion based on literature and the results of this study, highlighting the implications of how schooling can address science awareness in Integrated Science lessons.

## 4.1 Sample Characteristics

This section provides a statistical analytical overview of the sample of students represented in this study in relation to gender, type of school attended, and family background. It also provides a general picture of the science education this cohort were exposed to up to the time of the study. Feedback from the focus group discussions is also included which support the numerical results. This part of the analysis provides a deeper insight about those factors that can have an impact on students' development of science awareness which is analysed in detail in the next section.

### 4.1.1 General Sample Characteristics

The sample of Form 2 (Year 8) students studied (n = 400) consisted of almost half male and half female students with the actual numbers and percentages indicated more accurately in **Table 4.1**.

**Table 0.1: Frequencies and percentage distributions of sample according to gender**

| Gender | Frequency | Percent |
|---|---|---|
| Male | 198 | 49.5 |
| Female | 202 | 50.5 |
| Total | 400 | 100.0 |

The questionnaire respondents also represented all school types in Malta namely State, Church and Independent Schools. In 2012, when the data were collected, State Schools were still divided into two, Junior Lyceums and Area Secondary Schools. Thus, these two school types were also embodied in the collection of data. As seen through **Table 4.2**, the sample was also representative of the number of students attending each school type with the majority attending State Schools (n = 227, 56.8%), followed by Church Schools (n = 136, 34.0%) and Independent Schools (n = 37, 9.3%) respectively.

**Table 0.2: Frequencies and percentage distributions of representative sample according to type of school attended.**

| Type of school | Frequency | Percent |
|---|---|---|
| Junior lyceum | 135 | 33.8 |
| Independent School | 37 | 9.3 |
| Area Secondary | 92 | 23.0 |
| Church School | 136 | 34.0 |
| Total | 400 | 100.0 |

In the last section of the questionnaire, the respondents were also asked questions regarding their family and home background. When asked to state the language usually spoken at home, the majority marked Maltese (n = 316, 79.0%).  It is significant to note that English is the official language of instruction of Integrated Science in schools. Students who speak mainly English at home were much fewer than those who speak Maltese (n = 78, 19.5%). There were also a few students (n = 6, 1.5%) who speak another foreign language at home. The language spoken was also analysed according to the type of school attended and it was found that only the sample of students from Independent Schools had a majority who mainly speak English at home. The situation is reversed for the three other school types where Maltese is the main language spoken at home. This contrast is shown in **Figure 4.1**.

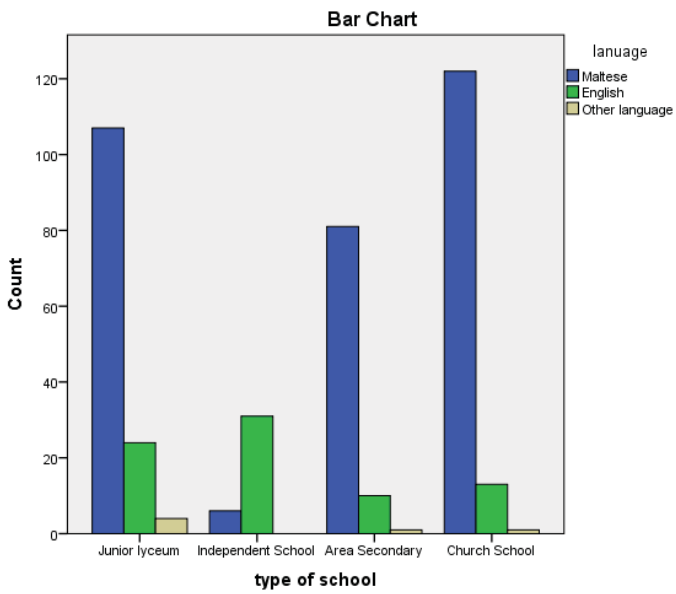


**Figure 0.1: Distribution of students per school type according to the main language spoken at home**

Students also answered questions regarding their parents' education and political activity. Some students were not aware of the level of education and political engagement of their parents and in such cases they were asked to leave the questions out. All questions in this section were answered by more than 360 of the respondents. Among those who answered, the highest level of education achieved by the majority of parents is secondary education (n = 198, 52.8% mother/female guardian and 44.2%, n = 159 father/male guardian). Slightly more fathers/male guardians (n =113, 31.4%) than mothers/female guardians (n = 93, 24.8%) had achieved a tertiary level of education. Political activity of parents was quite low with students stating that 86.9% (n = 338) of all mothers/female guardians and 80.0% (n = 304) of fathers/male guardians do not take part in any political activity. Respondents had a mean of 3.74 out of the 6 resources at home from the list given in the last question to the research instrument.

Means of parents' level of education, their political activity and home resources were also computed and analysed according to the type of school. The level of education was assigned a rank from 1-4 depending on whether the highest level of education achieved by the parents was a primary, secondary, post-secondary or tertiary one. The political activity was graded from 1-4 according to the total number of political activities out of the four given in the questionnaire students reported their parents to participate in. Availability of home resources was graded from 1-6 according to the total number of resources marked by the students from the six included in the questionnaire.

Through **Figure 4.2**, it can be clearly observed that while the political activity of the parents was low across all school types, their level of education does vary according to the type of school. The same applies to home resources. The recurring trend is that students attending Independent Schools come from richer family backgrounds in several ways, such as having parents with a higher level of education, and a greater availability of home resources. These were followed by students attending Church Schools and those attending Junior Lyceums respectively. Students attending Area Secondary schools were the ones with the poorest home background in these aspects.

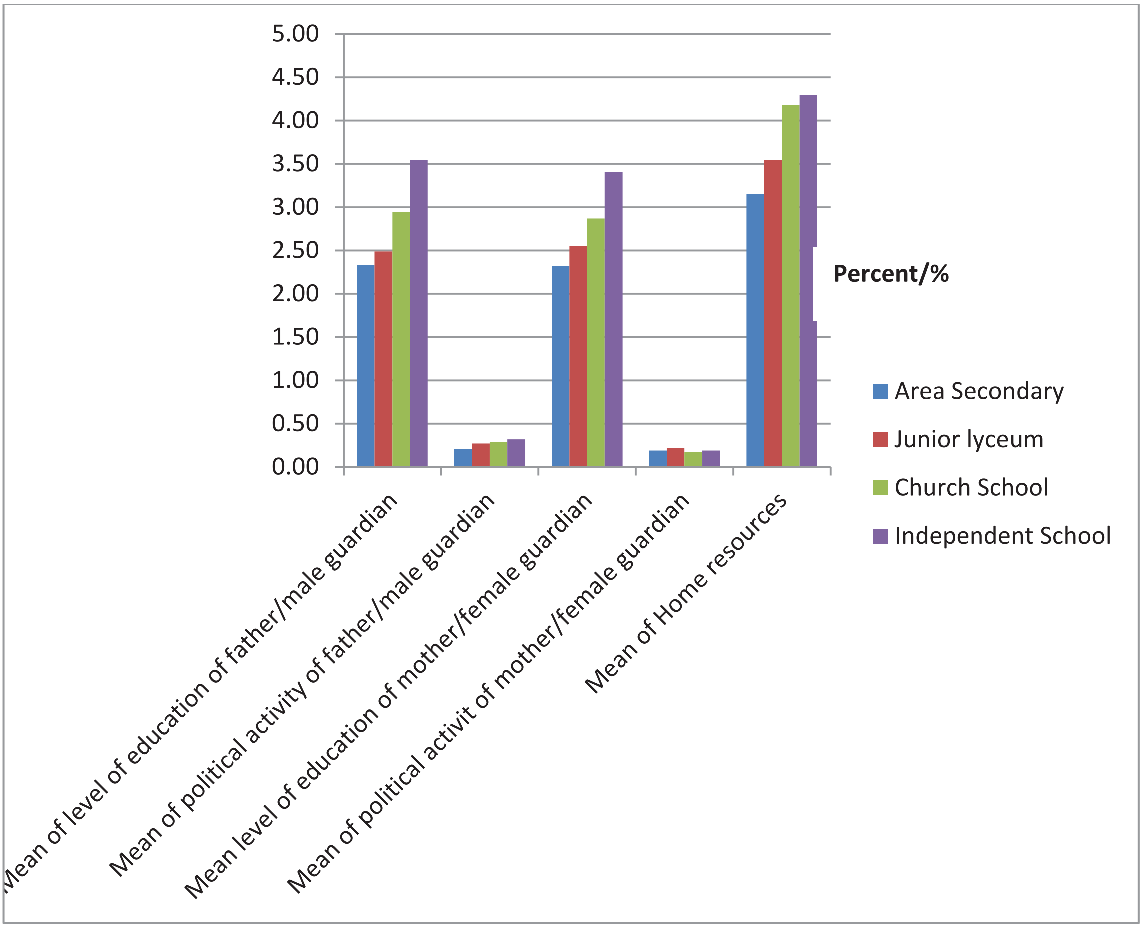


**Figure 0.2: Means of level of education of parents, political activity of parents and home resources according to school type**

### 4.1.2 Science Education of the Sample and their Attitudes to Science

The questionnaire and focus group interviews captured more than just the students' level of science awareness, but also included additional aspects such as: the type of school they attended; the number of science lessons they were exposed to during the last year of primary schooling; their general attitudes towards science education; as well as their out-of-school exposure to science. This section provides insights into the factors that might be having an impact on the students' science awareness.

- **Respondents' School Science Profile**

Before answering items related to their secondary school science education, students were also asked to indicate their level of exposure to science during their last year of primary education. More than half the students (54.3%, n = 216) stated that they had no science lessons or less than one science lesson per week during their last year of primary schooling as is also clearly shown in **Figure 4.3**. Thus, the exposure of Form 2 students to school science at primary level was limited. Since no data was collected regarding the science activities that were carried out during the primary years, the limited exposure to science must be interpreted with caution. This is because having more lessons during the primary years, based on a transmissive mode of teaching might actually have adverse effects on science awareness as featured in this study.

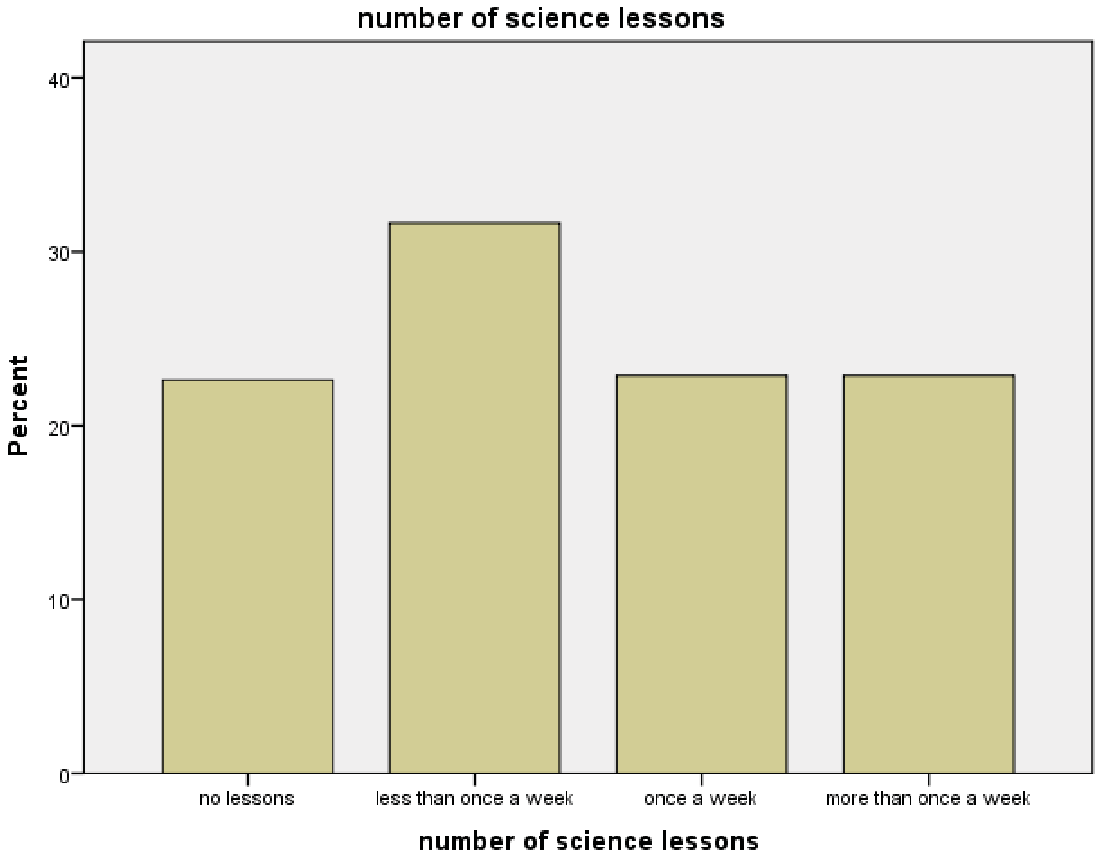


**Figure 0.3: Percentage distribution of students according to the number of science lessons they had in their last year of primary schooling**

Students tend to do well in Integrated Science exams, as illustrated in **Figure 4.4** with a surprising 87.1% (n = 348) of students reporting obtaining a pass mark in their last Integrated Science exam.

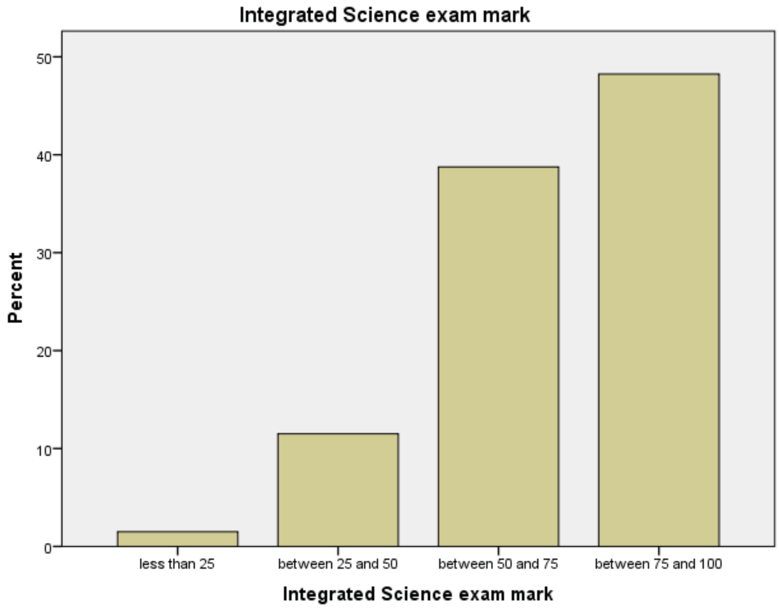


**Figure 0.4: Percentage distribution of students according to the mark they obtained in their last Integrated Science exam**

The students seemed to be proud of this attainment as is clearly expressed by this student below.

*"One of the best subjects li mmur tajjeb fihom, compared ma' suġġetti oħra. Personalment immur tajjeb fis-science, jogħġobni bħala suġġett."*

"One of the subjects I do best in when compared to other subjects. Personally, I do well in science, I like it as a subject." (Girl, Church School)

Despite this good performance, only 17.6% (n = 70) of the sample stated that they would opt to choose the three science subjects in Form 3 when they have to decide their subject specialisation. As expected, the majority (67.3%, n = 268), intended to study one science subject, while the rest (15.1%, n = 60) stated that they would opt for two science subjects. Considering the total number of students who opt for two or three science subjects (32.7%), one can actually state that at this stage almost a third of the students can still be potential scientists. This distribution of students according to subject choice is shown in **Figure 4.5**.

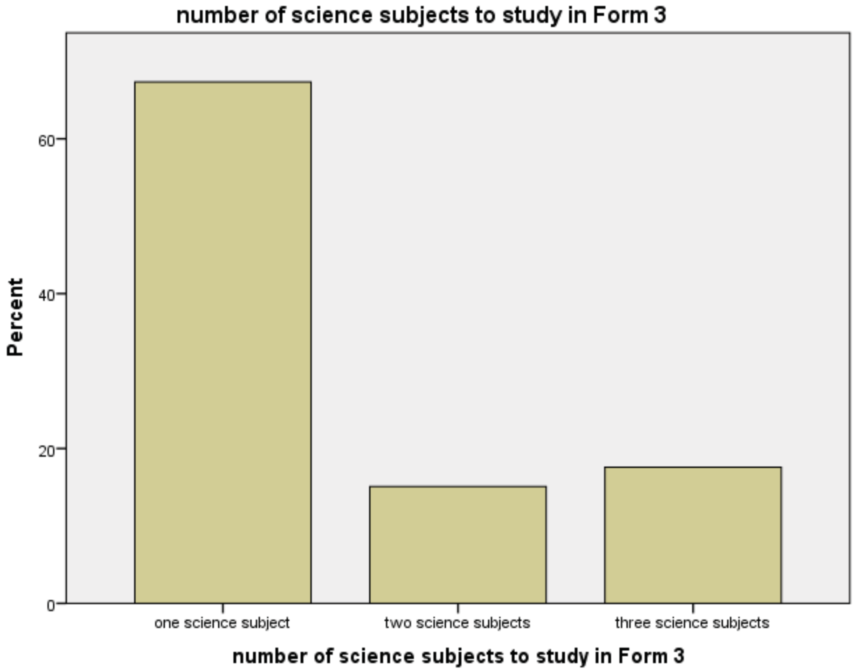


**Figure 0.5: Percentage distribution of students according to the number of science subjects they intend to study in Form 3 (Year 9, age = 13)**

Focus group responses with respect to subject specialisation showed that the majority of students base their choice on the career path they want to take up as expressed below:

*"Jien m'għażilthomx (three science subjects) għax minħabba dak li nixtieq insir m'għandux x'jaqsam fih is-science."*

"I didn't choose the three science subjects because of what I want to become. It doesn't have to do with science." (Girl, State School, Low achiever)

*"Jien wieħed (science subject) għax il-Physics bilfors tipo compulsary....jien nixtieq insir interpreter allura as such ma tantx kelli bżonn."*

"I chose one science subject because it is compulsary....I want to become an interpreter, so as such I didn't need it." (Girl, State School, High achiever)

"because I'm planning to be a lawyer and that isn't anything to do with Biology...really, so." (Boy, Church School).

*"Jien Biology nixtieq nagħżel għax jogħġbuni ħafna l-life sciences, iktar għandek fuq il-ħajja ta' kuljum milli Chemistry u Physics, qisek dawk tidħol aktar fid-dettall. U l-karriera tiegħi għal dik id-direzzjoni. M'għandix bżonnhom."*

"I wish to choose Biology because I really like life sciences. It is more related to everyday life than Chemistry and Physics in which you go into more detail. My career is in that direction. I don't need them." (Girl, Church School)

One or two science subjects tended to be chosen by students who aspire to become architects, journalists, interpreters, lawyers, mechanical engineers, etc. Physics was the subject most frequently chosen by these students mainly because it was compulsary in most State Schools at the time of the study. Some students stated that they chose Biology because it is the most relevant subject for everyday life as indicated hereunder:

"Because Biology when we did it in class, about the heart, I seemed to like it because I know how my body works....so that's why I like it." (Boy, Church School)

Students who aspired to become doctors, vets, science teachers and researchers tended to choose three sciences as exemplified below:

"I chose the three sciences because I want to become a doctor and I know that Chemistry and Biology are the required.... and Physics will also help. I am also into research and development so it will come in." (Girl, Independent School)

The three science subjects were also chosen by some students who were not yet sure of what career paths they want to follow. As shown below, they were none the less aware that studying science subjects opens up many opportunities for the future.

*"Jien kollha beħsiebni nagħżilhom, it-tlieta li huma. Għażilthom kollha għax jiftħulek ħafna options. Jiġifieri, għax jien nixtieq insir science teacher u forsi meta nikber iktar, forsi nibdilha din li nsir teacher tas-science u jiftħulek ħafna options u jobs li jistgħu jaqblu mas-science"*

"I intend to choose them all, the three of them. I will choose them all as they open up many options. Because I want to become a science teacher and maybe when I grow up I will change this idea of becoming a teacher. They open up many options and jobs that are related to science." (Girl, Church School)

Two other common factors that affect subject choice which transpired from the focus groups were personal interest in, or liking of any one of the traditional science subjects, and the difficulty associated with each subject. These two contrasting views are expressed respectively in the statements below:

"I chose the three of them not really because of the job because I never really wanted to become a doctor. The job I want definitely involves Biology, and I always wanted Biology. I chose Chemistry and Physics as well, really, just because I like them." (Girl, Independent School)

"I picked one as well, Physics....and I picked it cause if I pick all three I won't concentrate. Sometimes I would get confused. I wanted to pick Chemistry as well and my sister told me it was hard, so..... I still wanted to pick it but I took this into consideration and I just picked Physics." (Girl, Independent School).

While discussing subject choice, disappointment was also expressed by some students who were restricted to choose just one science subject due to their career aspiration. They wished to continue studying science as they like it and they considered it as important.

Students, mainly those attending Independent Schools said that they were free to make the choice on their own as shown in the statements below. However, they did consult their parents, guidance teachers, and older siblings.

"My decision wasn't really influenced cause since my father is an accountant, he always wanted me to take Accounts and Economics but I never really liked Accounting so I took all the three sciences." (Boy, Independent School)

"Nobody affected me regarding my choices. In fact, if anything, like my parents probably disagreed than agreed in me taking the three sciences as I don't have very good attention spans...." (Girl, Independent School)

- **General Attitudes towards School Science and Science**

The quantitative results for the general attitudes of early secondary students towards school science were not very well defined as shown by the low values of the agreement indices listed in **Table 4.3**. While students disagree to a slight extent that school science is difficult, boring and that there is too much of it at school, they still slightly disagree that they would like to do more science at school or that they prefer science to most other subjects at school.

**Table 0.3: Agreement indices in relation to the general attitudes students have towards school science**

| Questionnaire items | Strongly Disagree (%) | Disagree (%) | Agree (%) | Strongly Agree (%) | Agreement Index (%)* |
|---|---|---|---|---|---|
| School science is boring | 30.9 | 36.2 | 13.5 | 19.4 | -34.2 |
| School science is difficult | 19.8 | 42.1 | 23.1 | 15.0 | -23.8 |
| We do too much science at school | 20.9 | 41.0 | 24.4 | 13.8 | -23.7 |
| I would like to do more science at school | 33.1 | 27.3 | 23.1 | 16.5 | -20.8 |
| I like science better than most other subjects at school | 33.0 | 23.8 | 26.2 | 17.0 | -13.6 |
| I look forward towards my science lessons | 31.2 | 22.6 | 25.4 | 20.9 | -7.5 |

*Agreement Index = (%Strongly Agree + %Agree) – (%Strongly Disagree + % Disagree)

These seemingly conflicting numerical results were clarified during the focus groups. In general, students did like school science because they did see its relevance and importance in their personal lives. They considered it to be an interesting subject as they came to know about things that are usually taken for granted or which tend to get unnoticed. Science was also liked due to its element of fun, especially through experiments that also aid learning. Such views were expressed across gender, school types and abilities when answering the focus group question of whether they like school science.

*"Jogħġobni għax fih ħafna esperimenti, nagħmlu ħafna affarijiet li ma nagħmlux f'ċertu lessons oħra, nitgħallmu fuq affarijiet li jistgħu jgħinuna fil-ħajja taghna."*

"I like it because it includes many experiments and we do things that we don't usually do in other lessons. We learn about things that can help us in our lives." (Girl, State School, Low achiever)

"I like science because you learn what goes on. If it's Physics, how stuff happens, Chemistry like when you eat, sort of everything, it's like interesting." (Girl, Independent School)

"Yes, because you learn new things and it's not always like you start off with something and you build up on it, you switch topics and it's fun to have a different type of topic each month." (Boy, Independent School)

*"Iva, għax hekk titgħallem iktar fuq dak li qed jiġri madwarek u m'hemmx tip wieħed biss. ...jiġifieri int jekk ma tħobbx....ma jogħġbokx wieħed hemm tipi oħrajn."*

"Yes, because like that you learn more about what is happening around you and there isn't only one type, so if you don't like one....there are other types." (Girl, Church School)

Another distinctive positive feature of school science was that it consisted of several fields/topics and that if they could not relate to one topic they could still engage with other areas. Some students, especially those coming from Church and Independent Schools also referred to some skills that may be learnt through science. These positive views were also echoed by those who do not consider science as their favourite subject, by those who do not aspire to become scientists and also by those who see science lessons as boring.

*"Jien mhux il-favourite subject tiegħi, imma jogħġobni....li tara l-affarijiet li ħafna drabi tgħid ovvji imma tara kif jaħdmu u minn xiex ġejjin ...sabiħ."*

It is not my favourite subject, but I like it.....that you see things that we usually take for granted and you see how they work and where they are coming from....interesting. (Girl, State School, High achiever)

*"Jogħġobni tkun taf speċi bħal experiments, per eżempju, tkun importanti li tkun taf x'għandek ġo fik, x'għandhom tipi oħra, per eżempju l-plants minn xiex huma magħmulin u hekk....tkun taf ħafna informazzjoni....jogħġobni imma mhux li nsir scientist."*

I like the fact that you do experiments, for example it is important that you learn what you have inside you, what other species have, for example what plants are made up of ....you get to know a lot of information....I like it but not to the extent of becoming a scientist. (Girl, Church School)

When specifically probed, the only students who stated point blank that they find science difficult, due to the difficult terminology used and because lessons are delivered in English, were the low achieving male students attending State Schools. Most of the others stated that they find science difficult only when the lessons are boring, when they are not interested in a particular topic or if it is poorly explained by the teacher. These ideas are clearly mirrored in the statements below:

"No, not very difficult, it's actually interesting and not very complicated. When I'm interested in a certain subject I never find it complicated because I always want to know lots about it." (Boy, Church School).

"Space, I find it difficult because I have to know the planets and if you don't do something practical....maybe an experiment I don't stay that attentive to the lesson cause I'll get bored." (Boy, Church School)

*"Jiena skont, imma ġieli jkun hemm ċerta topics li jkunu ħarira itqal u trid qisek....bħal Biology....trid titgħallimhom bl-amment u hekk."*

"It depends, but sometimes there are certain topics that are slightly more difficult and you have to...like Biology.... you have to learn them by heart." (Girl, Church School)

*"Jien ma nħosshomx tqal imma ġieli jkun hemm tfal, per eżempju, t-teacher ma tantx isibuha tajba allura biex jifmhu jdumu naqra.*

"I don't find them difficult, but sometimes there are students who do not think that the teacher explains well and therefore take longer to understand. (Girl, Church School)

The students acknowledged that the increased use of ICT and experiments helped them to relate more with school science.

*"Jien naħseb kollox avvanza mhux is-science biss. Ikollna l-interactive whiteboard, eżempju, naraw ħafna videos ċari, għandna l-apparat biex nifmhu aktar l-affarijiet."*

"I think that everything advanced, not only science. We have interactive whiteboards, for example. We watch videos clearly, we have materials to understand things better." (Boy, State School, High achiever)

Some also felt that even though they found school science to be comparatively easy, they were aware it would eventually become much more difficult in the future and entails a lot of studying.

"Like, right now science hasn't been that difficult to learn, like it's all been easy for us to understand but I'm sure that in the future, once we start....once there will be many sciences, I'm sure it will get tougher and I'm sure it won't stay that easy." (Boy, Church School)

"I like science but I am not really much of a fan of studying. I am more of a fan like of the practical side of science like doing experiments and stuff like that" (Boy, Independent School)

Students' attitudes towards the utility of science for their everyday life was clearly positive. As shown in **Table 4.4,** they agreed strongly with statements such as *science is important for society* (A.I. = +64.9%) and *science is important for a country's development* (A.I. = +53.8%). Simultaneously, they disagreed strongly with statements that render a bad image of science, such as *scientific discoveries do more harm than good* (A.I. = -66.8%).

During the focus groups, when asked specifically whether they think that science is important, most of the students responded affirmatively and recapped most of the reasons they gave for liking school science, mainly that: it teaches you a lot of basic knowledge; gives you an explanation of how things work; how the body works; and what constitutes the world around us. In addition, they also underlined the importance of science as it opens a lot of possibilities for a future career. However, jobs mentioned were still those that are traditionally associated with the sciences such as doctor, vet, scientist, archaeologist and restoration works.

**Table 0.4: Agreement indices in relation to the general attitudes students have towards science**

| Questionnaire items | Strongly disagree (%) | Disagree (%) | Agree (%) | Strongly Agree (%) | Agreement Index (%)* |
|---|---|---|---|---|---|
| Scientific discoveries do more harm than good | 31.4 | 52.0 | 12.6 | 4.0 | -66.8 |
| Science has ruined the environment | 43.4 | 38.6 | 13.3 | 4.8 | -63.9 |
| Science is not useful in my everyday life | 36.9 | 39.9 | 19.6 | 3.5 | -53.7 |
| Science interferes with nature | 20.1 | 27.8 | 35.6 | 16.5 | 4.2 |
| I will use science in many ways when I am an adult | 12.9 | 18.9 | 49.5 | 18.7 | **36.4** |
| Science is very important for a country's development | 7.5 | 15.6 | 45.7 | 31.2 | **53.8** |
| Science makes our lives healthier, easier and more comfortable | 3.5 | 17.8 | 55.1 | 23.6 | **57.4** |
| Science is important for society | 5.0 | 12.5 | 57.2 | 25.2 | **64.9** |

*Agreement Index = (%Strongly Agree + %Agree) – (%Strongly Disagree + % Disagree)

Overall, their beliefs about the importance of science and science education were still rather insular, in that they were restricted to themselves and their needs. During the focus groups, there was no reference to the importance of science to humankind or to the sustainability of the planet showing that science and its importance are perceived in an egocentric way. Importance is envisaged only in what they can personally get through learning science, e.g., that they prepare for a job, or that they know what's going on when they are sick or that they know how to fix things that do not work.

- **Out-of-School Exposure to Science**

Voluntary participation in out-of-school activities related to science, such as: reading science articles in newspapers; watching scientific documentaries; attending a science club; etc., is low, with all means for frequency in engagement in such activities below the value of 2.11.

In addition, through the qualitative data one can see that, even out-of-school, the focus is still on school science. When asked whether they engage in conversations related to science, students stated that they do so mainly at school with their friends, or at home with their parents or siblings as is stated below:

| | |
|---|---|
| *"Fil-break, ġieli mall-ħbieb...ikollna topic u ngħidu kemm ħadna gost nagħmlu l-experiment illum!"* | "During break, with friends, ....we choose a topic and we discuss how much we enjoyed doing the experiment that day!" (Girl, State School, Low Achiever). |
| *"Bħal forensic science, fuq it-topics, kif tista' ssib dak li qatel lill-mara jew lil xi ħadd ieħor...eżempju, mall-familja ġieli noqgħod nitkellem. Per eżempju, għamilna dik....xi kultant il-Ms. ittina websites u nidħlu fihom."* | "Like forensic science, how you can find the murderer,...for example, I sometimes discuss with my family. For example, we did this....sometimes the teacher gives us websites and we log onto them." (Girl, State School, Low Achiever) |
| *"Per eżempju dwar l-għażla tas-suġġetti u anke x'għamilna dak in-nhar, x'tgħallimt ġdid l-iskola."* | "For example, about the subject options and also about what we did during that day, what was covered at school." (Boy, State School, High Achiever) |
| *"Jiena wkoll nitkellem naqra mall-mama għax issa, per eżempju, se niġi nagħżel mis-sciences u l-mummy qisha tifhem għax teacher tal-Biology."* | "I also discuss with my mum, because now, for example, I am going to decide which of the sciences to choose and mum is a Biology teacher and so she sorts of understands." (Girl, Church School) |

As is clearly shown by these statements, these conversations revolved around what happened at school during the science lessons or else on whether to choose the subject for further studies. Younger students also discussed the learning activities carried out during the science lessons of older students especially when these involved a very interesting event such as dissecting an eye or a heart.

Those students whose parents are science teachers, or those whose siblings have studied science at a higher level benefit more from home conversations about science as they get an extended explanation of the topics covered at school.

*"Jien għandi missieri teacher tal-Chemistry u ġieli anki jiġi jfehmni affarijiet li ma tantx inkun fhimt"*

"My father is a Chemistry teacher and he sometimes also explains to me things that I didn't understand." (Girl, State School, High achiever)

*"Jien l-aktar ukoll m'oħti għax ikbar minni. Allura taf ħafna mill-affarijiet u ġieli nkunu, eżempju, qed naraw xi programm fuq affarijiet hekk u qisna naqbdu dik il-konverżazzjoni.....jien qisni nitkellem fuq x'għamilt fil-lezzjoni....u hi qisha qegħda tfehmni aktar milli naf."*

"I speak mostly to my sister as she is older than me. She knows most of the things and sometimes, for example, we are watching a related programme and we start that type of conversation....I speak about what was covered during the lesson....and she explains to me further." (Girl, State School, High achiever).

On the other hand, students whose parents are not very knowledgeable in science engage enthusiastically in home conversations about science to pass on the interesting facts that they learnt at school to their parents.

*"Jiena iva, ġieli mall-mama, għax hi ma tkunx taf xi ħaġa u jiena nieħu gost noqgħod nispjegalha."*

"Sometimes yes, with my mum as she wouldn't know something and I enjoy explaining to her." (Girl, Church School)

Through the focus group discussions, it was observed that students whose parents or siblings were interested in science were also the ones who were most likely to engage in conversations that go beyond the boundaries of school science, e.g. discussing a scientific documentary being watched on TV. Others discussed what they had read in books other than school textbooks or websites. Students from Independent Schools were the only ones who stated that they engaged in conversations about science with people other than family and friends. More specifically, as expressed below, they engage in discussions with doctors when they are sick as they want to know more and also with the staff at stands when they visit a science fair.

"Whenever I go to the doctor, for example, I always talk about what he is doing and why." (Boy, Independent School)

"I go to the science fairs, I discuss with them, see how they made it, what they used to make it, what made them want to build something like that." (Boy, Independent School)

A few students, who happened to be all male, stated that they never participate in conversations about science.

The students who participate in out-of-school activities related to science mainly come from Independent Schools. Most referred to the science fair organised by the Malta Council of

Science and Technology (MCST) at the University of Malta to which they were accompanied either by parents or teachers. Some of these students also referred to their visits to science museums abroad and to the interaction with the staff involved in such places.

"When I'm abroad. I always like to go to a science museum and there is a specific one in London where you can actually make experiments and play games and it shows you how things work and there are like persons speaking....so it's very interesting" ( Girl, Independent School)

Students from other schools stated that they participated in activities related to science either when these were organised in summer schools or in out-of-school extracurricular activities organised by the schools themselves. The students referred to these activities as fun, interesting and that they make you think by being more hands-on and therefore allow you to participate more. They were also more likely to engage in discussions with the people concerned.

The low achievers from State Schools indicated that they rarely participated in such activities not due to lack of interest, but mainly because they are not aware of the organisation of such activities.

*"Le, ma tantx. Fil-fatt issa għaddhietli minn moħħi jien li jsiru attivitajiet tas-science għax kieku ma semmejtilnhiex inti anqas naf biss."*

"No, not really. In fact, it is now that I realised that such science activities are organised. If you didn't mention it, I wouldn't have known." (Girl, State school, Low achiever)

This lack of awareness of out-of-school science activities was also coupled with the fact that such activities are few and far between although this may now be improving due to the opening of Esplora Interactive Science Centre (Bighi, Malta). Some also referred to their participation in activities organised by NGO's e.g. Klabb Ħuttaf Birdlife.

To conclude this general review of the sample studied, one can say that the Form 2 Maltese students studied in 2012:

- spoke mainly Maltese at home (79.0%) with the rest speaking English except for a very small percentage who spoke another foreign language;
- had parents who generally had achieved a secondary or higher level of education (77.6% mother/female guardian and 75.6% father/male guardian);
- had parents who participate poorly in political activities;

- had limited exposure to science during their primary years with 54.3% reporting having no science lessons or less than one science lesson per week during the last year of primary schooling;
- did very well in Integrated Science exams with 87.1% stating to have obtained a pass mark in their last Integrated science exam;
- generally planned to opt for one science subject in Form 3 (67.3%) with the other third choosing to study two or three science subjects in Form 3 ;
- had general positive attitudes towards science and science education; and
- had low exposure to out-of-school activities related to science.

It was also reported that the language mainly spoken at home, parents' level of education, parents' participation in political activities and exposure to out-of-school activities related to science were also related to the type of school attended.

## 4.2 Gauging Science Awareness

The main target of the first phase of the research study was to provide a measure of science awareness for students in their early phase of secondary education in Malta. A numerical and qualitative analysis of the results obtained for each of the indicators developed to measure this educational target is given below. This section provides a snapshot of students' awareness through isolated and amalgamated analysis of the indicators of science awareness as developed through the literature review. It also provides an insight into their interest for different forms of pedagogies that can be used to enhance science awareness and higher order targets in the quest for science for citizenship.

The following is an analysis of the students' perceptions of science and science education in relation to the three main indicators developed in defining science awareness in this research study. It is mainly based on an analysis of the results for Section 1 of the questionnaire supported by related responses from the focus group discussions.

### 4.2.1 INDICATOR 1: Awareness of the Science Component in Personal, Social and Global Issues

As a first indicator of science awareness, students had to show their recognition of the increasing impact of science on their own lives and on society. In Section 1 of the questionnaire, the students indicated the extent to which they think that a number of personal (Section 1A), social (Section 1B) and global issues (Section 1C) or decisions were related to science.

**Table 4.5** shows the means for the responses obtained for Section 1A of the questionnaire that covered personal issues. Students did not see items as related to science when the matter in question was purely a private, individual choice that can be taken with no external interference or support. Deciding *what car to buy* (Mean = 1.78) or *what food to buy* (Mean = 2.41) were seen as decisions that can be taken based on factors other than science, e.g., personal preferences, economic factors, convenience, etc. Students did not recognise the impact that these decisions may have beyond the personal realm, e.g. due to their impact on the environment. On the other hand, they did see the relation to science in personal issues that are related to health and those that are promoted perhaps also in a scientific manner by external bodies such as the Government, businesses, etc. as in the case of solar water heaters in relation to energy usage.

**Table 0.5: Means for the responses to the question: To what extent do you think the following are related to science? (personal issues)**

| **Questionnaire items - Section 1A** | **Mean** | **Std. Deviation** |
|---|---|---|
| what type of car to buy | 1.78 | 0.900 |
| whether to recycle waste | 2.30 | 1.020 |
| whether to breast-feed or bottle-feed a baby | 2.38 | 0.964 |
| what type of food to buy | 2.41 | 0.956 |
| **whether to take the swine flu vaccine** | **2.52** | 0.900 |
| **whether to install a solar water heater** | **2.80** | 0.912 |
| **choosing between a number of treatments for a deadly disease such as cancer** | **3.03** | 0.875 |
| **Average mean** | **2.46** | |

In the case of social issues, the results of which are presented in **Table 4.6**, one can observe that with the exception of items related to the power station, students disagreed that a decision or an issue is related to science unless it featured a clear scientific connotation to the environment or to health. When the statements were presented without an obvious negative consequence, e.g., *the type of transport to use* (Mean = 2.10), *the laws to control hunting of birds* (Mean = 1.89), *the type of landfill to build* (Mean = 2.27), etc., then it was not easy for the students to recognise the connection to science. When an obvious contingent context was mentioned, the respondents agreed more easily that such decisions are related to science. Higher means were in fact obtained for items such as *whether fish farming is having a negative effect on the marine environment* (Mean = 2.64), *the laws to protect the habitat of rare animals* (Mean = 2.88) or *whether pollution from a particular source, e.g., a power station is a risk to health* (Mean = 3.26).

**Table 0.6: Means for the responses to the question: To what extent do you think the following are related to science? (social issues)**

| Questionnaire items - Section 1B | Mean | Std. Deviation |
|---|---|---|
| the laws to control hunting of birds | 1.89 | 0.941 |
| whether an area should be built or developed | 2.04 | 0.862 |
| the type of transport to use | 2.10 | 0.943 |
| the type of transport systems to introduce | 2.15 | 0.985 |
| where to build a landfill | 2.16 | 0.937 |
| whether those who destroy the environment should be made to pay | 2.21 | 1.045 |
| the type of landfill to build | 2.27 | 0.936 |
| whether alcoholic drinks should be prohibited for young people | 2.34 | 1.111 |
| the type of methods of waste disposal | 2.42 | 0.909 |
| the level of risk presented by slow changes, e.g. coastal erosion | 2.47 | 0.997 |
| **whether fish farming is having a negative effect on the marine environment** | **2.64** | 0.902 |
| **the level of risk presented by fast changes, e.g. earthquakes, hurricanes** | **2.73** | 0.988 |
| **the type of power station to install** | **2.77** | 0.894 |
| **the laws to protect the habitat of rare animals** | **2.88** | 1.004 |
| **where to set up wind farms to produce electricity from wind energy** | **3.11** | 0.798 |
| **how to control the spread of infectious diseases** | **3.24** | 0.857 |
| **whether pollution from a particular source, e.g. a power station, is a risk to health** | **3.26** | 0.748 |
| **Average mean** | **2.51** | |

As shown in **Table 4.7**, means higher than 2.5 were obtained for the majority of global issues included in the questionnaire probably because they are tackled extensively during science lessons and even featured in the news.

An average mean was also calculated for each sub-section as shown in **Tables 4.5, 4.6** and **4.7**. One can observe that the average mean is only above 2.5 for the case of global issues. This implies that, in general, students see global issues (average = 2.75), such as *global warming*, *pandemics* and *exploration of space,* as more related to science than personal (Average Mean = 2.46) and social issues (Average Mean = 2.50) for which the average means were very close.

**Table 0.7: Means for the responses to the question: To what extent do you think the following are related to science? (global issues)**

| **Questionnaire items Section 1C** | **Mean** | **Std. Deviation** |
|---|---|---|
| population control | 1.78 | 0.920 |
| abortion | 2.41 | 1.125 |
| competition between food against fuel production | 2.42 | 0.979 |
| **ecological balance** | **2.76** | 0.904 |
| **extinction of species** | **3.00** | 0.896 |
| **use of pesticides and the destruction of the ozone layer** | **3.01** | 0.949 |
| **pandemics** | **3.15** | 0.919 |
| **exploration of space** | **3.44** | 0.794 |
| **Average mean** | **2.75** | |

Beyond context, a more significant factor that determines the connection to science is the degree to which an issue is related to factual school science content. This could be observed by putting all the three section items in order of their means as shown in **Figure.4.6**. Means higher than 2.5 were obtained for those items featuring technical terms (e.g. *cloning, pandemics, infectious diseases, nuclear waste, ozone layer*) indicating an obvious connection to scientific terms and facts.

On the other hand, low means were obtained for issues in Sections 1A, B and C in which factual science content is much less evident. These included social and global issues with a strong political connotation, e.g. *population control* (Mean = 1.78), *the laws to control hunting of birds* (Mean = 1.89), *whether an area should be built or developed* (Mean = 2.04), as well as personal decisions that can be based on factors other than science, e.g. *what type of car to buy* (Mean = 1.78), *the type of transport to use* (Mean = 2.10), *whether to recycle waste* (Mean = 2.30), etc. The means obtained imply that students either strongly disagree or disagree that these items are related to science.

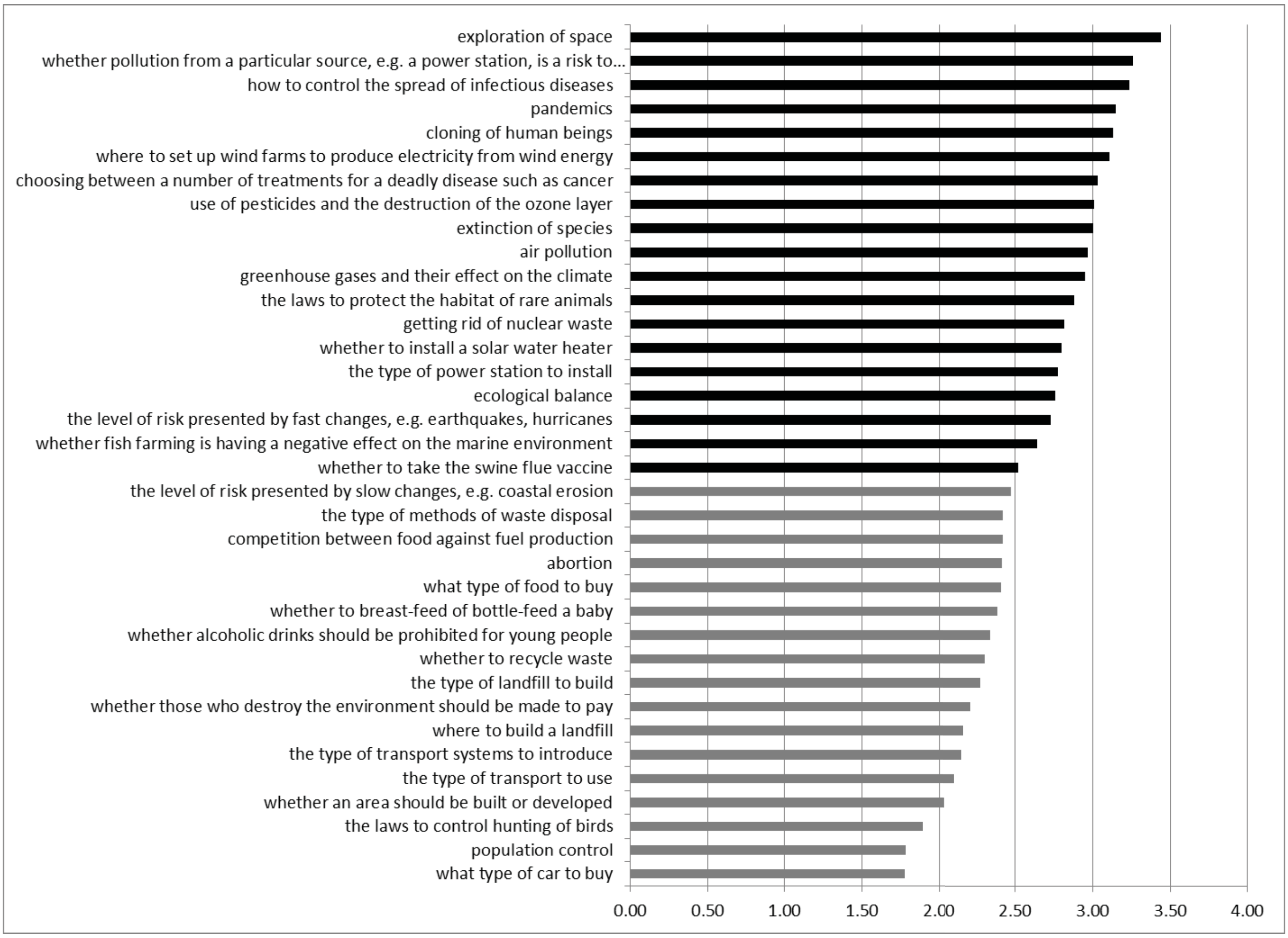


**Figure 0.6: Questionnaire items For Sections 1A, B and C in descending order of Means**

Health issues are strongly considered by students to be related to science. Students recognise the connectivity between science and the medical field probably because it is one of the areas that they have to engage with very early in their lives. It is also an area extensively covered in the Integrated Science syllabus. In fact, items that top the list in **Figure 4.6** are related to health, e.g. *pandemics* (Mean = 3.15), *how to control the spread of infectious diseases* (Mean = 3.24) and *whether pollution from a particular source is a risk to health (*Mean = 3.26).

All in all, students regard issues as related to science only when it is something covered at school but cannot apply the science content to everyday life. Respondents do not really have much awareness of science in their personal life and in society unless the content is similar to content covered in the science syllabus at schools or is in their science textbook. This was actually confirmed during the focus groups during which the students were asked which of the two items, *Exploration of Space* or *Whether an area should be built or developed,* they think is more related to science. As shown by the students' views below, they considered the item *Exploration of space* as more related to science as it is identified with lots of information and detail, tells you what things, like planets, are made up of, how things work, and because it could be related specifically to a science school subject, namely Physics.

"Like space is more related to science because you need to know what happened, the Big Bang, the stars, how they were formed" (Girl, Independent School)

*"Iva, għandu x'jaqsam għax jgħidlek x'ikun l-ispace, x'hemm ġo fih. Speċi science hu magħmul li jtik l-informazzjoni, u jgħidlek x'jiġri fl-affarijiet, f'postijiet...."*

"Yes, it is related as it tells you what space is, what it is made up of. Like science is made to give you information, and it tells you what happens in things, -places..." (Girl, State School, Low achiever)

High achievers in State Schools also stated that *Exploration of space* is related to science as it is something that is still unfolding, is still being studied. Some students went on to state that while they think that *Exploration of space* is related to science, they do not think it is important as it is too detached from us.

"I do think that it is related to science but I don't think it is that important cause it is not really going to affect us, like knowing what orbits the Sun and stuff like that." (Girl, Independent School)

On the other hand, most could not see the item *Whether an area should be built and developed* as related to science mainly because they could see it more linked to other school subjects, such as Geography, Technology, Social Studies, Business Studies as shown below:

"Because it doesn't really have anything to do with science. It sort of has to do with Physics but not with science exactly" (Girl, Independent School)

"I think exploration of space, because of the building it is more related to archaeology, while space is scientific and there's lots to learn about it." (Boy, Church School)

*"Jien naħseb ta' l-ispazju iktar għandha x'taqsam mas-science. L-oħra qisu tal-bini iktar għandha x'taqsam mas-Social Studies, Geography u hekk hux...."(Girl, Church School)*

"I think that of space is more related to science. The other, that of the building is more related to Social Studies, Geography and the like..." (Girl, Church School)

A few students could, however, identify this item with science as they could see the impact that such a project may have on the environment as indicated below:

*"Naħseb li għandha x'taqsam xi daqsxejn għax qisek trid tara x'impatt se jkollha fuq l-ambjent u n-nies li taffetwahom....naħseb li għandha x'taqsam naqra."*

"I think it is somehow related because you have to see the impact it will have on the environment and on people...I think it is related somehow." (Girl, State School, Low achiever)

*"Iva, għax jekk nibnu f'wied fejn hemm il-pjanti u hekk, allura nkunu qegħdin neqirdu l-habitat u annimali żgħar"*

"Yes, because if we build in a valley where there are plants, we are destroying the habitat and small animals." (Boy, State School, High achiever)

Since students were asked not to mark an item on the questionnaire if they are not familiar with the term, even when translated, it is also significant to identify the items with the highest missing values. These are given in **Table 4.8**. Again, these results indicate the extent to which students' views and knowledge are based on school science. Although issues such as cloning, nuclear waste, the ozone layer and pandemics feature heavily in media and politics, they are not tackled extensively in school science at Form 2 level (age = 12) in Malta.

**Table 0.8: Items with the highest percentage of missing values for Sections 1 A, B and C**

| Item Name | Item Label | Missing % |
|---|---|---|
| Sec1QC1 | Cloning of human beings | 39.0 |
| Sec1QC12 | Ecological balance | 31.3 |
| Sec1QC10 | Extinction of species | 23.8 |
| Sec1QB13 | The level of risk presented by slow changes e.g. coastal erosion | 21.8 |
| Sec1QC8 | Use of pesticides and the destruction of the ozone layer | 14.0 |
| Sec1QC2 | Getting rid of nuclear waste | 10.5 |
| Sec1QC5 | Competition between food and fuel production | 7.5 |
| Sec1QC11 | Exploration of space | 4.5 |
| Sec1QC4 | Greenhouse gases and their effect on the climate | 4.0 |
| Sec1QC6 | Abortion | 4.0 |
| Sec1QC9 | Pandemics | 3.5 |

- **Acknowledgement of the science-society association**

Beliefs on the increasing impact of science was also investigated through the questions in Section 1D where Form 2 students were expected to demonstrate familiarity with the uncertainty and risk presented by contemporary scientific applications, together with the interplay that exists between science, scientists and society. This section was the one that gave the most ambiguous quantitative results as shown in **Table 4.9** and surely needed further probing and explanations.

**Table 0.9: Means for the response to Section 1D**

| Questionnaire items - Section 1D | Mean | Std. Deviation |
|---|---|---|
| the effects of science application are always safe | 1.78 | .783 |
| what scientists research is determined by politicians and industrialists | 2.03 | .835 |
| science serves the rich at the expense of the poor | 2.04 | .934 |
| we should always trust scientists | 2.22 | .804 |
| the scientific method always leads to correct answers | 2.25 | .761 |
| everyone benefits from the progress of science | 2.31 | .850 |
| the effects of science applications are always known exactly | 2.32 | .831 |
| the Government can control any dangerous developments in science | 2.35 | .961 |
| only scientists can find solutions for scientific issues such as global warming | 2.36 | .894 |
| people like me and my family have little chance to influence scientists | 2.40 | .924 |
| common citizens can control the progress of science | 2.40 | .878 |
| science can help solve social problems e.g. poverty | 2.43 | 1.014 |
| **scientists often disagree with each other** | **2.60** | .889 |
| **the latest scientific applications are more risky than ever before** | **2.73** | .910 |
| **scientists often need to work with other experts** | **2.95** | .843 |
| **science helps protect our planet for future generations** | **3.17** | .738 |
| **all scientists are responsible people** | **3.19** | .820 |
| **Average mean** | **2.50** | |

An average mean of 2.50 was obtained when the value labels of the inversely worded items (e.g. the effects of science application are always safe, we should always trust scientists, the scientific method always leads to correct answers) were reversed showing that the level of awareness related to this aspect is overall quite low.

Students are aware of the uncertainty and risk that characterises the scientific method, results and applications as shown by the mean values given in **Table 4.9**. Students disagreed with statements such as The scientific method always leads to correct answers (Mean = 2.25) and We should always trust scientists (Mean = 2.22). Students are also aware that scientists are humans and therefore may have conflicts, agreeing with the statement that Scientists often disagree with each other (Mean = 2.60). They are also aware that scientific inventions may not always be safe. In fact, the lowest mean was obtained for the item the effects of science application are always safe (Mean = 1.78). Concordantly, students agreed that the latest scientific inventions are more risky than ever before (Mean = 2.73).

The first anomaly that can be identified is that in spite of the recognition of the uncertainty and risk associated with the scientific method and scientific applications, the questionnaire respondents still have a positive image of science. They agreed strongly with sweeping statements that portray a blind-folded positive perception of science such as *Science helps protect our planet for future generations* (Mean = 3.17) and that *All scientists are responsible people* (Mean = 3.19).

Students are also weakly aware of the impact that society may have on the progress of science. This finding can also be seen through other numerical results given in **Table 4.9.** Students disagreed with statements such as, *What scientists research is determined by politicians and industrialists* (Mean = 2.03), *The Government can control any dangerous developments in science* (Mean = 2.35) and *Common citizens can control the progress of science* (Mean = 2.40). However, they believe that scientists have to work with other experts to solve global problems. In fact, they disagree with *Only scientists can find solutions for scientific issues such as global warming* (Mean = 2.36) and agree that *Scientists often need to work with other experts* (Mean = 2.95).

In general, students also fail to recognise the disservice that the scientific enterprise may be doing to Third World countries. Even the quantitative results have shown that the students disagree that *science serves the rich at the expense of the poor* (Mean = 2.04).

During the focus groups, some of the students actually explained their mixed beliefs about scientists as portrayed through the questionnaire results.

"I would say they are responsible but I would also say they're a bit irresponsible. They are responsible because before they do something they do intensive planning and research a lot about it and a bit irresponsible because sometimes it may not turn out the way they predicted." (Boy, Church School)

"We get the impression that scientists are really smart people, they're studious, they're always experimenting and finding out new things but yes they could be irresponsible. But we need them to find out new things and all that," (Boy, Church School)

*"Ma naħsibx li kollha jkunu responsabbli. Per eżempju, hemm xjentisti li jużaw ix-xjenza u n-knowledge tagħhom biex jagħmlu affarijiet bħall-armi nuklejari u hekk li jistgħu jagħmlu ħafna ħsara."*

"I don't think that all are responsible. For example, there are scientists who use science and their knowledge to do things like nuclear bombs and the like which can do a lot of harm." (Boy, State School, High achiever)

As shown above, generally students believe that most scientists are responsible people who do intensive planning and research. In fact, we rely on them a lot and without them we would not have the quality of life we enjoy today. However, the students also indicated that scientists sometimes may act irresponsibly, such as when they put their and other peoples' lives at risk during their work, e.g., space explorations, or through the scientific applications they create, e.g., nuclear bombs). Some even stated that science makes scientists go mad after some time and they eventually become irresponsible as they get carried away and start to do crazy things, a view probably reflecting the virtual image of scientists as presented in cartoons and other television programmes

Several examples of irresponsibility given by the students point again to the strong influence that school science has on students' beliefs about scientists. Some spoke about irresponsibility in terms of school lab scenarios, e.g., leaving glassware lying around, holding the apparatus in the wrong way or mixing the wrong amount of chemicals. Commonly, science teachers were actually equated with scientists when speaking about this aspect as is shown below:

*"Per eżempju tal-iskola tagħna għandhom qisha cupboard biex ipoġġu l-affarijiet....issa ċertu teachers irresponsabbli jħallu l-affarijiet fin-nofs u kollox jinkiser...imbagħad plus li jweġġgħu huma."*

"For example, in our school we have like a cupboard to put things in...now some irresponsible teachers leave everything lying around and everything breaks.....plus they hurt themselves." (Girl, State School, Low achiever)

Students also referred to the fact that all scientists are humans and thus may make mistakes as stated below:

*"Huma responsabbli imma peress li huma umani, bħal kulħadd jagħmlu żbalji. Allura mhux kollox li jgħidu huwa tajjeb imma l-maġġoranza."*

"They are responsible, but because they are human they do mistakes like everybody else. So, not everything they say is good, but on the whole yes." (Girl, Church School)

Only male low achievers attending State Schools did not question the responsibility of scientists and simply accepted the statement *all scientists are responsible people*. This also indicates that the type of school attended and the academic ability of students may also be important factors that affect science awareness.

During the focus groups, students also discussed why they disagree with the statement *everyone benefits from the progress of science* (Mean = 2.31). They mostly referred to personal health issues or individual trivial decisions when doing so. Students stated that not everyone benefits from science as either some people might not need a particular medicine, others would be allergic to it, or else they would not have the money to buy it as is explained by these students.

"Just because you have a vaccine and you cannot afford to get it, or you are not in a position to get it, you cannot benefit from it." (Girl, Independent School)

*"Għalhekk mhux kulħadd igawdi l-istess għax jekk dik it-tali persuna ma tbatix minn dik il-marda, per eżempju ażma, mhux se tgawdi l-istess ammont"*

"That is why not everyone benefits equally because if that particular person does not suffer from that illness, for example asthma, she is not going to benefit to the same extent." (Girl, State School, High achiever)

Scientific development today is not seen by Western youth to globally free humans from the restraints of lack of food, water, etc., or, in other words, to solve social and global scientific issues, but to fit our personal needs, tastes and ways of life which may be trivial. When referring to technological products, the students said that developers cannot make all the people in the world happy with one artefact because everyone has her own lifestyle and preferences. When asked whether everyone benefits from technological products, one student stated:

"Yes and no, because some people might like the new scientific discovery but some people they have different lives, so they don't like." (Boy, Independent School)

Only male students attending a Church School most closely referred to the politics encompassing scientific development during the focus groups. They stated that since most inventions are happening in Europe, America, etc., these are not reaching Third World countries mainly because of the restrictions imposed by their own Governments as in what used to happen in Libya before the Arab revolution. Also, this concentration of research and development in the Western world implies that more money is being put into development of cures for diseases that affect Western countries, such as cancer, rather than those that infest Third World countries. Deciding what to study scientifically may also be politically manipulated. All in all, the results tackled above show that students have quite a high awareness of the uncertainty and risk associated with the scientific method and its products. Again the influence of school science features heavily in students' responses to statements related to the uncertainty of science and the irresponsibility of scientists. However, science is still regarded as an entity that endows society or, perhaps, individuals with its precious inventions. Little do they see the uneven and unjust distribution of scientific discoveries across the world. Their recognition that Governments and citizens in general can actually affect the progress of science is also poor.

### 4.2.2 INDICATOR 2: Recognition of attributes needed to engage and act upon scientific issues.

The second indicator of science awareness considered the extent to which the students recognise the competencies they need to engage with issues of a science component. This was mainly investigated through the context-based questions in Sections 1E and F of the questionnaire.

The questionnaire results show that students are strongly aware of the attributes needed to engage and act upon scientific issues. The first context-based question was about Paul*, an accident victim, who ended up paralysed and who needed to decide whether to go for new treatments provided by stem cell research. When asked to indicate the extent to which they agree that Paul* needs certain scientific attributes to improve his quality of life, all means for the responses were above 2.5, with an average mean of 3.1 as shown in **Table 4.10**. The lowest mean (2.72) was obtained for the item *his school science education.* These results show that Form 2 students are able to identify which competencies are essential to deal with personal, science-based life situations. They also agree that school science education was important for Paul to improve his quality of life. However, the mean for *his school science education* was quite low when compared to the other competencies mentioned. They see the acquisition of the competencies mentioned as more important in improving Paul's quality of life than his school science education. This may imply that they do not see science education as the route to achieve these competencies, as otherwise a comparable mean would have been attained for this item.

Analysis of **Table 4.10** also shows that students tend to give more importance to knowledge and facts, e.g., *knowing about the curing effects of stem cells* (Mean = 3.41), and *knowing how his body works* (Mean = 3.32), in contrast to the development of higher-order scientific skills, social skills and attitudes. In fact, lower means were obtained for items such as *being able to listen to the views of others* (Mean = 3.18) and *analysing why different researchers obtained different results* (Mean = 2.96).

In Section 1F, as shown in **Table 4.11**, the students indicated that one should not remain passive in relation to socioscientific decisions with which one disagrees, but should ensure that one should gain the relevant knowledge in order to take effective action. In fact, the lowest means were obtained for the only two items that were worded contrary to the rest of the items and thus feature passiveness, namely, *accept such a decision as good and final as it was taken by experts* (Mean = 1.96) and *only speak up if the decision affects them personally* (Mean = 2.29). The means for all the other items were above 2.86. An average mean of 2.93 was obtained when the value labels of the inversely worded items were reversed.

**Table 0.10: Means for the questionnaire items in Section 1 E in response to the statement:** ***State the extent to which you agree that the following are/were important for Paul to improve his quality of life:***

| **Questionnaire Item – Section 1E** | **Mean** | **Std. Deviation** |
|---|---|---|
| **his school science education** | **2.72** | .911 |
| **showing interest in scientific research** | **2.89** | .790 |
| **analysing why different researchers obtained different results** | **2.96** | .815 |
| **being willing to take action to collect money for his treatment** | **2.99** | .819 |
| **comparing and evaluating the results obtained by different researchers** | **3.09** | .688 |
| **evaluating whether the risks of the treatment outweigh the benefits** | **3.13** | .736 |
| **being able to listen to the views of others** | **3.18** | .707 |
| **knowing where to look for reliable information about stem cell research** | **3.27** | .701 |
| **knowing how his body works** | **3.32** | .629 |
| **knowing about the curing effects of stem cells** | **3.41** | .652 |
| **Average mean** | **3.10** | |

In summary, students are on the whole aware of the knowledge, skills and competencies needed to engage with personal and social scientific issues. They assign more importance to knowledge rather than other essential skills and competencies that are perhaps equally useful for citizens to become agents of change. However, they assign less importance to school science education in tackling personal and social scientific issues.

**Table 0.11: Means for the questionnaire items in Section 1F in response to the statement:** ***Citizens who do not agree with this decision should:***

| Questionnaire items – Section 1F | Mean | Std. Deviation |
|---|---|---|
| accept such a decision as good and final as it was taken by experts | 1.96 | .893 |
| only speak up if the decision affects them personally | 2.29 | .945 |
| **take part in demonstrations to stop the project** | **2.86** | .850 |
| **take part in television debates regarding the issue** | **2.95** | .844 |
| **write about the issue in newspaper. Blogs, etc.** | **3.07** | .839 |
| **collect signatures for a petition and present it to the relevant authorities** | **3.10** | .874 |
| **collect useful data from different sources to understand the issue better** | **3.19** | .764 |
| **Average mean** | **2.93** | |

### 4.2.3 INDICATOR 3: Recognition of the contribution of science education in the acquisition of attributes needed to engage with and act upon issues of a science component

In the questionnaire, students were asked specifically about the science education they received. Through this retrospective outlook, one could derive the knowledge, skills and other competencies that students believe were tackled through their science education. This can allow one to investigate whether students' are actually acquiring the attributes necessary to engage with and act upon issues of a science component.

Students reported that school science is still heavily teacher-centred as shown by the means listed in **Table 4.12** obtained for the question *How often do you carry out the following during your science lessons?* Means for *listening to the teacher* (Mean = 3.33) and *reading or writing notes* (Mean = 3.22) top the list, while student-centred, action-based pedagogies such as *community work* (Mean = 1.39) or *field work* (Mean = 1.52) are never or rarely used. It is interesting to note that *discussion* is employed quite frequently (Mean = 2.92). However, this might still be a type of discourse heavily controlled by the teacher.

**Table 0.12: Ascending means for learning activities carried out during science lessons**

| **Learning Activity** | **Mean** | **Standard deviation** |
|---|---|---|
| Community work | 1.39 | .743 |
| Fieldwork | 1.52 | .733 |
| Doing an experiment yourself | 1.98 | .895 |
| Trying to solve a problem | 2.38 | 1.007 |
| Watching the teacher do an experiment | 2.58 | .892 |
| Working with friends | 2.66 | .886 |
| Discussion | 2.92 | .925 |
| Reading or writing notes | 3.22 | .984 |
| Listening to the teacher | 3.33 | .858 |

Parallel to the prominence of teacher-centred and content-based activities, students have reported retrospectively the acquisition of competencies at the lower strata of the ladder of attributes characterising Indicator 2 of science awareness given in the methodology section. As shown in the answers to Section 1G of the questionnaire, while the students recognise that their science lessons gave them an understanding of the world around them and an inkling of how scientists go about their work, they believe that they are less prepared with respect to the aptitudes needed to participate in political action which, perhaps, should be the main objective of science education as part of scientific literacy. In fact, as shown by **Table 4.13** , means less than 2.5 were obtained for *participating in political action* (Mean = 1.90) and *willingness to participate in political action as a reflective citizen* (Mean = 2.25). This finding indicates that the type of science learning activities in schools fail to mirror functionality and are still highly teacher-centred and content-based as has been discussed in a previous section to this analysis.

This situation was also confirmed during the focus groups where the most common type of class activities mentioned were the following: PowerPoints, videos, drawings on the board, handouts, reading textbooks, writing notes and filling in worksheets. A few also mentioned group work and games. Several commented that due to the vast syllabus and lack of availability of the lab, they do not carry out many experiments and even when so these usually take the form of demonstrations.

**Table 0.13: Means for the questionnaire items in Section 1 G in response to the question:** ***To what extent do you agree/disagree that school science has been helping you in the following areas?***

| **Questionnaire items – Section 1G** | **Mean** | **Std. Deviation** |
|---|---|---|
| Participating in political action | 1.90 | .898 |
| Willingness to participate in political action as a reflective citizen | 2.25 | .923 |
| **Negotiating possible solutions through democratic ways** | **2.64** | .869 |
| **Strengthening your values** | **2.76** | .953 |
| **Presenting your opinions to others** | **2.80** | .865 |
| **Listening to people with different views** | **2.85** | .859 |
| **Distinguishing between what is right and what is wrong** | **2.99** | .849 |
| **Understanding how scientists work** | **3.04** | .745 |
| **Questioning the things or issues around you** | **3.05** | .745 |
| **Using scientific results to draw a conclusion** | **3.07** | .787 |
| **Understanding the importance of science in your lives** | **3.12** | .769 |
| **Taking care of your health** | **3.33** | .764 |
| **Understanding the world around you** | **3.37** | .663 |

A parallel frequency of activities is verbalised hereunder:

*"Ġeneralment jispjegawlna bil-PowerPoints u hekk, imbagħad ġieli nagħmlu xi activities oħra bħall- experiments, xi games ...biex naqbdu iktar."*

"Generally they explain to us with PowerPoints and such, then sometimes we do other activities like experiments, some games......so that we understand better." (Girl. State School, High achiever)

Students also mentioned the teacher as important in determining what type of activities are carried out during science lessons. With reference to the activities carried out on the interactive whiteboard, one of the students said:

*"Għax issa biddilna t-teacher u issa m'għadux jagħmlilna"*

"Because now we changed teacher and he doesn't do it (use the whiteboard) anymore" (Boy, State school, Low achiever)

Some also classified the activities in order of their element of fun starting from writing notes to PowerPoint presentations, videos, lab activities and outings which they tend to find the most exciting as indicated by the following students:

"Because there is the written lesson, where you stay writing which isn't so attractive. There's the PowerPoint which is more, but I think that the most nice thing is when you go down in the lab....you write...she'll show us stuff and how it works...that's when it gets a little bit more attractive." (Boy, Church School)

"I think PowerPoints and experiments are useful but the best things that I think is like when we go out on an outing, like we have different activities, like to test out things, draw sketches and all that. I think that's the most attractive." (Boy, Church School)

The activities they enjoy the most are also the ones rarely used during science lessons in Malta. These activities are not only preferred due to their element of fun but also because students feel that through activities, such as experiments and fieldwork, they can understand better as their degree of involvement increases.

*"Nagħmlu experiments fil-lesson, eżempju għamilna t-topic Separating Techniques, dak kellu ħafna experiments, għamilna ħafna u dawk l-iktar li jolqtuk u tagħmilhom inti, tħossok iktar kunfidenti titgħallem iktar fuqhom għax tkun għamilthom inti stess."*

"We do experiments during the lesson, for example we covered the topic Separating Techniques, that included a lot of experiments, we did a lot and those are the ones that strike you as you do them yourself, you feel more confident learning about them as you do them yourself." (Boy, State School, High achiever)

They are even aware that they may not be learning a lot from teacher-centred activities as shown below:

"We never really do something that attractive in a science lesson because what we do is read and she gives us some explanation and then we do the homework. But we never like do anything to help us learn, like any activities, ....I don't mind it but it is not that fun." (Girl, Independent School)

Focus group analysis showed that students still perceive science as a load of facts and details and science education as the main channel through which these elements are transmitted. In fact, they are aware that through their science education, they are getting the knowledge base to understand important science issues but not the skills to become more active citizens. They see this mainly as the objective of other subjects such as Geography, Personal, Social and Career Development (PSCD) and Social Studies. Students still compartmentalise their education into school subjects and are not aware of their holistic development. If something does not fit in the traditional notion of a particular school subject, it should not be there.

However, Form 2 students believe that common citizens should attempt to influence decisions taken by politicians. After all, common citizens constitute the majority and so politicians should take heed.

"I think they have to agree with the majority of the people because we are living in this country...not only them...so." (Girl, Independent School)

*"Għax aħna pajjiż demokratiku, aħna wkoll għandna nagħtu s-sehem f'dik l-għażla. Veru li l-politikanti jieħdu l-aħħar deċiżjoni imma aħna wkoll għandna bżonn li nidħlu fiha, mhux huma biss qegħdin ġo Malta, aħna wkoll."*

"Because we are a democratic country, we also have to participate in making choices. It is true that the politicians take the final decisions but we also need to take part, not only they are in Malta, we too." (Boy, State School, High achiever)

Students also acknowledged that this is a far cry from what actually happens as citizens very rarely attempt to do so and politicians seldom take note.

"....but it's quite difficult and quite rarely the citizens would stand up to their needs and say I would like this....I want to make it happen." (Boy, Church School)

"We might influence them a bit but usually the politicians just do what they think is best for us" (Boys, Independent School)

Students are aware of the methods that can be used to this effect. In fact, they mentioned lobbying politicians, peaceful protests, petitions from the people mostly affected, conducting surveys, participating in television or radio programmes through telephone calls, posting on social networks such as Facebook, offering alternative solutions and the example referred to by the following student:

*"Bħal gruppi ta' pressjoni u hekk, ġieli......il-poplu jekk ma jkunx qiegħed jaqbel, jekk il-valuri jmorru kontra, se jagħmel gruppi ta' pressjoni biex jaffetwa l-ideja tal-Gvern."*

"Like pressure groups and such, sometimes when people do not agree, when the values are in contradiction, they are going to form pressure groups to influence the Government's ideas." (Girl, State School, High Achiever)

They also recognise that voting is not sufficient as one may not agree with the politicians elected on specific issues, as indicated by the dialogue below between male students from a State School:

*"...jekk ma taqbilx miegħu, ma tivvutalux darboħra."*
*"...imma d-deċiżjoni ħa ssir...ikollok tistenna ħames snin oħra"*
*"Tista' tagħmel protesta, f'pajjiz demokratiku tista' tagħmel protesta, l-importanti li ma tiksirx il-liġijiet."*

"...if you do not agree with him, you don't vote for him next time"
"...but the decision will be taken...you have to wait for another five years."
"You can carry out a protest, you can carry out a protest in a democratic country, the important thing is that you do not break the law". (Boys, State School, High Achievers)

Some of the qualities required by those people who take such initiatives were also identified. First of all they have to be knowledgeable about the issue in question as underlined below:

*"Naħseb persuna trid tkun infurmata, irid ikun jaf x'qiegħed jiġri madwaru, ikun jaf f'hiex tikkonsisti l-għażla li se jagħmel, il-partiti politiċi tipo...ma jistax jaqbad ma jkunx jaf x'qiegħed jiġri, irid ikun jiffolowja dak li qiegħed jiġri madwaru"*

"I think that a person has to be informed, needs to know what is happening, knows what the choice he is going to make consists of, the political parties sort of....he cannot not know what is happening, he has to follow what is happening around him." (Girl, State School, High Achiever).

Characterwise, they also have to be determined, do not give up or are not intimidated easily. They should have good reasons for their action, know how to argument, aren't shy and have good speaking, leadership and listening skills, etc. This can be summarised in the statement below:

"You need to be charismatic, you need to be confident, you know the limit and you cannot stay like really shy. You like get out of the bubble." (Girl, Independent School)

They, however, should also be aware of their legal limitations as sometimes things may not work out as planned as explained by this student:

*"Ikun responsabbli li jkun leader, għax f'każ li se tibda protesta, trid tkun responsabbli wkoll, tkun taf id-drittijiet u d-dmirijiet tiegħek f'dak il-każ, ma tridx taqta' qalbek għax hemm naqra protesti li jmorru naqra out of control u jsiru daqsxejn mhux ċivili."*

"He has to be responsible if he is going to lead because if one is going to start a protest, one has to be responsible as well, know the rights, and you don't give up because there are some protests that go a bit out of hand and become somehow uncivilised." (Boy, State School, High Achiever)

Asked whether their science lessons are helping them in any way in order to become more active citizens, the students stated that mainly they were giving them more information and detailed explanations about certain important issues like global warming and pollution so that they can become more aware and better understand current affairs and political decisions with a science basis. One typical response was the following:

"It is helping us a bit, ....like if there are science issues, you understand them more obviously and if you want to talk to someone, you know what you are talking about because of this education we had at school" (Boy, Independent School)

Science education is providing them with basic background scientific knowledge without which other actions would be impossible. For example, one cannot put forward an argument and take action against pollution or global warming if he or she doesn't know anything about them or if he or she cannot explain what is going on. Science education may also help to shape personal decisions around issues that have a science basis, e.g., whether to recycle waste, how to behave in natural reserves. It's as if they assume that having the knowledge is sufficient to make one an activist as is shown by this comment from a male student:

"Maybe because of science, you see what's going on. Let's say you never had science and you don't know anything about pollution or a little bit, and you don't recognise any pollution. But if you took science and you see what's happening, you can take action if you're that kind of activist...but if you don't know anything, there's no point in being an active citizen." (Boy, Church School)

Science education as described by the students seems to have more action-based effects with regards to issues or decisions that have to be taken personally such as the example of recycling of waste discussed in the following statement:

*Fl-Integrated Science qed nagħmlu affarijiet bħat-triple R – ir-Recyling u per eżempju jekk qabel kien ikollok flixkun tal-plastic u tarmih fir-rubbish normali issa tirriċiklah. Allura jekk qabel kont titfa' l-boroż il baħar għax ma kontx taf, ma kontx aware, issa taf li dak il-flixkun li kont se titfa' l-baħar imutu s-sea turtles, allura iktar taf x'se jkunu l-konsegwenzi"*

"During Integrated Science, we are doing things like the three R's – Recycling , and for example if before you didn't know and you had a plastic bottle and you used to throw it with the normal rubbish, now you recycle it. So if before you used to throw the plastic bag in the sea because you didn't know, you weren't aware, now you know that that bottle you were going to throw in the sea, sea turtles die because of it...so you know more about the consequences. ." (Boy, State School, High Achiever)

However, one can still identify the assumption that knowledge will automatically lead to action.

To sum up, the students in the study indicated that teacher-centred activities are still the order of the day in Maltese Integrated Science classrooms. In tandem, students thus believe that science education is mainly focused on the transmission of knowledge and less on skills and other competencies needed to engage with and act upon scientific issues. They are convinced that such attributes should be acquired through other school subjects. It is also significant to note that they would like to have more student-centred activities as these are considered to be more enjoyable and allow them to participate more fully in the learning process.

In general, as shown in **Table 4.14**, while students are strongly aware of the attributes needed to engage with and act upon personal and social scientific issues, there is need for more work in other areas of science awareness. In fact, students still have low level of awareness with respect to the extent they are able to recognise the relation of everyday personal and social decisions to science. There is a need to go beyond simply explaining the factual science content related to these issues in Integrated Science lessons. The repercussions of such issues or decisions beyond the self should be deliberately pointed out. Other competencies than knowledge are needed to tackle such issues, and students need to realise that these competencies are broad and go beyond subject boundaries.

**Table 0.14: Average means for the respective indicators and sub-indicators in the questionnaire used to gauge science awareness in this study**

| Indicator of science awareness | Average mean |
|---|---|
| Recognition of science in personal scientific issues | 2.48 |
| Recognition of science in social scientific issues | 2.51 |
| Recognition of science in global scientific issues | 2.76 |
| Acknowledgement of science-society association | 2.50 |
| Acknowledgement of competencies needed to deal with personal scientific issues | 3.10 |
| Acknowledgement of competencies needed to deal with social scientific issues | 2.93 |

The same applies to the students' level of recognition of the role of politics in scientific enterprise. They are only weakly aware of the impact that society has on progress of science and the uneven global distribution of scientific applications. This political aspect is missing from science lessons and the students' image of science and scientists is still very naive and very much based on what students observe in a school science lab. More effort has to be made with respect to this aspect so that students can have a more realistic image of science and the scientific enterprise.

## 4.3 Factors Affecting Science Awareness

The numerical data were analysed further to identify the main factors that have an effect on the level of science awareness amongst Form 2 students. The following sections provide a résumé of the main differences identified.

### 4.3.1 Gender Differences

The Mann-Whitney *U* test was performed on the questionnaire items included in Sections 1A-1F (featuring students' beliefs regarding science and science education) and Sections 2I and 2J (featuring students' attitudes/judgements towards science and science education) to analyse whether there are any gender differences in responses.

**Table 4.15** indicates the items for which a significant difference was identified together with the differences in mean scores across gender. Significant differences were found for 24 out of the 84 ($p < 0.05$) items analysed showing that gender differences in beliefs and attitudes are not highly pronounced. However, the significant discrepancies found are quite interesting. As shown by the positive mean differences in **Table 4.15**, boys seem to show more awareness of the 'hidden science' that threads through personal and social issues or Indicator 1 of science awareness such as *what car to buy* or *whether an area should be built or developed.* A negative mean difference was obtained only for the item *abortion* indicating that female students agreed more strongly that this issue is related to science.

**Table 0.15: Questionnaire items featuring significant gender differences based on the Mann-Whitney U test for Indicator 1 component *Awareness of the science component in personal, social and global issues***

| **Indicator 1: Awareness of the science component in personal, social and global issues** | **Mann-Whit. U test sig.** | **Mean (Boys)** | **Mean (Girls)** | **Mean difference (Boys-Girls)** |
|---|---|---|---|---|
| What type of car to buy | 0.005 | 1.93 | 1.62 | 0.311 |
| Whether to install a solar water heater | 0.003 | 2.93 | 2.67 | 0.266 |
| Whether an area should be built or developed | 0.000 | 2.22 | 1.86 | 0.361 |
| Where to set up wind farms to produce electricity from wind energy | 0.000 | 3.28 | 2.94 | 0.338 |
| The type of power station to install | 0.035 | 2.86 | 2.69 | 0.170 |
| The type of landfill to be built | 0.036 | 2.38 | 2.16 | 0.215 |
| The type of transport systems to introduce | 0.002 | 2.32 | 1.98 | 0.340 |
| Getting rid of nuclear waste | 0.019 | 2.92 | 2.70 | 0.223 |
| Abortion | 0.005 | 2.27 | 2.55 | **-0.275** |
| Exploration of space | 0.005 | 3.55 | 3.34 | 0.209 |

Boys also seem to have a more authentic awareness of the interplay that exists between science, technology and society which is another component of Indicator 1 of science awareness. As shown in **Table 4.16**, boys scored higher agreement with items such as *the latest scientific applications are more risky than ever before* and *what scientists research is determined by politicians and industrialists.*

**Table 0.16: Questionnaire items featuring significant gender differences based on the Mann-Whitney U test for Indicator 1 component *Acknowledgement of the science-society association***

| **Indicator 1: Acknowledgement of the science-society association** | **Mann-Whit. U test sig.** | **Mean (Boys)** | **Mean (Girls)** | **Mean Difference (B-G)** |
|---|---|---|---|---|
| The latest scientific applications are more risky than ever before | 0.000 | 2.89 | 2.57 | 0.313 |
| the effects of science applications are always known exactly | 0.035 | 2.39 | 2.24 | 0.150 |
| Scientists often disagree with each other | 0.008 | 2.72 | 2.48 | 0.235 |
| All scientists are responsible people | 0.012 | 3.29 | 3.09 | 0.208 |
| What scientists research is determined by politicians and industrialists | 0.004 | 2.16 | 1.90 | 0.254 |
| Only scientists can find solutions to scientific issues such as global warming | 0.005 | 2.50 | 2.23 | 0.266 |

As shown in **Table 4.17**, very few significant gender differences exist in relation to Indicator 2 of science awareness or the recognition of the attributes needed to engage with and act upon scientific issues. A significant difference was reported for only three items that featured this indicator showing that both girls and boys acknowledge the competencies required to engage with issues of a scientific/technological component to approximately the same extent.

**Table 0.17: Questionnaire items featuring significant gender differences based on the Mann-Whitney U test for Indicator 2.**

| **Indicator 2: Recognition of attributes needed to engage with and act upon scientific issues** | **Mann-Whit. U test sig** | **Mean (Boys)** | **Mean (Girls)** | **Mean Difference (B-G)** |
|---|---|---|---|---|
| Comparing and evaluation results obtained by different researchers | 0.042 | 3.01 | 3.17 | **-0.161** |
| Analysing why different researchers obtained different results | 0.017 | 2.85 | 3.06 | **-0.208** |
| Collect signatures for a petition and present it to the relevant authorities | 0.000 | 3.27 | 2.94 | 0.326 |

As to the general attitudes students have towards science and school science, given in **Table 4.18**, one can note that boys seem to judge science in society more negatively than girls, agreeing more strongly with *science is not useful for my everyday life* and *scientific discoveries do more harm than good* and *science has ruined the environment*. This might imply that the perceptions or stronger beliefs boys have about science in society are leading to these negative judgements about science. However, boys prefer school science more than girls with the latter agreeing more that school science is difficult. This might indicate that a higher level of science awareness as exhibited by the male gender may actually lead to more positive attitudes towards school science.

**Table 0.18: Questionnaire items featuring significant gender differences based on the Mann-Whitney U test for *General attitudes towards science and school science***

| **General Attitudes towards science** | **Mann-Whit. U test sig.** | **Mean (Boys)** | **Mean (Girls)** | **Mean Difference (B-G)** |
|---|---|---|---|---|
| Science is not useful in my everyday life | 0.023 | 2.01 | 1.79 | 0.223 |
| Scientific discoveries do more harm than good | 0.002 | 2.01 | 1.78 | 0.223 |
| Science has ruined the environment | 0.000 | 1.96 | 1.63 | 0.328 |
| | | | | |
| **General attitudes towards school science** | | | | |
| I like science better than most other subjects at school | 0.043 | 2.39 | 2.16 | 0.000 |
| School science is difficult | 0.018 | 2.21 | 2.46 | **-0.247** |

### 4.3.2 Schooling Factors

Significant differences in distributions for the responses to Sections 1A-F (featuring students' beliefs regarding science and science education) and Sections 2I and 2J (featuring students' attitudes/judgements towards science and science education) were also analysed for other factors apart from gender through the Kruskall-Wallis H-test. This test is similar to the Mann-Whitney U test but it can be used to compare scores in more than two groups. Those factors which were found to have a profound effect were all related to schooling and ranged from the type of school attended, number of science lessons at the end of primary schooling as well as the number of science subjects to be opted for in Form 3.

More than half the items were found to be significantly different for type of school making the type of school attended the strongest determinant of science awareness. For practical reasons, only those items with $p<0.01$ are listed in the tables that follow. Results show that students from Independent and Church Schools are in general more similar than students from State Schools. As shown in **Table 4.19**, the former two also tend to be more scientifically aware with reference to Indicator 1 of science awareness in that they agree more that science is related to the personal, social and global issues included in the questionnaire. They also tend to identify more the uncertainty and risk characterising contemporary science and the political milieu in which it is embedded.

The school type statistically significant differences in relation to Indicator 2 of this study were less clear cut as shown in **Table 4.20**. This is because, in general, it was already found that all students, irrespective of school type, show very high recognition of the attributes needed to engage with scientific issues and therefore differences according to school type do not follow any particular pattern. In addition, there seems to be a relation between these beliefs characterising science awareness and the judgements or attitudes towards science analysed in Sections 2I and 2J. As shown in **Table 4.21**, students from Church and Independent Schools, who have been found to be more scientifically aware, are also the ones who have the more positive attitudes towards science and school science. This tends to imply that by ameliorating science awareness one can actually help students have more positive attitudes towards science and science education.

**Table 0.19: Questionnaire items featuring significant school type differences based on the Kruskall-Wallis test for Indicator 1**

| Questionnaire items | Type of school Agree % (following recoding) | | | | Krus. Wall. (p<0.01) |
|---|---|---|---|---|---|
| | Area Secondary | Junior Lyceum | Church School | Independent School | |
| *Indicator 1: Awareness of the science component in personal, social and global issues.* | | | | | |
| Where to build a landfill | 21.7 | 29.1 | **52.2** | **42.8** | 0.000 |
| The type of landfill to build | 29.3 | 39.3 | **51.5** | **41.7** | 0.003 |
| Whether alcoholic drinks should be prohibited for young people | 41.3 | 33.5 | **57.3** | **51.3** | 0.001 |
| The type of transport systems to introduce | 23.3 | 31.8 | **46.0** | **48.6** | 0.002 |
| How to control the spread of infectious diseases | 69.6 | 81.3 | **91.2** | **97.3** | 0.000 |
| Whether to take the swine flu vaccine | 43.3 | 44.0 | **63.3** | **78.4** | 0.000 |
| Whether to breast-feed or bottle-feed a baby | 48.4 | 34.8 | **74.8** | **52.8** | 0.002 |
| Choosing between a number of treatments for a deadly disease such as cancer | 67.8 | 70.9 | **83.7** | **97.3** | 0.000 |
| What type of food to buy | 41.3 | **45.2** | **60.3** | 40.5 | 0.002 |
| Getting rid of nuclear waste | 58.0 | 59.6 | **76.1** | **94.5** | 0.000 |
| Air pollution | 83.0 | 65.2 | **83.1** | **83.8** | 0.002 |
| Abortion | 47.7 | 41.4 | **57.9** | **70.2** | 0.006 |
| Pandemics | 73.3 | 72.0 | **85.6** | **97.2** | 0.002 |
| Extinction of species | 57.9 | 66.9 | **82.7** | **91.7** | 0.000 |
| | | | | | |
| *Indicator 1: Awareness of the science-society association* | | | | | |
| The effects of science applications are always known exactly | **48.9** | **44.4** | 25.0 | 29.7 | 0.006 |
| The effects of science applications are safe | **24.7** | 9.0 | 11.0 | **16.2** | 0.003 |
| Scientists often disagree with each other | 46.1 | 52.6 | **67.4** | **62.2** | 0.003 |
| All scientists are responsible people | **85.6** | **86.7** | 84.6 | 43.2 | 0.000 |
| Only scientists can find solutions for scientific issues such as global warming | 45.5 | 59.1 | **35.8** | **21.6** | 0.003 |
| Science serves the rich at the expense of the poor | 24.2 | 24.8 | **40.5** | **27.8** | 0.001 |
| **Two highest %Agree values**/Two lowest % Agree values | | | | | |

**Table 0.20: Questionnaire items featuring significant school type differences based on the Kruskall Wallis test for Indicator 2.**

| Questionnaire items | Type of school Agree % (following recoding) | | | | Krus. Wall. (p<0.01) |
|---|---|---|---|---|---|
| | **Area Secondary** | **Junior Lyceum** | **Church School** | **Independent School** | |
| *Indicator 2: Recognition of the attributes needed to engage with scientific issues.* | | | | | |
| Accept such a decision as good and final as it was taken by experts | **38.2** | 27.6 | 16.5 | **43.2** | 0.000 |
| Take part in demonstrations to stop the project | 52.2 | 69.6 | **83.8** | **75.0** | 0.000 |
| Collect signatures for a petition and present it to the relevant authorities | 70.8 | **80.7** | **82.7** | 64.9 | 0.004 |

**Two highest %Agree values**/Two lowest % Agree values

**Table 0.21: Table showing questionnaire items featuring significant school type differences based on the Kruskall Wallis test for *General attitudes towards science and school science*.**

| Questionnaire items | Type of school Agree % (following recoding) | | | | Krus. Wall. (p<0.01) |
|---|---|---|---|---|---|
| | **Area Secondary** | **Junior Lyceum** | **Church School** | **Independent School** | |
| *General attitudes to science and school science* | | | | | |
| Science is important for society | 72.8 | 80.7 | **88.2** | **91.9** | 0.003 |
| Science makes our lives easier and more comfortable | 71.4 | 73.3 | **86.0** | **89.2** | 0.001 |
| I will use science in many ways when I am an adult | 62.6 | 59.1 | **78.5** | **81.1** | 0.001 |
| Science is very important for a country's development | 72.2 | 70.4 | **84.6** | **83.8** | 0.005 |
| School science is boring | **38.5** | **51.9** | 13.3 | 24.3 | 0.000 |
| We do too much science at school | **57.6** | **48.9** | 18.4 | 24.3 | 0.000 |
| I look forward to my science lessons | 37.0 | 37.3 | **56.6** | **63.9** | 0.000 |
| I would like to do more science at school | 32.6 | 31.9 | **51.1** | **43.2** | 0.001 |
| I like school science better than most other subjects | 28.3 | 34.1 | **62.5** | **43.2** | 0.000 |
| School science is difficult | **44.6** | **54.3** | 22.1 | 21.6 | 0.000 |

**Two highest %Agree values**/Two lowest % Agree values

Even the focus group transcripts have shown that students from Independent and Church Schools tend to be more scientifically aware. They do acknowledge more the two-way interaction between science and society or the political side of science. Due to their social background they also have more opportunities to engage with science such as in science museums abroad. They are also the ones who take part in conversations about science with people other than family and peers. Such socio-economic differences were also recorded for the TIMSS and PISA international surveys carried out in Malta in 2015 (MEE, 2016a; MEE, 2016b).

Although having a less pronounced effect, the number of lessons in primary schooling of the students also seems to be an important variable as shown in **Table 4.22** respectively. In general, the more the students are exposed to science during the early years, the better their science awareness and the more positive attitudes they have about science and science education.

**Table 0.22: Questionnaire items featuring significant differences based on the Kruskall Wallis test for the number of science lessons in the last year of primary schooling**

| **Questionnaire items** | **Number of science lessons % Agree (following recoding)** | | **Krus. Wall (p<0.05)** |
|---|---|---|---|
| | **No science lessons** | **more than one per week** | |
| *Indicator 1: Awareness of the science component in personal, social and global issues* | | | |
| Whether alcoholic drinks should be prohibited for young people | 50.0 | **59.3** | 0.000 |
| Whether to take the swine flu vaccine | 42.7 | **62.2** | 0.010 |
| Whether to breast-feed or bottle-feed a baby | 39.3 | **57.3** | 0.015 |
| Whether to install a solar water heater | 66.7 | **78.0** | 0.042 |
| Where to build a landfill | 42.2 | **43.8** | 0.018 |
| Getting rid of nuclear waste | 62.2 | **80.7** | 0.037 |
| Abortion | 54.0 | **61.4** | 0.014 |
| Population control | 27.8 | **23.3** | 0.024 |
| | | | |
| *Indicator 1: Awareness of the science-society association* | | | |
| The latest scientific applications are more risky than ever before | **88.0** | 71.4 | 0.006 |
| The effects of science applications are always safe | 14.4 | **16.5** | 0.008 |
| All scientists are responsible people | **87.8** | 66.7 | 0.001 |
| | | | |
| *Indicator 2: Recognition of Attributes* | | | |
| Comparing and evaluating results obtained by different researchers | 86.7 | **89.9** | 0.019 |
| Being able to listen to the views of others | **87.8** | 81.1 | 0.023 |
| | | | |
| *General Attitudes towards Science and School Science* | | | |
| Science is important for society | 76.7 | **92.3** | 0.001 |
| I will use science in many ways when I am an adult | 53.4 | **83.3** | 0.000 |
| School science is boring | **41.6** | 20.9 | 0.008 |
| I look forward to my science lessons | 32.2 | **65.6** | 0.000 |
| I would like to do more science at school | 33.7 | **57.1** | 0.000 |
| I like school science better than most other subjects | 38.9 | **56.0** | 0.000 |
| School science is difficult | **51.7** | 20.9 | 0.000 |
| | | | |

**Highest %Agree value**/Lowest % Agree value

### 4.3.3 Future Science Specialisation

At Form 2, students in Malta are expected to choose whether to continue studying one, two or three science subjects. The student responses were thus analysed for differences according to the students' intention to take up science specialisation (2 or 3 science subjects) or not. **Table 4.23** shows that students who intend to opt to study more than one science subject are also more scientifically aware and portray more positive views of science and science education. This finding is important because it implies that if efforts are made to increase science awareness as featured in this study, students' attitudes towards school science may become more positive and there would be a higher probability that more of them will opt to specialise further in science.

One can also note that for these two factors significant differences were found for the majority of attitude statements in Sections 2I and 2J while the discrepancy in science awareness seems to be less. This might imply that factors other than science awareness may play a part in the formation of attitudes. This is also important as it is proof that science awareness and attitudes towards science are in fact related but different concepts.

## 4.4 Students' Views about Science Learning Activities for Scientific Literacy and for Citizenship

Since this study was not restricted to measuring, but also to raise science awareness in the quest of achieving scientific literacy and science for literacy, during the focus groups, the students were asked to state their opinions about learning activities that go beyond transmitting scientific information to preparing students to engage in and act upon scientific issues. Such activities were discussed in **Section 2.2.2** of the literature review.

In general, students liked the idea of having a debate on a particular issue as part of their science lessons. They stated that it would be more fun and appealing compared to a traditional science lesson based on listening to the teacher and copying down notes.

**Table 0.23: Questionnaire items featuring significant differences based on the Kruskall Wallis test for the number of science subjects students plan to study in Form 3 (Year 9)**

| Questionnaire items | Number of science subjects to be chosen Agree % (following recoding) | | | Krusk. Wal. (p<0.05) |
|---|---|---|---|---|
| | 1 | 2 | 3 | |
| *Awareness of the science component in personal, social and global issues* | | | | |
| Whether to take the swine flu vaccine | 45.9 | 70.0 | **71.0** | 0.000 |
| Choosing between a number of treatments for a deadly disease such as cancer | 71.2 | 86.7 | **90.0** | 0.000 |
| What type of food to buy | 45.9 | **60.0** | 52.9 | 0.000 |
| Whether alcoholic drinks should be prohibited for young people | 39.9 | 52.2 | **58.6** | 0.015 |
| How to control the spread of infectious diseases | 79.8 | 86.7 | **95.7** | 0.002 |
| Getting rid of nuclear waste | 65.7 | 71.9 | **78.8** | 0.022 |
| Competition between food and fuel production | 41.9 | **63.2** | 52.3 | 0.035 |
| Abortion | 45.3 | 53.3 | **72.1** | 0.002 |
| Pandemics | 76.1 | 75.9 | **94.0** | 0.00 |
| Extinction of species | 68.4 | 84.8 | **88.1** | 0.007 |
| Ecological balance | 57.9 | 69.2 | **78.9** | 0.007 |
| | | | | |
| *Acknowledgement of the science-society association* | | | | |
| All scientists are responsible people | **88.0** | 66.1 | 71.4 | 0.002 |
| Scientists often need to work with other experts | **73.9** | 70.2 | 91.2 | 0.004 |
| | | | | |
| *General Attitudes towards science and school science* | | | | |
| Science is important for society | 79.9 | 83.3 | **92.9** | 0.000 |
| Science makes our lives easier and more comfortable | 74.5 | 81.7 | **92.9** | 0.000 |
| I will use science in many ways when I am an adult | 61.0 | 70.0 | **90.9** | 0.000 |
| Science is not useful in my everyday life | **26.7** | 21.7 | 11.4 | 0.000 |
| Science is very important for a country's development | 72.6 | 80.0 | **90.0** | 0.002 |
| School science is boring | **43.1** | 21.7 | 5.7 | 0.000 |
| We do too much science at school | **44.6** | 27.1 | 24.3 | 0.000 |
| I look forward to my science lessons | 32.7 | 60.0 | **85.7** | 0.000 |
| I would like to do more science at school | 29.9 | 42.4 | **74.3** | 0.000 |
| I like school science better than most other subjects | 29.1 | 53.3 | **88.6** | 0.000 |
| School science is difficult | **45.3** | 35.0 | 12.9 | 0.000 |
| | | | | |

**Highest %Agree value**/Lowest % Agree value

"Definitely, for me as an example I would be more involved and take more interest in it. I mean most of the time we look at the board, seeing what she's writing; copying down notes, reading from the book...I mean it gets boring after a while." (Girl, Independent School).

*"Ikollok l-opportunita` li tgħid dak li tħoss. Per eżempju, waqt il-lesson jekk titkellem qisu qed tagħmel xi ħaġa ħażina. Jekk ikollok dibattitu, qisu jkollok permess li tgħid dik il-ħaġa."*

"You would have the opportunity to state what you feel. For example, if you talk during the lesson, it's as if you did something wrong. If you have a debate, it's like getting permission to say that thing."
(Boy, State School, High achiever)

A debate was described as something which is "hands-on but not so hands-on" which will enhance their interest, understanding and engagement.

"A few years ago we had a debate, I still remember it.....it really helped me." (Boy, Independent School)

*"Tieħu l-opinjoni ta' xulxin, għalhekk tajjeb"*

"Sharing of opinions, that it why it is worthy."
(Boy, State School, Low achiever)

"I think that discussing other people's opinions is very important because it would be more fun and you understand more" (Girl, Independent School)

Some students mentioned that they prefer not to have an expert in class during such debates as the experts may be too patronising such that students' opinions may be mellowed. This concern is exemplified below:

"....because the teacher and the expert will go on and on and no one will understand" (Girl, Independent School)

*"Għax jekk per eżempju tkun tħoss xi ħaġa u ma tkunx taqbel ma' dak it-tabib, per eżempju, forsi tiddejjaq tgħidha minnħabba fih."*

"Because if for example you feel you do not agree with that doctor for example, maybe you would be too shy to say it because of him." (Boy, State School, High achiever)

Some students may even be too shy to speak. They believe that students should be given space to state their opinions because one does not have to be an expert to do so. They are also aware that what the experts say might not be always right. Others, on the other hand, regarded experts in such debates as essential as they may come up with important information that may change the course of the discussion. A student looks at experts as being more knowledgeable in that particular subject even than the teacher himself or herself and thus may aid to prevent the formation of misconceptions.

*"Jekk aħna nkun qegħdin nargumentaw xi ħaġa u forsi għidna xi ħaġa ħażina, forsi jkun hemm xi ħadd aqwa mit-teacher, xi ħadd li jifhem aħjar f'dak is-suġġett, ħalli la nikbru mhux naqbdu u nfattru....le le dak ħażin u fil-fatt ikun tajjeb."*

"If we are arguing and maybe we said something wrong, maybe there would be someone even better than the teacher, somebody who is an expert in the area, so that when we grow up we don't just mess it up...we say that something is wrong when in fact it would have been right" (Boy, State School, High Achiever)

The students interviewed, in general, envisage science projects in the community as being cool, interesting, relevant, highly applied, and thus provide better understanding of scientific concepts. They even compared this to traditional activities that characterise school science as shown below:

*"L-affarijiet li fil-klassi nitgħallmu bit-tejorija, hekk ħa npoġġuhom fil-prattika u jien nemmen li meta l-affarijiet tarahom isiru fil-prattika iktar jidħlu go moħħok.*"

"The things we cover in class through theory, we would be practising and I believe that when you see things being done, you learn more." (Girl, State school, High Achiever)

"I think it would be really fun and interesting because it's like better to have a hands-on practical job rather than always reading from the book and learning theory because you can show what you know and express ideas." (Boy, Independent School)

Such activities would allow them to follow first-hand the role of several persons in the community in the execution of such projects. In addition, it would be giving them a chance to get out of the school environment and to build a legacy that they might look back on with pride later on in life. The students feel that even children should have their say in such community projects. As in the case of debates, it was pointed out that some students may be too shy to participate or may actually be distracted by such projects. They might feel more comfortable with a traditional science lesson. Boys from Independent Schools are quite sceptical about the extent that students may actually influence projects in the community.

While personal narrations regarding health also had positive feedback as they might be personally relevant, the use of media analysis during a science lesson got some mixed reactions as some students voiced their concern that such discussions may be too political for a science lesson and may lead to fights rather than to actual argumentation.

"I think like it would be a good idea and it would be fun but it can be a bit dangerous as some people might get into fights... like they disagree completely." (Girl, Independent School)

Through some comments one can also identify the fear of going beyond the boundaries of a subject such that students lose on important factual information.

*"Ma naqbilx għax jekk tibda titkellem fuq qisu politika, hemm ċertu nies li qisu se jinteressahom imma fl-istess ħin ikun hemm ċerta nies li jaqbżulek fuq affarijiet oħra milli fuq dak li qed titkellem fuqu....ittellef il-lezzjoni, ittellef il-lezzjoni minn dak is-suġġett bażiku li tkun qed tagħmel."*

"I don't agree because if you start talking politics, then there are some people who would be interested but then there are others who go out of point....it distracts the lesson from the subject being covered." (Girl, State School, High Achiever).

Some students also suggested that such activities may be more appropriate for a Social Studies lesson.

*"Jien ma tantx naqbel magħha għax qisha mhux science."*

"I don't really agree because it is not science" (Girl, State School, Low Achiever).

Others are in favour of the inclusion of analysis of media as shown by the quotes below. It is different from a traditional lesson and helps in the formation of skills as in learning to agree or disagree with each other. It will also provide an outlet for the students to voice the opinions they have formed whilst interacting with the media.

"I think it is a very important task as we all have to learn how to agree and disagree with other people and everyone shares their opinion and it's a fun way to learn and you can remember more this way." (Girl, Independent School)

*"L-istudenti jkunu qed jagħmlu xi ħaġa differenti milli jagħmlu s-soltu. Mhux just kemm tisma', tagħmel il-homework...imma tkun tip ta' lesson differenti li tgħinek tiddiskuti aktar."*

"The students would be doing something different than usual. Not just listening and doing homework...but it is a different type of lesson that helps you discuss more." (Girl, Church School)

At the end of the discussion, the students were allowed to give some general comments regarding the topics that had been just tackled during the focus group session. Most stated that they were not aware of the strong links that science has to everyday life and especially to politics. This underlines the importance and relevance of science. The learning activities proposed also struck the students, e.g., debates, projects in the community, etc., as they never thought that these could be part of a science lesson.

"I think that something that struck me was that science plays an even bigger role in our lives than the average person thinks...." (Boy, Church School)

*"Dawn l-attivitajiet li jista' jkollna. Għax qatt m'għaddieli mill-kurituri ta' moħħi li nistgħu nagħmlu dawn l-affarijiet. Din kienet l-ewwel darba li qed nismagħhom. Għoġbuni jiġifieri."*

"These activities we can have. Because it never occurred to me that we could do these things. It is the first time I heard of them. That is I liked them." (Boy, State School, High Achiever)

*"Rajna dawn l-ideat kollha tat-tagħlim. Aħna s-soltu inkunu fil-lab tipo. Int urejtna modi kif nistgħu nieħdu gost fis-science stess."*

"We looked at all these teaching methods. We are usually in the lab. You showed us how we can have fun during science itself." (Girl, Church School)

The students' comments above are actually proof that even through a half-hour focus group discussion there was a hint to an increase in science awareness as it is being featured in this study let alone if science activities in classrooms are specifically geared at such a target.

## 4.5 Discussion – Phase 1

In this first phase of the research, mixed methodology was employed in order to gauge the level of science awareness of Form 2 students in Malta. A sample from the whole population was investigated so that the results could be generalised. Overall, there were three important outcomes from the first phase of this study that called furthermore for the need to develop and pilot a number of school-based learning activities that could specifically target this aspect.

Firstly, students demonstrated a limited level of **science awareness with respect to several indicators used to gauge science awareness among this age group.** As responses obtained in this study show, students still tend to fail to recognise the impact that science has on their personal and social lives. They identify the science in an issue when it refers to well established scientific content usually tackled in one of the school science topics, e.g. (air pollution, exploration of space). However, when the issue becomes more complex and when decisions related to it can be based on other factors such as economic (e.g. what type of car or food to buy) or political (e.g. the laws to control the hunting of birds), then they fail to recognise and acknowledge that such decisions may have more positive, immediate, and wider consequences if they are also based on science and its findings.

While both qualitative and quantitative results collected through the first phase of this study have shown that early secondary students are well aware of the skills and attitudes needed when facing such personal and social scientific issues, they also show that students do not tend to acknowledge science education as the route to the development of such competencies. They see the function of science education as something personal, restricted to giving them knowledge and skills generally to understand the world and helping them in their future careers. They don't recognise science education as a tool that will help them to express opinions, listen to others, develop values and be able to take some form of action in a collective effort to ensure sustainability of our planet (Hodson, 2003). Since individualistic interests are usually stronger than collective interests when choosing a career (Cassar, 2010), students tend to disengage with science once they realise that it is not relevant to their career pathway.

These findings also shed light on the poor results obtained by Form 5 (age 15-16) Maltese students in PISA tests (MEE, 2016a ; OECD, 2006). Here, students are tested on the ability to engage and understand issues of a science component. This study has shown that sometimes students do not even recognise that some of these issues that are relevant to their everyday life are related to science, thus not being able to transfer their scientific knowledge and skills to address these scenarios.

**Secondly, students' beliefs have been found to be so much embedded in school science that it follows naturally to use science lessons as the main route to address the shortcomings in science awareness.** In fact, as reported earlier in the focus group discussions, the students' participation in out-of -school activities related to science in Malta is minimal not only because of lack of enthusiasm but also because of lack of and ignorance of the organisation of such activities. Most of the time their conversations about science are restricted to their families and friends, and focus on what happened at school during the science lessons. Only students who report high levels of science awareness engage in conversations and participate in activities about science beyond the circle of school, family and friends, e.g. with people at stands when they visit a science fair.

Also, the cohort studied could recognise elements of the science-society association only if it featured somewhere in their school science. Results show that students identify issues as being related to science when they include elements they covered through the school syllabus. They are quite aware of the uncertainty of scientific results as it's usually implicated when they are engaged in experiments. However, they do not acknowledge the effect that society can have on researchers and in the resolution of scientific issues because this aspect is seldom tackled in science classrooms.

As shown by other studies (Osborne *et al*., 2003), students' beliefs and attitudes are clearly influenced by the pedagogies used in science classrooms. In this study, students have very positive attitudes towards science and scientists in general. They tend to agree much more with the positive impact of science than the negative repercussions that it may have on humanity and the environment. Hence, they seldom question science and scientists. Generally, they also agree that all scientists are responsible people. The most frequent pedagogical tools they experience, such as listening to the teacher and reading and writing notes, are heavily teacher-based, and strongly convey the image that science represents the Truth that has to be transmitted from scientists, through teachers to the students. Fieldwork and projects embedded within the community that may convey a more humanistic view of science are, in fact, rarely used. This is a missed opportunity since during the focus group students rated such activities organised in summer schools or school extracurricular activities as more interesting as they are more hands-on and they allow more active participation. Students are also more attracted to more interdisciplinary topics. In fact, during the focus groups, the topic Forensic Science was repeatedly identified as the students' favourite as it goes beyond traditional subject-specific science content.

This study has shown that beliefs about science are related to the beliefs about science education that are in line with the pedagogical tools being used. If we use pedagogies that help students come to recognise how science education can also help them develop their values, their attitudes and skills to be able to tackle personal, social and global scientific issues, then their perceptions of the contribution of science education can change. Hopefully, students' beliefs about science will also transform and they would see the interplay that exists between science, technology and society more clearly.

There was quite a positive response when students were asked about pedagogies commonly used in Science, Technology and Society, STS, and Science, Technology, Society and Environment, STSE, educational approaches, such as media analysis (Hodson, 2010), argumentation (Driver *et al*., 1996; Millar & Osborne, 1998), community work (Roth & Lee, 2004), etc. They are interested in debates as they seem to be hands-on but not so hands-on. Experts may be more knowledgeable than the teacher in certain areas and thus may avoid build-up of misconceptions. Field or community work is considered to be more relevant and applied, and gives them a chance to get out-of-school. Media analysis will also help in the formation of skills such as learning to agree or disagree with each other. They will also provide an outlet for the students to voice the opinions they have formed whilst interacting with the media. However, one should note that students remain quite sceptical about these approaches with their main concerns being whether all students are comfortable with such methods, and the issue of whether such approaches should, in fact be part of a science lesson especially when this means less time for the traditional transmission of science facts.

The third point is that ***there also seems to be a relationship between a high level of science awareness and positive attitudes to science.*** Students coming from Church and Independent Schools, who were reported as the highest scorers of science awareness in this research, were also the ones who have the most positive attitudes towards science and science education. Even students who will choose to study the three science subjects tend to have a higher level of science awareness and correspondingly more positive attitudes towards science and science education. Tackling science awareness may thus also improve the chance that students will have more favourable attitudes or judgements about science and the way it is portrayed in schools. Although not the direct objective of this study, focusing on science awareness may also result in more students opting for science at Form 2.

## 4.6 Conclusion – Phase 1:

The results of Phase 1 of this study, aimed at measuring science awareness have shown that there is still much to be desired regarding the achievement of this educational outcome amongst Form 2 students. In addition, a recurring finding is that school science has a very important effect on the development of students' beliefs about the importance of science and science education in their everyday lives. Analysis of the results for this phase of this study has also indicated the type of learning activities that students prefer. These outcomes, together with the theoretical perspectives from the literature review, provided a good starting baseline to plan a number of learning activities based on school science that were piloted to raise science awareness of this age group.

The development and piloting of the learning activities that were used to raise science awareness amongst Form 2 students constituted the second and final phase of this study which will be discussed in the next chapter.

# Chapter 5. METHODOLOGY – PHASE 2 – RAISING SCIENCE AWARENESS

Phase 1 of this study has indicated that several aspects of the educational objective of science awareness are still lacking amongst Form 2 (Year 8) Maltese students. This is worrying when one considers science awareness to influence beliefs that determine motivation for further engagement in science. Students struggle to recognise the impact of science on their everyday lives especially in areas that go beyond personal, health issues. They find it difficult to recognise the importance of science education beyond the transmission of knowledge and scientific skills. They have little awareness of how science education can promote the development of skills and other attributes much needed to act upon scientific issues as citizens. These attributes are considered to be developed as outcomes of other school subjects rather than of science, probably due to the transmissive teacher-centred pedagogies still heavily used in science classrooms as has been reported in the previous chapter. Additionally, because students are restricted in their participation in the learning process, they have come to accept the scientific enterprise as it is presented in classrooms. In schools, science is usually portrayed as an isolated entity, endowing society with its applications. The political implications that encompass it are left hidden and rarely tackled.

Based on these insights about science awareness concluded from the first phase, as well as from literature, this second phase of the research involved the development of a number of learning activities, mainly focusing on metacognitive reflection, that were developed and trialled to study if it is possible to increase the students' level of science awareness. The pedagogical framework and the methodology used to this effect are described in the sections below.

## 5.1 Pedagogical framework

This section deals with the philosophical reflections, teaching preferences and learning values that informed and motivated the researcher while designing the set of learning activities aimed at raising science awareness.

### 5.1.1 Philosophical considerations

The reasons why science awareness should be tackled through school science are several. Some have been derived from literature but several have been elicited from the results obtained during Phase 1 of this study during which science awareness of Form 2 Maltese students was gauged. These motives will be discussed in more detail below.

Engaging with and acting upon personal, social and global scientific issues entails higher order attributes that can only be achieved sequentially (Hodson, 1994, 2003; Sperling & Bencze, 2010). The thorough literature reviewed to structure the conceptual framework of this research has shown that science awareness is necessary as a foundation to the development of competencies usually associated with scientific literacy and science for citizenship. The first step in engagement with scientific issues is that of recognising the existence of such issues and of the importance of science education in the development of the knowledge, skills and attitudes necessary to handle them.

These activities in science awareness are targeted at helping students appreciate more an *education through science* versus *science through education* (Holbrook & Rannikmae, 2007). When education is the ultimate aim, science is not an end but a means through which students achieve knowledge, skills, attitudes, etc., needed for functionality in scientific issues. Raising science awareness thus implies helping students become more cognizant of the knowledge, skills, and attitudes they need to develop to be able to act upon personal, social and global scientific issues.

A deliberate focus on science awareness through school science is also necessary since students should be made explicitly aware of what educators are attempting to convey (Wellington, 2001). If the underlying philosophy of the National Curriculum Framework, NCF (MEE, 2012) is to ensure that learning will serve as a means towards personal growth, social justice and active citizenship, then the students should be made explicitly aware of this philosophy. Science awareness has been frequently portrayed as a phenomenon that can be addressed more effectively through out-of-school activities, such as science fairs, museums, etc., as opposed to schools, and for too many years, has been left up to chance. However, this study has shown that the responsibility for students' development of science awareness, especially for those coming from the less endowed social backgrounds, is heavily dependent on school science. The Form 2 curriculum-based learning activities that were planned for Phase 2 of this research target science awareness specifically, such that students further recognise: the roles of science in issues that may seem at face value unrelated to science; that one needs other attributes than just knowledge to be able to engage with scientific issues; and that science education is essential to achieve these competencies.

If science awareness is to be a matter of chance, then formal science education would be resisting the ideals of participation and democracy (Carter, 2010; Tobin, 2011). On the other hand, if science awareness is deliberately tackled by all students in schools, then school science would help to overcome this 'resistance' and make a planned move towards equality. The first phase of this study has shown that students from Independent and Church Schools tend to come from richer family backgrounds providing them with more opportunities to develop their awareness of the relevance of science and of their science education beyond the acquisition of individual excellence and the attainment of a career in science. Although opportunities to develop science awareness seem to be available for all students, in reality few students have the right out-of-school settings to ensure adequate science awareness.

### 5.1.2 Pedagogical outline

In this research, science awareness is tackled from a psychological perspective of attentive recognition of how science has an effect on our lives and how science education helps us gain the necessary attributes to become more active in facing scientific issues. Reaching this state of being aware of one's awareness, of meta-awareness, involves the development of a number of beliefs and perceptions that are cognitive in nature. A desired level of meta-awareness can thus be developed through a process of thinking about one's own cognition, or in more technical terms through a pedagogy of metacognitive reflection.

The pedagogical framework utilising metacognition to raise science awareness, was based on a more basic version (**Figure 5.1**) of the model of scientific literacy for the 21st century developed by Choi *et al*. (2011). In this model of scientific literacy, a *metacognition and self-direction* dimension is included and is considered to be the driving force in the development of the other four components of scientific literacy (*content knowledge, habits of mind, character and values, science as a human endeavour*). According to the conceptual framework that guides this research, science awareness does not involve achievement but merely awareness of one's own awareness of scientific issues, of the specific cognitive and other demands needed to tackle such issues and of science education as an important pathway in this achievement. In accordance, the four components of scientific literacy of Choi's model illustrated on p.60 were replaced with the equivalent indicators of science awareness. This still allows *self-direction* as the development of the associated components of science awareness will lead students to decide whether they need to give more importance to their science education to be able to develop competences needed to tackle scientific issues they encounter in their lives.

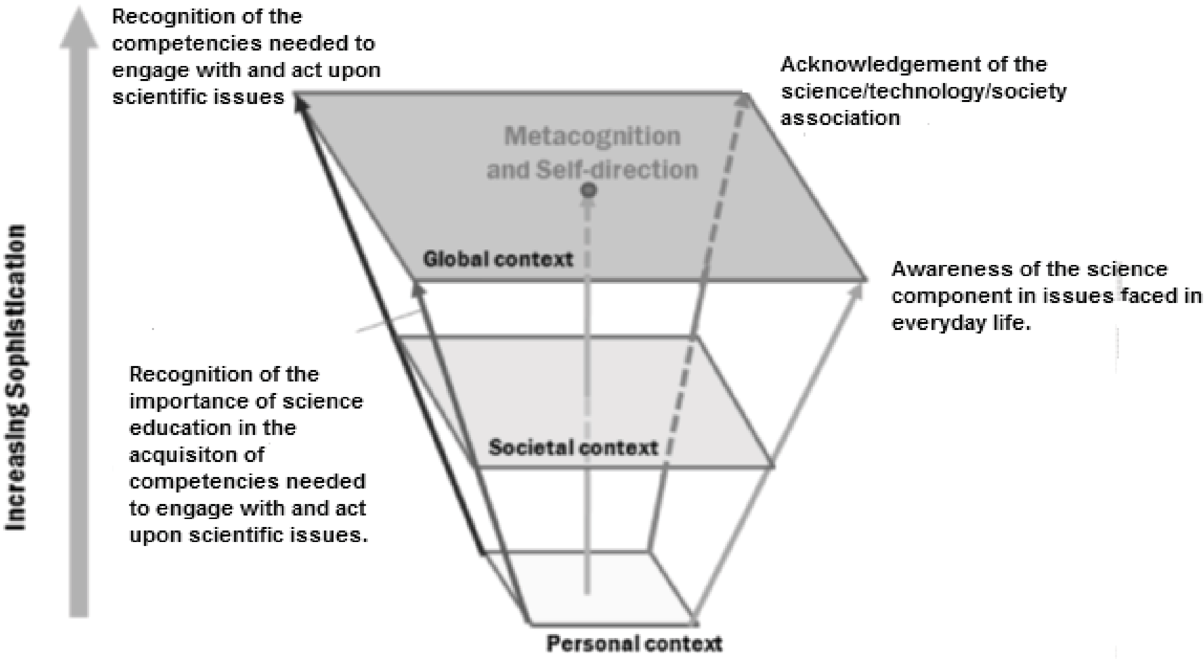


**Figure 0.7: A framework for science awareness based on that for scientific literacy developed by Choi *et al.* (2011). The student engagement in the personal, social and global context were retained as was the dimension of metacognition and self-direction. The dimensions of scientific literacy in the original model were replaced with the components of science awareness as developed in this study.**

The 'meta' approach used in this research is thus not a full blown metacognition as the students are not asked to think about their understanding of concepts or higher-order cognitive processes, but rather, to reflect on their level of awareness or beliefs regarding their learning context.

Metacognitive reflection was the main component of the learning activities used to promote science awareness. These exercises in metacognitive reflection are aimed at helping students think about their recognition and their appreciation of science in their everyday lives. They also make students think about their awareness of the importance of science education beyond the attainment of a science career. Psychological theories relate beliefs to the formation of attitudes and desired behaviours (Ajzen, 1985; Fishbein, 1963). It is important to highlight that the resulting state of science awareness is not the ultimate outcome of science education of the general student. These learning activities are rather the first step in the attainment of scientific literacy and science for citizenship, which the students will hopefully be able to achieve through more advanced learning as part of their science education.

Studies tackling the use of metacognition in science education vary quite distinctly. To better specify the use of metacognition in this research, the pilot study featured in Phase 2 of this research is here described in terms of the list of categories that Zohar & Barzilai (2013) created in their review of metacognition in science education. One of the categories developed was *focus on metacognition* based on the importance assigned to metacognition during the study. In this research, metacognition is *marginal* as it does not feature in the research question but is an important aspect of learning and instruction in relation to the key construct of science awareness. The use of metacognition in science education studies can also vary according to the *scientific context* in which it is embedded. The scientific context of this research is *general science* as there was no relation to specific scientific disciplines or subject topics. It is also an *empirical* study as it included data collection and analysis.

Metacognition had several purposes. It served as an *input* as it was part of the instructional practice used in the design of the learning activities. However, it was also an *outcome* as it could be seen and measured following piloting of the activities.

As to the category of *metacognitive instruction* (Zohar & Brasilai, 2013), the practices used in this study were the following. These were chosen in the light of their use in science education.

- *Metacognitive prompts* – these were in the form of written questions, cues (e.g. case studies, handouts), checklists or probes introduced by the teacher. Metacognitive prompts are the most common metacognitive instructional practices used in science learning (*ibid*.). They act as reminders so that students activate their metacognitive skills during science learning. Experimental studies (Conner, 2007; Peters & Kitsantas, 2010) have shown that students tend to become more metacognitively aware in relation to the nature of science, their scientific thinking, content knowledge and their self-regulatory efficacy when they are given prompts. Prompts also serve as standards with which students can compare their thinking.
- *Metacognitive discussions* – These discussions were either teacher or student-led. In the former, the teacher/researcher talked with the students to help them think about their science awareness aspect in relation to an activity. The latter were managed by the learners themselves in small groups. This was done in planned semi-structured ways that were intended to facilitate thinking about different aspects of science awareness. Studies in the use of metacognitive discussions in science learning have

shown that such collaborative learning should be scaffolded (Anderson, Nashon & Thomas, 2009; Conner, 2007; Shamir, Zion & Spektor-Levi, 2008) . In this study, scaffolding was employed as cues and prompts, presentations of scenarios, case studies, assignment of student roles, etc.

Research has shown that cognitive conflict can be facilitated by peer interaction (Palincsar & Brown, 1984; Piaget, 1985). As learners interact and encounter different perspectives of others, they may try to revisit their original understanding. Once learners identify gaps in their beliefs or knowledge they actively may seek new information to fill these gaps. Verbal interactions are considered to be the most useful means for the construction of knowledge (Palincsar, 1986; Palincsar & Brown, 1989; Webb, 1989). In classrooms, one of the most widely used tools of verbal interaction is discussion (Palincsar, 1998) "where members join together in addressing a question of common concern, exchanging and examining different views to form their answer, enhancing their knowledge or understanding, their appreciation or judgement, their decision, resolution or action over the matter at issue" (Dillon, 1994, p.8)

- *Metacognitive writing* – writing of 'journals', in which the students had to write short reflections in response to a number of written cues given by the teacher at the end of each activity. Reflection can be used to promote deep, lasting learning (Suskie, 2009), and it can also be used to assess whether a particular program helped the students to reach certain outcomes. Use of reflective writing to foster the learner's metacognition is the second most used metacognitive practice practiced in science learning (Zohar & Brasilai, 2013). In this study, this was limited to written responses to reflective questions as the students were considered to be too young and not trained enough to write reflective essays. Although the term 'journal' was used in this study, this was the name assigned to the copybook in which the students wrote the answers to the reflective prompts provided by the teacher. It was not used to denote an accumulation of dated extensive reflections as in other metacognitives studies in science education (Kipnis & Hofstein, 2008).

The philosophical elements discussed above were transformed concretely into a number of learning activities as will be described in the next section.

## 5.2 Key practical features of the designed learning activities

The concrete process used to plan and assess the learning activities is described in the section below. Mainly it involved the following steps: choice of the scientific issue to be tackled; specification of the learning intentions to be addressed in terms of the concept of science awareness developed in this research; and planning of the learning activity itself and the assessment method based on the pedagogical framework discussed in the section above.

### 5.2.1 Choice of theme/issue

One of the aims of this research was to investigate whether science awareness can be raised through school science. In addition, Phase 1 of this study has shown that school science is crucial in the development of science awareness. Thus, although the array of scientific issues that one can tackle during science lessons is endless, it was decided to choose those that could be easily integrated or which already formed part of the science curriculum of Form 2 students. Areas that were identified, including the ones that were tackled are listed in **Table 5.1**:

**Table 0.24: Areas included in the Form 2 Integrated Science Syllabus (DQSE, 2014) that can be used to tackle science awareness. Issues tackled and the titles of the actual activities planned are listed in BOLD.**

| **Topic** | **Areas that can be used to tackle Science Awareness** | **Title of activity planned** |
|---|---|---|
| Healthy Living I and II | The benefits and dangers of following certain diets (p.5)<br>Misleading food labels and consumer rights (p.5)<br>**The effect of smoking on the lungs** (p.7)<br>Raising awareness about renal problems (or disease) (p.15)<br>The role of vaccines against disease (p.18) | **Raising Awareness against Smoking** |
| Elements, Compounds and Mixtures I<br>Elements, Compounds and Mixtures II | The history of Dalton and Mendeleev who created the first Periodic Table (p.26)<br>**Naturally occurring elements (their extraction)** | **The Story of Diamonds in Botswana: Diamond Hopes and Diamond Blues** |

| | | |
|---|---|---|
| Separating Techniques | | |
| Light and Sound | Ask students to think what it would be like to be completely blind. Link to PSCD to create awareness re problems faced by these people (p.48)<br>**Hearing difficulties** (p.51) | **Are Cochlear Implants the solution to Deafness?** |
| Forensic Science | **The work of forensic scientists** (p.57) | **The Image of Scientists** |
| Climate Change I and II | The link between burning of fossil fuels and environmental issues (p.65)<br>The link between the burning of fossil fuels and health issues (p.66)<br>The lifestyles in 1st world countries and their environmental implications (p.67)<br>The issue of sustainable living (p.67)<br>The cost of renewable energy sources (p.68)<br>The success of waste management depends on legislations and initiatives taken on a national level and on the cooperation of each citizen (p.75)<br>Over-extraction of water from the water table and sustainable use of water resources (p.76) | **Who is responsible to combat pollution and climate change?** |
| Fieldwork | **The role of local NGO's** (p.82) | **How can normal citizens affect the decisions taken in relation to social and global scientific issues? The role of NGO's** |
| Earth and Space I and II | Living on other planets (p.91)<br>The benefits of space exploration (p.100) | |

Two types of issues/areas were considered to be suited for the purpose of this research. Firstly, the Integrated Science syllabus (DQSE, 2014) was analysed to identify those areas that could be categorised as Personal, Social or Global scientific/technological issues as classified in the PISA framework (OECD, 2016). Since the focus was on educating through science rather than science content itself, then areas that featured an established body of scientific content, e.g. parts and functions of body systems or definitions, classifications of elements, compounds, and mixtures, facts about space, etc., were not considered. Issues which included humans interacting with science and technology in their lives were deemed to be more suited.

Scientific issues were considered to be ones which corresponded to one or more of the following:

- are at the forefront of scientific and technological research characterised by high levels of societal application, complexity, uncertainties and possible risks e.g. deafness resolved through cochlear implants;
- involve a decision or action at a personal, social or global level e.g. raising awareness against smoking;
- are value-laden and cannot be solved by simple reference to scientific knowledge e.g. issues of pollution; and
- have given rise to a multiplicity of competing and sometimes biased perspectives especially in the media e.g. extraction of resources, issues of climate change etc.

Secondly, as shown in **Table 5.1**, areas that mirror the work of scientists were also singled out as the recognition of the nature of science and its political context were considered to be components of science awareness as featured in this research. Such aspects included the focus attributed in the Integrated Science syllabus (DQSE, 2014) to the work of forensic scientists and to the role of environmental NGO's.

### 5.2.2 Specification of learning intentions and development of activities

Once the issue tackled was chosen, a number of learning intentions in line with the concept of science awareness that guided this study were specified. The learning intentions for each activity are given in **Table 5.2**. It was made sure that each of the learning intentions addressed at least one of the indicators or sub-indicators of science awareness. For example, the learning intentions developed for the activity related to the issue of *Hearing Difficulties – Are Cochlear Implants the solution to Deafness?* addressed the indicators of science awareness as shown below.

**Table 0.25: A summary of the learning activities used to raise science awareness and the associated learning intentions.**

| **Syllabus area/Issue tackled** | **Description of Main activity** | **Learning Intentions**<br>**At the end of the learning activity the students should recognise that:** |
|---|---|---|
| Healthy Living – **Raising Awareness against Smoking** | Class discussion, scaffolded by the teacher through physical and reflective prompts to help students reflect on the competencies of a group of students who won a local based science competition by means of a project that was aimed at raising awareness against smoking. | • smoking is a science-based personal and social issue.<br>• a range of knowledge, skills and attitudes are needed to be able to act and raise awareness against smoking.<br>• such competences can be achieved through science education. |
| Elements, Compounds and Mixtures - <br><br>**The Story of Diamonds in Botswana: Diamond Hope and Diamond Blues** | Students were divided into small groups to prepare for a presentation related to the extraction of diamond in Botswana. Preparation was scaffolded by the teacher and resources to help students reflect on all the attributes they needed to complete such a presentation. Presentation/model was presented to the rest of the class and this was followed by a class discussion regarding the issue tackled where the students thought about the pros and cons of extracting diamonds. | • the extraction of minerals is a social scientific issue with several pros and cons.<br>• competencies needed to work in a group and give a good presentation in relation to scientific issues.<br>• such competencies can be achieved through science education. |
| Light and Sound – **Are Cochlear Implants the solution to Deafness?** | Class discussion with an Audiological Scientist and a person who lost his hearing ability aged 13 and who had a cochlear implant 20 years later. Issues tackled were deafness and its prevention, the pros and cons of cochlear implants, how they work and how they are implanted. The issues parents have to face when deciding whether to opt for cochlear implants for their sons/daughters and whether to implant one or two were also discussed. | • deafness is an issue that has a science component.<br>• the knowledge, skills and attitudes needed to engage with and take decisions related to deafness.<br>• that through science education one can get the competencies needed to take decisions related to deafness to improve one's quality of life. |
| Forensic Science – <br>**The Image of and Scientists** | The students were asked to reflect on how their image of a scientist changed following their informal discussion with a number of scientists during the Teen Science Café (DQSE). Scientists included a forensic expert. | • scientists work closely with other experts to solve problems.<br>• the competencies of scientists go beyond the possession of scientific knowledge.<br>• scientists tend to have positive attitudes and enthusiasm to take action but can also make mistakes. |

| | | |
|---|---|---|
| Climate Change - **Who is responsible to combat pollution and climate change?** | Students worked in groups to discuss local newspaper articles in order to derive sources, effects and remedies related to land, water and air pollution. They also had to think about the key players involved in tackling these problems. Group reflections were shared in a class discussion that through metacognitive prompts by the teacher helped the students also to think about how science education is helping them to combat this problem. | • science and science education are very important to tackle issues of pollution and climate change.<br>• issues of pollution and climate change have social and global, political and economic implications.<br>• the role of several key players is crucial to tackle and solve such issues. |
| Fieldwork – **How can normal citizens affect the decisions taken in relation to social and global scientific issues? The role of NGO's** | Students were divided into groups and asked to reflect on the issues tackled by Birdlife, a local NGO and the activities it organises by referring to its website. In particular, the students were asked to discuss whether the activities and issues tackled by Birdlife are related to science, the qualities needed by members of such an NGO and in what ways science education may have helped them in the acquisition of such competencies. They were asked to update their reflections following a fieldwork session organised by Birdlife during which the students also interviewed a veteran active member of this NGO. | • the issues tackled by Birdlife e.g. laws to control hunting of birds are related to science.<br>• activists such as members of Birdlife have skills and attitudes that go beyond scientific knowledge.<br>• common citizens can have a say in conserving the environment through active participation in NGO's.<br>• the competencies needed to achieve this end.<br>• such competencies can be achieved through science education. |

Through this activity, the students were expected to recognise:

- that deafness and the decision to use cochlear implants is an issue that has a science component (addressing Indicator 1- Awareness of the science component in personal, social and global issues).
- the knowledge, skills and attitudes needed in order to engage with and take decisions related to tackling deafness (addressing Indicator 2 – Recognition of attributes needed to address and act upon scientific issues).
- that through science education one can get the qualities needed to take decisions related to deafness to improve one's quality of life (addressing Indicator 3 – Recognition of the importance of science education in the acquisition of attributes needed to engage with and act upon issues of a science component).

Learning activities to raise science awareness were designed to also address the students' beliefs about science and science education in relation to the concept of science awareness developed in this research. In each of the activities the students were to be metacognitively engaged through discussions with teachers, peers or significant others to help them in the construction of a higher recognition of the extent that science permeates their personal, social and global lives, and the degree to which science education is important to provide them with the necessary skills to act upon scientific issues. A summary of how discussion and verbal interaction were actually employed in the respective activities to raise science awareness is given in **Table 5.2**. A more complete report of each of the learning activities together with any associated learning resources is given in **Appendix I**.

The results of Phase 1 of the study had also shown that students do not prefer teacher-centred activities. This finding was also taken into consideration when planning the learning activities as it was ensured that the student was at the centre of the learning process. The students worked in groups as they tackled the different aspects of the issue of the extraction of diamond in Botswana and as they analysed newspaper articles to identify sources of pollution, its effects, and the key players involved in its resolution. The students also participated in class discussions, with experts or significant others, as in the issue of cochlear implants, the Teen Science Café, and with the Birdlife representative with very minimum input from the teacher.

Another important feature of the learning activities to target science awareness referred to the expected level of attainment of the competences needed to engage with and act upon scientific issues in everyday life. This research places science awareness at the very basis of engagement prior to the achievement of scientific literacy and science for citizenship. The activities chosen were thus not targeted at the acquisition of the range of attributes usually associated with scientific literacy. They were, on the other hand, aimed at helping students reflect and become more aware of the competencies needed to face scientific issues in their everyday life and to see science education as the route to such an achievement. For example, the students were not asked to mimic the work of members of an NGO but to simply reflect on the competencies of such people and to understand the importance science education might have had in their life. The study group were not asked to set an awareness campaign against smoking but to reflect on an activity organised by older students in another school to review the competences they needed to succeed.

### 5.2.3 Assessment

In line with the pedagogy based on metacognition, the assessment tools were designed for the students to capture their awareness through their reflections on a number of metacognitive reflective questions assigned after each learning activity. In cases where the teacher was not involved to prompt the metacognitive reflective process as in the case of the Teen Science Café, the students were also asked to write their reflections before the activity so that they could compare them to those after the activity and thus easily witness the learning taking place. It also gave the students a clearer idea of what they had to focus on. All the metacognitive questions are listed in **Table 5.3**. The metacognitive questions addressed the learning intentions originally specified for each learning activity directly.

Thus, for example in the case of the issue of using cochlear implants to tackle the issue of deafness, the metacognitive questions addressed each of the learning intentions outlined above, included the following questions:

- Do you think that choosing whether to have a cochlear implant is related to science?
- What do you think that Mr. X did before deciding to have a cochlear implant?
- Do you think that Mr X.'s science education was important in this respect?

It is significant to note that reflections were restricted to thinking about the extent to which science was related to the issues tackled, the attributes needed to tackle these issues and whether science education was helping them in this regard. Students were not asked to think about understanding of concepts or learning of higher cognitive tasks that went beyond awareness. The students' reflections were recorded in their journals which were later collected and analysed as will be described further on.

**Table 0.26: Table including the metacognitive questions used to help students reflect on the learning activities.**

| Syllabus area/Issue tackled | Metacognitive reflective questions |
|---|---|
| Healthy Living –<br>**Raising Awareness against Smoking** | Do you think that smoking is related to science in any way?<br>Which of the above (competencies needed to take action) do you think are you able to do right now?<br>List the things that may be stopping you from being able to do the items that you did not tick. |
| Elements, Compounds and Mixtures -<br><br>**The Story of Diamonds in Botswana: Diamond Hope and Diamond Blues** | List some of the things you need to know how to do in order to prepare for a presentation about a scientific issues.<br>A country becomes richer when diamonds are found. Comment. |
| Light and Sound –<br>**Are Cochlear Implants the solution to Deafness?** | Do you think that choosing whether to have a cochlear implant is related to science?<br>What do you think Mr. X did before deciding to have a cochlear implant?<br>Do you think that Mr. X's science education was important in this respect? |
| Forensic Science –<br>**The Image of Scientists.** | Draw a scientist and write a few sentences related to your picture.<br>Write a few steps to explain how scientists usually go about their work.<br>Do you wish to become a scientist? Yes/no and why?<br>(Following Teen Science Cafe). Refer to the image of a scientist you drew in your journal a few lessons ago. Do you still look at scientist and science in the same way following this activity? |
| Climate Change -<br><br>**Who is responsible to combat pollution and climate change?** | Do you think that pollution is a problem created by the rich?<br>Who are the key players involved in finding a solution to pollution and climate change? How do they work together to achieve this?<br>How do you think you can be part of the solution?<br>Are your science lessons helping you in this regard? Yes/no and why? |
| Fieldwork –<br>**How can normal citizens affect the decisions taken in relation to social and global scientific issues? The role of NGO's** | Do you think that the issues tackled by Birdlife are related to science? Why?<br>What qualities does a person need to carry out these activities?<br>In what way is your science education helping you to get these qualities?<br>(answered before and after the activity) |

Thus, in summary, metacognition served the purposes of learning, assessment and data collection as is illustrated in **Figure 5.2**.

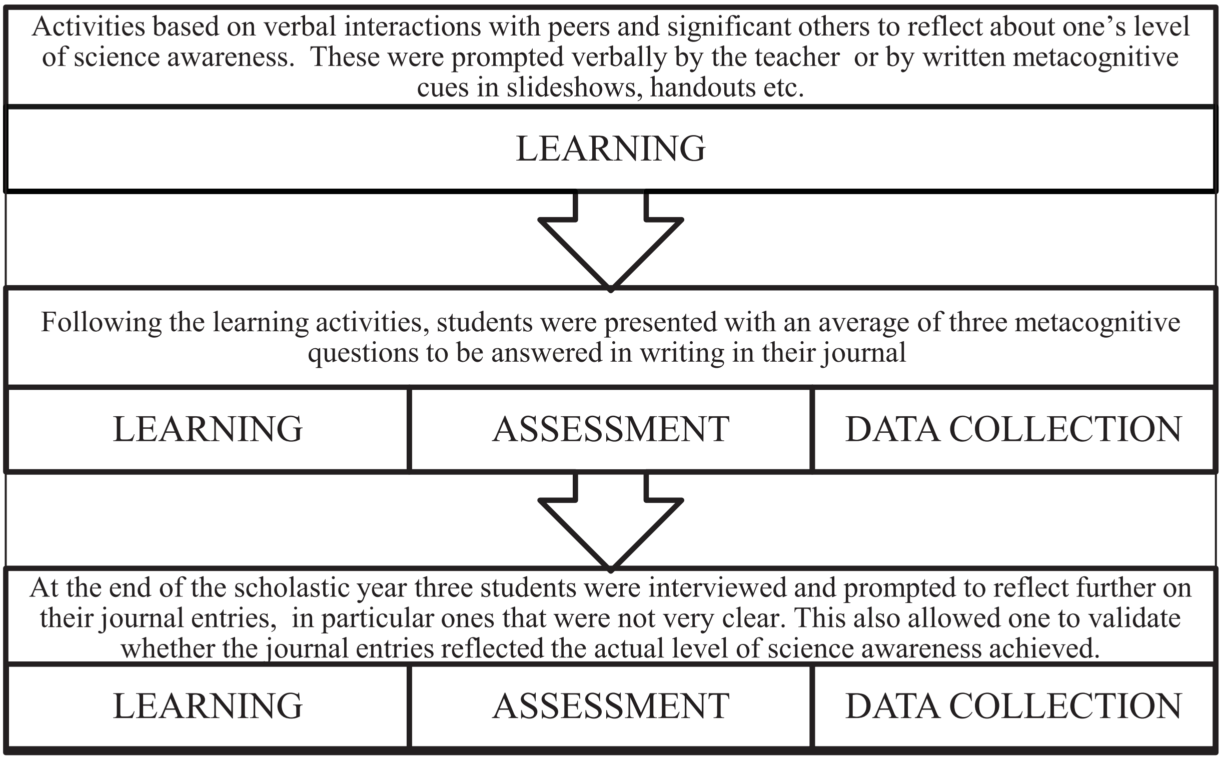


**Figure 0.8: The different purposes of metacognition during Phase 2 of this research**

## 5.3 Research design

The following is a description of the piloting process and the research tools used to gather data in this phase of this study.

### 5.3.1 Implementation Process

Following ethics clearance by UREC (See **Appendix J**) for the use of the research tools developed, the learning activities to increase science awareness were implemented in the Church School where the researcher had been employed as a teacher since 2003 and with a class she taught. This factor allowed ease of access.

The study group was assigned at the beginning of the scholastic year 2015/2016 by the school administration to the teacher/researcher. Choice of the group was solely dependent on timetable issues. The group consisted of thirteen Form 2 (Year 8) female students, equivalent to half an average class in a Church school. According to safety regulations, students must be divided into small groups during science lessons in Malta. All the students in this group participated in the science awareness activities organised during the school year as they were part of the science curriculum and during the science lessons themselves (4 lessons per week). All the other Form 2 science groups in the school were taught by two other teachers with whom the science awareness activities were shared and discussed. Although the metacognitive reflective process was not specifically targeted by the other teachers, they agreed that some of the activities should be organised for all the Form 2 Integrated Science groups. These included the Teen Science Café that tackled the Image of Scientists, the discussion with the Audiological Scientist which tackled the issue of deafness and the fieldwork organised to make students more aware of the role of local environmental NGO's.

At the beginning of the scholastic year, the students were briefed about the project by the teacher/researcher. The information sheets and consent forms (see **Appendix J**) were also handed out at this stage. Three students decided not to participate in the study and consequently data were not collected from them. In the first week of the scholastic year, before any of the activities were carried out, the students were asked to fill the original questionnaire measuring science awareness used in this research. This served to embed the study group in the range of science awareness obtained from the survey in phase 1 and to then gauge any changes in science awareness by the end of the scholastic year. This was done during two recess times. No lesson time was used since not all students were taking part in the data collection.

Choice and preparation of the activities to address the results of the Phase 1 of this study and to address the respective syllabus areas was done before the scholastic year. However, the teacher/researcher had to be constantly prepared to change science awareness activities when better, unscheduled opportunities to address scientific issues arose in the school community. This happened in two cases. Originally, it was planned for the students to meet a forensic scientist and discuss his career as an introduction to the topic Forensic Science. Following the receipt of a communication in November 2015, it was decided to embed this in the *Teen*

*Science Café*, an initiative by DQSE, during which the students could informally meet, on a rotational basis, other scientists in succession in addition to the forensic scientist, making the outcomes of the activity much broader. In addition, in the case of the syllabus area *Elements, Compounds and Mixtures*, the choice of issue and the activity initially planned were changed completely. Instead of tackling the illegal extraction of water from the water table in Malta, the learning activity actually piloted was linked with a one-off project the school teaching staff was informed about at the beginning of the scholastic year. In this initiative, schools in Malta were being twinned with a Commonwealth country in preparation for CHOGM (Commonwealth Heads of Government Meeting) 2015, due to be hosted by the Maltese Government and asked to deliver lessons related to the respective country. An exhibition was then set up at the Ministry of Education and Employment in Floriana. Since Malta was linked with Botswana, it was decided to target the issue of the excessive use of water in the process of diamond extraction in this country.

Merging with such school initiatives levered the activities to a higher dimension and made them more easily embraced by the students, other educators and the School Management Team as they were in line with the school culture. In addition, since these projects were rooted out of school, they also allowed a closer link to society in which most scientific issues are embedded.

After all the activities were carried out, the ten students who participated in this study were again asked to fill in the questionnaire. Although the sample of students studied was too small to analyse results statistically, the numerical results obtained through this exercise were still compared to the ones recorded at the beginning of the scholastic year in conjunction with qualitative data to observe any possible changes in the level of science awareness of the study group with whom these activities were piloted.

### 5.3.2 Research tools

During Phase 2 of this study, data were collected by several means to allow triangulation of results. The purpose of triangulation is to increase the credibility and validity of results. Cohen and Manion (2000, p.254) define triangulation as an "attempt to map out, or explain more fully, the richness or complexity of human behaviour by studying it from more than one standpoint. Triangulation thus "gives a more detailed and balanced picture of the situation" (Altrichter *et al*., 2008, p.147). The study group in Phase 2 was too small for solitary quantitative results to be analysed statistically. Backup from qualitative means was necessary.

As shown in **Table 5.4**, data were collected at different stages of the piloting process.

**Table 0.27: Timeline of learning activities used to raise science awareness of Form 2 students during the scholastic year 2015/2016. Details of data collection procedures are also given.**

| Syllabus area/Issue tackled | | Date | Data Collection |
|---|---|---|---|
| | | September 2015 | Quantitative data collected through original questionnaire to check the level of science awareness of the students before learning activities to raise science awareness were implemented. |
| Elements, Compounds and Mixtures | **The Story of Diamonds in Botswana: Diamond Hope and Diamond Blues** | 29/10/2015 | After each learning activity, data was collected through the metacognitive reflections that students recorded in their journals.<br><br>Qualitative data was also collected through the teacher's journal that was focused on identifying challenges that the educator has to face in planning and implementing such activities. |
| Healthy Living | **Raising Awareness against Smoking** | 15/12/2015 | |
| Forensic Science | **The Image of Scientists** | 10/03/2016 | |
| Light and Sound | **Are Cochlear Implants the solution to Deafness?** | 12/04/2016 | |
| Climate Change | **`Who is responsible to combat pollution and climate change?** | 17/05/2016 | |
| Fieldwork | **The role of environmental Non-Governmental** | 30/05/2016 | |

| | | | |
|---|---|---|---|
| | **Organisations (Birdlife)** | | |
| | | June 2016 | Quantitative data was collected again through the original questionnaire to check the level of science awareness of the students after learning activities to raise science awareness were implemented.<br><br>Data was also collected qualitatively through interviews with three students found to have attained different levels of science awareness. During the interviews students were asked to reflect further on their journal entries. |

The following is a more detailed description of the research instruments used:

**Questionnaire**

At the beginning of the scholastic year 2015/2016, the study group were asked to answer the questionnaire designed for Phase 1 of this study. A thorough description of the development of this instrument to measure science awareness and its analysis is given in the methodology section for Phase 1 of this research. This data provided the main source of information regarding the students' beliefs prior to the pilot project. It also allowed the study group to be embedded in the range of science awareness measured for the population of Form 2 students in Malta in 2012. In addition, data allowed verification of whether results and conclusions from Phase 1 of the study were still valid for the planning of learning activities to raise science awareness that were implemented in 2015, three years after the original data was collected.

The study group were also asked to answer the questionnaire again at the end of the scholastic year. These quantitative results were compared to the ones obtained at the start of the scholastic year to see whether there was any general improvement in science awareness after the implementation of the activities. These quantitative results (n = 10), that were too small in number to analyse statistically, were also triangulated with qualitative data obtained by other means that will be described below.

### Students' journal

Since the students had not been engaged in metacognitive instruction prior to this pilot study, the students' journal reflections were not open but were structured by means of a number of questions given by the teacher which made the students deliberately think about different aspects of science awareness tackled in each of the respective activities. This qualitative data was used in triangulation with the questionnaire results at the end of the scholastic year to evaluate the extent of overall increase in science awareness. It also allowed the researcher to distinguish between students who achieved different levels of science awareness.

### Teacher's journal

The journal of the teacher/researcher had a more open format including weekly reflections about the process of piloting and of blending such activities as part of the Integrated Science curriculum of Form 2 students. These journal entries were coded to identify the challenges and limitations such activities entail and to formulate recommendations for further work in this area. The teacher's journal also addressed the problem of bias or "the interpretive crisis" (Denzin, 1994) that is still heavily debated in qualitative research. There is lack of agreement on how much researcher influence is acceptable. Reflective journals are thus promoted to make the experiences, feelings and thoughts of the researcher more visible and thus creating more transparency in the research process (Ortlipp, 2008).

### Semi-structured Interviews

Qualitative data were also collected at the end of the scholastic year through semi-structured interviews with three of the students whose questionnaire responses and journal entries featured different levels of science awareness at the end of the pilot study. The questions asked were based mainly on the students' journal entries through which the students were prompted further by the teacher/researcher to clear any ideas written in the journal or to see if higher levels of science awareness could be achieved through further prompting. Some questions were also set to get general feedback regarding the activities the students were exposed to during their Form 2 science lessons. The sets of questions used to structure each of the interviews are given in **Appendix K**.

“The interview is an important data gathering technique involving verbal communication between the researcher and the subject” (Mathers *et. al,* 1998, p.1). An interview is also “one of the most powerful ways we have of understanding others” (Punch, 1999, p. 175). The direct interaction of the interview offers a variety of advantages as a research technique:

- It allows for greater depth than other research methods and for accurate data to be obtained if the researcher does his job well and the subjects are motivated.
- It is generally filled with rich verbatim passages directly from the participants. The excerpts are used in an evidentiary fashion to support or illustrate the researcher’s interpretations (Polit & Hungler, 1999).
- It is less likely that respondents give ‘I don’t know answers’ as in questionnaires.
- Relatively few people refuse to be interviewed in person (Polit & Hungler, 1999).

There are several formats the interview may assume, from completely unstructured to highly structured. In this research, a semi-structured approach was adopted where a list of questions to be covered by each respondent.

*Semi-structured interviews were considered to be appropriate for our qualitative research as:*

- the researcher has general questions and allows respondents to tell their stories;
- it is conversational and interactive in nature;
- it encourages respondents to define the important dimension of a phenomenon and to elaborate on what is relevant to them rather than being guided by the investigator’s a priori notions of relevance and
- it is appropriate for studies such as ours “when the researcher does not have a clear idea of what it is he or she does not know” (Polit & Hungler, 1999, p.331).

As much as possible open-ended questions were used to provide a framework for the interviews. The open-ended nature of the questions provided the opportunity to discuss some topics in more detail. If the interviewee had difficulty answering a question or provided only a brief response, cues or prompts were used to encourage the interviewee to consider the question further. In a semi-structured interview, the interviewer “has the freedom to probe the interviewee to elaborate on the original response or to follow a line of inquiry introduced by the interviewee” (Mathers, 1998, p.2).

The way the researcher goes about the interview would have an inevitable effect on the research outcomes. Several precautions suggested by various authors were taken. These included:

- having the necessary skills to ask questions and leave the respondent in a "considerable degree of latitude within" (Bell, 1993, p.94) which to answer;
- being a good listener in addition to being a good questioners (Polit & Hungler, 1999);
- being well informed on the purpose of the research interview and to be well prepared and familiar with the topic guide (Mathers, 1998); and
- being systematic and consistent in the way one interacted with each respondent (Mathers, 1998).

The interview situation is "a highly subjective technique and therefore there is always the danger of bias" (Bell, 1993, p.91). Various authors suggested ways in which this bias strength could be reduced. "All opinions of the respondents should be accepted as natural – the interviewer generally should not express surprise, disapproval or even approval" (Polit & Hungler, 1999, p. 346). Cohen and Manion (2000), suggest that one must take care to formulate the questions in a way that the meaning is crystal clear. Leading questions that suggested a particular kind of answer were avoided.

The three interviews were audio-recorded with the permission of the participants. This freed the researcher to really listen to what was being said and to respond accordingly. It allowed the discussion to flow because one did not have to write down the response to one question before moving on to the next. In note-taking, there is an increased risk of interviewer bias because the interviewer is likely to make notes of the comments, which make immediate sense or are perceived as being directly relevant or particularly interesting (Mathers, 1998). Audio recording ensures that the whole interview is captured and provides complete data for analysis, so cues that were missed the first time can be recognised when listening to the recording.

### 5.3.3 Key Research Issues – Phase 2

This part of the research could have had more effective results if it was carried out with students who were shown to have the poorest levels of science awareness as indicated by the results of Phase 1 of this study. However, since this study had to be carried out over a scholastic year, it was easier for the teacher/researcher to gain access to the school where she was employed. This also allowed the research to be conducted while the teacher/researcher could still work on a full-time basis in the same school. Since the teacher/researcher had been employed in this school for more than a decade she had a very good understanding of the logistics and ethos of the school.

Phase 2 of this research was carried out on a small number of subjects in a particular setting. Thus, there is very little basis for scientific generalisation. Any numerical changes in science awareness should be interpreted with caution. However, since the activities that were being piloted were planned in response to findings from a survey study with a representative population, then one can say that there is more confidence that such learning activities can have similar effects when applied with other Form 2 Maltese students in other school contexts.

Such a research, conducted over a period of one scholastic year could also result in a massive amount of data that may lead to confusion and difficulties in analysis procedures. A compromise therefore had to be reached between the depth and quantity of data that was collected and that which could eventually be managed and organised systematically by a single researcher.

A number of classroom activities including handson experiences, experiments, fieldwork, groupwork, project work, etc., other than metacognitive reflection were carried out by the researcher during the year to addres all areas of the science curriculum. This implies that one can never be sure that any changes in science awareness were solely due to the activities piloted in Phase 2 of this study. However, at least, this study indicates whether such activities can be used to complement the rest of the science curriculum in early secondary years.

The fact that this phase of the research was performed by a teacher/ researcher might have also led to bias in data collection that can influence the results more than in other research designs. However, taking up the role of a teacher/researcher can also be considered to be an asset. Boundary crossing by science teacher researchers, who are thus acting as brokers, is actually being encouraged at the doctoral level (Bakx *et al*., 2016) because there seems to be a lack of productive interaction between academic research in science education and professional teaching leading to what is called the research-practice gap (Vanderlinde & Van Braak, 2010). Such a study thus ensures that the outcomes of this research are practice-based and thus can be more easily used by and more available to other practitioners.

## 5.4 Conclusion

While this chapter presented an outline of the science awareness activities that were piloted with a small group of Form 2 students, an analysis of the effectiveness of these activities in a real-life classroom context will be given in the next chapter preceding an overall discussion of the major outcomes of this research.

# Chapter 6. ANALYSIS – PHASE 2

Mixed data collected during the pilot study were analysed to establish whether the learning activities, mostly based on metacognitive reflection, had an effect on different aspects of science awareness of the study group targeted in Phase 2 of this research. Results are also expected to show whether science awareness can actually be augmented through school science, even through a curriculum that had not been specifically planned for this purpose.

## 6.1 Analysis of questionnaire results before piloting of learning activities – The students' original level of science awareness.

Although the sample of students studied was very small, the questionnaire results obtained before the piloting of the learning activities were analysed numerically in order to obtain an insight of the cohort's baseline level of awareness compared to the measure of the representative sample of science awareness of the whole population of Form 2 students obtained back in 2012. As already described in the previous chapter, the class group assigned consisted of thirteen students, ten of whom decided to participate in this study and who therefore answered the questionnaire. They were numbered as Student 1 to Student 10 for the sake of this research.

As expected for Church Schools, the majority of students (n = 8) said that they spoke mainly Maltese at home with the rest (n = 2) stating that they speak English. As to their school science profile, half the students (n = 5) stated that they had no lessons or less than one lesson per week during their last year of primary schooling. The other half (n = 5) reported to have had science once or more than once a week. At this point it is significant to note that the students came from different primary feeder Church Schools. The distribution of the students according to the number of science subjects they were thinking of opting for in Form 3 was also very similar to that of the general population with the majority planning to choose 1 science subject ( n= 6). Only one student was planning to choose two science subjects while the rest (n = 3) were thinking of choosing three.

As in the case of the whole population, achievement in Integrated Science exams was also very good, with the majority (n = 9) reporting to have attained a pass mark in their last Integrated Science exam. Similar results were also obtained for the types of learning activities the students had experienced in Form 1 with the highest average means obtained for teacher-centred activities like *reading and writing notes* (Mean = 3.80) and *listening to the teacher* (Mean = 3.60) as shown in **Table 6.1**.

**Table 0.28: Ascending means for learning activities carried out during science lessons on a four-point Likert scale (1= Never, 4 = Very Often)**

| ***Learning Activity*** | ***Mean*** |
|---|---|
| Community work | 1.20 |
| Field work | 2.00 |
| Doing an experiment yourself | 2.50 |
| Discussion | 2.70 |
| Trying to solve a problem | 3.00 |
| Watching the teacher do an experiment | 3.40 |
| Working with friends | 3.50 |
| Listening to the teacher | 3.60 |
| Reading or writing notes | 3.80 |

As to the attributes that the students think they had acquired through their science education, results were generally similar to that of the overall sample questioned in 2012. Overall, slightly higher means were obtained than those of the whole population as shown in **Table**

**6.2**. As in 2012, students agreed strongly that science education is relevant mainly in transmission of facts and to help us understand the world around us. They also agreed, although not as strongly, that it has given them scientific skills, such as questioning the things around them, and social skills such as negotiating solutions and presenting opinions to others. However, they do not agree that science education has helped them to participate in political action.

**Table 0.29: Comparison of means of the whole population to those of the group studied in Phase 2 in relation to students' beliefs regarding their science education**

| Questionnaire items | Average mean of whole population (2012) | Average mean of sample (2015) |
|---|---|---|
| Participating in political action | 1.9 | 1.9 |
| Willingness to participate in political action as a reflective citizen | 2.3 | 2.7 |
| Negotiating possible solutions through democratic ways | 2.6 | 2.8 |
| Strengthening your values | 2.8 | 3.0 |
| Presenting your opinions to others | 2.8 | 2.9 |
| Listening to people with different views | 2.9 | 3.3 |
| Distinguishing between what is right and what is wrong | 3.0 | 3.1 |
| Understanding how scientists work | 3.0 | 3.3 |
| Questioning the things or issues around you | 3.1 | 3.0 |
| Using scientific results to draw a conclusion | 3.1 | 2.7 |
| Understanding the importance of science in your lives | 3.1 | 3.3 |
| Taking care of your health | 3.3 | 3.5 |
| Understanding the world around you | 3.4 | 3.3 |

The students' out-of-school exposure to science was very low with all the means for the items being below 1.9 except for watching scientific documentaries which was 2.6. Two students never watched scientific documentaries, three never bought books related to science topics, seven never visited websites related to science, nine had never attended a science club while another one also said that she had never visited a museum, zoo or aquarium.

With respect to home resources, an average mean of 2.94 was obtained which is less than the average mean of the whole population (Mean = 3.94). This means that the students in the class had fewer resources than the average. Political activity of the parents was very low with only one student reporting such participation. Not all the students were aware of the level of education completed by their parents/guardians. 3 of the mothers/female guardians completed secondary education, 1 completed post-secondary while another 3 completed tertiary education. The rest did not answer. Another 5 students were not aware of the level of education of the father/male guardian. As to those who replied, one stated that he had completed primary, two secondary, one post-secondary and another one a tertiary level of education.

Means for the indicator items related to science awareness were also calculated and compared to those of the rest of the population as shown in **Table 6.3**. Despite the small number of students from which the data were extracted, very close average means were obtained for each of the components signifying that the sample of students with whom the learning activities were piloted had a similar science awareness profile as the average of the general population studied in 2012.

**Table 0.30: Comparison of the average means of different aspects of science awareness for the population studied in 2012 and the sample who took part in the study in 2015.**

| Indicator of science awareness | Average mean of whole population (2012) | Average mean of sample (2015) |
|---|---|---|
| Recognition of science in personal scientific issues | 2.48 | **2.50** |
| Recognition of science in social scientific issues | 2.51 | **2.45** |
| Recognition of science in global scientific issues | 2.76 | **2.80** |
| Acknowledgement of science-society association | 2.50 | **2.35** |
| Acknowledgement of competencies needed to deal with personal scientific issues | 3.10 | **3.00** |
| Acknowledgement of competencies needed to deal with social scientific issues | 2.93 | **2.88** |

## 6.2 The extent to which science awareness was raised

The students' journal entries were analysed to identify instances where elements of science awareness were clearly expressed through the students' metacognitive reflections. These were triangulated with comparative numerical results obtained from the questionnaire that was again administered at the end of the scholastic year after all the activities were implemented. Shifts in the average means (Table 6.4) for the main indicators of science awareness that guided this study were analysed.

**Table 0.31: Comparison of the average means for the main indicators of science awareness before and after the piloting process**

| **Indicator of science awareness** | **Average mean at the beginning of the scholastic year ($M_b$)** | **Average mean at the end of the scholastic year ($M_a$)** |
|---|---|---|
| Recognition of science in personal scientific issues | 2.50 | **2.78** |
| Recognition of science in social scientific issues | 2.45 | **2.83** |
| Recognition of science in global scientific issues | 2.80 | **2.89** |
| Acknowledgement of science-society association | 2.35 | **2.55** |
| Acknowledgement of competencies needed to deal with personal scientific issues | 3.00 | 2.98 |
| Acknowledgement of competencies needed to deal with social scientific issues | 2.88 | 2.87 |

One can note that improvement in the average means was recorded for the indicators in which the lowest science awareness was originally measured both in the whole population as well as in the sample of students studied. These changes or lack thereof will be discussed below.

- **Awareness of the science component in personal, social and global issues.**

**Table 6.4** shows that following the learning activities, the students could recognise more the science in personal ($M_b$ 2.50 → $M_a$ 2.78) and social issues ($M_b$ 2.45 → $M_a$ 2.83) included in the questionnaire. There was also a slight increase in recognition of the science in global scientific issues ($M_b$ 2.80 → $M_a$ 2.89) but the shift was less than that recorded for personal and social scientific issues. This was probably because the students already had a higher recognition of their relation to science before the pilot study itself.

Through the journal entries one could also delineate recognition of the science present in personal and social issues one encounters in everyday life. Following the Botswana activity related to diamonds, several students were able to realise that the extraction of diamonds is not a fairy-tale but can also be a detriment to the environment, especially in dry countries such as Botswana due to its heavy usage of water resources. One such response to the prompt: *A country becomes richer when diamonds are found. Comment.,* a student replied:

*"Veru u mhux veru għax meta biegħu d-diamonds li sabu iktar saru sinjuri imma biex isibuhom riedu ħafna ilma u naqas ħafna ilma milli kellhom bżonn biex jgħixu n-nies."*

"It is true but in a way it is not. When they sold the diamonds they became richer but to extract them they needed a lot of water which was taken from the supply people needed to live." (Student 3)

The work carried out by environmental NGO's in Malta is usually only tackled marginally in the field work that all Integrated Science students have to carry as part of their curriculum. The strong emphasis made on the role of Birdlife during one of the learning activities, might have helped in making students recognise the role of science in issues that are usually tackled by NGO's such as Birdlife, most of which are also social scientific issues. This indicator of science awareness can be traced in the journal entry below:

"The main issue that is tackled by Birdlife is spring hunting. It is related to science because science is about understanding what is around us and bird hunting is one problem we have." (Student 6)

Most of the students could relate personal issues, such as smoking and deafness to science because of the relation to the human body which is covered extensively in several school science topics as reflected by the statements below.

"Yes, because one of the science subjects is Biology and Biology is related to the body and its systems and how it works. And smoking cigarettes is a harm to our body...and so it is related." (Student 9)

“I think deafness is related to science because it’s related to the ear and in science we are doing about the ear.” (Student 8)

However, others showed a higher level of science awareness by stating that it is related to science because it is making us more prepared to face issues in our everyday life. This implies that students were able to see science as traversing beyond that which is covered at school to other areas in their lives.

“Yes, because it is important for children of our age to know how bad it is for our lungs to smoke. Therefore science shows us which apparatus and science explain the chemical change” (Student 7)

“Yes, because it is the study of how a person can be deaf and scientists help us prevent it from happening.” (Student 4)

- **Awareness of the science-society association**

**Table 6.4** also shows that following the implementation of the learning activities, there was an increase in the mean of the statements related to the recognition of the reciprocal association that exists between science and society ($M_b$ 2.35 → $M_a$ 2.55). Back in 2012, a low level of science awareness, especially among female students, was reported in relation to the recognition of the politics surrounding the scientific enterprise as well as to the actual work of scientists. The students’ perceptions of science and scientists were still very much based on traditional, transmissive school science scenarios. The learning activities related to the Teen science Café and those related to Climate Change might have actually been effective to change students’ perceptions in this regard. When asked to draw a scientist before the Teen Science Café activity, they drew a man or woman in labcoat and glasses carrying out chemical experiments in a lab.

“I wanted to draw a scientist with a beaker in one hand and another beaker in the other hand to show that he is a real scientist.” (Student 8)

“He has curly hair wearing a lab coat and gloves. He is thin and about a normal height. He also has some beakers in front of him on a table.” (Student 6)

Most also commented that scientists have to plan meticulously, be very serious and focused, and take the necessary safety and other precautions as they go about their work. They also need to record everything they do. Following the Teen Science Café during which the students had successive short informal discussions with a number of people in science careers, the students’ perceptions of science changed as is shown by the following reflections:

"Today I learned that not all scientists can be like I drawn. They are more interesting now." (Student 2)

"Yes, I think that this has changed the way I look at scientists and science. This is because I now realise that there is much more to science and scientists than just chemicals and potions. I also thought that scientists were very serious men and women. But now I realise that they can also be fun." (Student 6)

"A scientist doesn't always need to work in a laboratory. A scientist can go out for forensic science or maybe he or she can go up to court to prove his or her evidence." (Student 9)

"Scientists and jobs that include science sometimes are a lot different than they seem on TV." (Student 1)

Through the Climate Change activities, during which students were asked to analyse and reflect upon newspaper articles related to pollution and global warming, a better recognition of the uneven distribution of the advantages of scientific discoveries in the world was recorded. In relation to pollution, some of the students stated:

"I think that it is created mostly by rich people as they would have much more gadgets and ways of transport that create a lot of pollution." (Student 9)

"Yes, I think that pollution is created by the rich because the rich have everything. So they throw away any waste they don't like" (Student 10)

Through this learning activity, students were in a better position to identify social bodies who work with scientists in the quest to solve problems of pollution and global warming. This is illustrated in the statement below:

"The key players are scientists, the Prime Minister, the Minister of the Environment and the Pope. They are working together by meeting and discussing and also they can influence the people." (Student 5)

The students' writings also showed that they do recognise their role in the solution of such social and global scientific issues.

"I can recycle waste and walk instead of using the car. I can eat everything and don't waste food." (Student 7)

"My science education is helping me because science is helping us to get the knowledge and the skills". (Student 6)

- **Recognition of the attributes needed to engage with and act upon scientific issues.**

As shown in **Table 6.4**, the means for the Acknowledgement of the competencies needed to engage with and act upon personal scientific issues ($M_b$ 3.00 → $M_a$ 2.98) and Acknowledgement of the competencies needed to engage with and act upon social scientific issues ($M_b$ 2.88 → $M_a$ 2.87) remained practically the same before and after the learning activities. This may probably have resulted because the level of science awareness before the pilot study itself in relation to this indicator was already very high with respect to other indicators of science awareness. This high level of awareness in relation to this indicator is clearly articulated in the statement below as one of the students was reflecting about the qualities needed by a person active in NGO's such as Birdlife.

"He needs to be someone who loves the environment and someone who is willing to go against the Government's word and they have to be someone who don't give up."

An additional interesting finding illustrated through the journal reflections was that while the students were able to recognise the attributes needed to act upon scientific issues, such as in raising awareness against smoking, they do not feel prepared to do them all. They can do things such as leaflets and Facebook pages and things related to knowledge such as explaining the negative effects of smoking but when it comes to higher order cognitive scientific skills (e.g. designing an experiment) and to social skills needed to interact with people, especially those in out-of-school scenarios, it becomes more difficult. This is corroborated by such comments:

*"Naħseb li miniex kapaċi nagħmilhom waħdi.* ""I don't think I am able to do them on my own" (Student 1)

"I think I'm not able to set up stands because it needs a lot of neatness, organisation and planning and I think I wouldn't be able to do them. I don't think I would be able to talk to higher people in the Health Promotion Unit to help me raise awareness." (Student 9)

"I cannot set up stands and enter a competition because sometimes I get shy and I would be worried about something going wrong. I cannot produce leaflets and bands and stuff like that because I don't know where I could make the bands." (Student 6)

"I am not old enough and I don't have much experience with doing experiments and setting up everything. I need more practice and more lessons for me to learn more." (Student 3)

This also corroborates the foundational level assigned to science awareness in the conceptual framework of this study. Science awareness is a suitable starting learning objective at this, or perhaps even younger ages and will set the way for the attainment of higher educational objectives such as scientific literacy and science education for citizenship when the students are older.

- **Recognition of the contribution of science education in the acquisition of attributes needed to engage with and act upon issues of a science component**

**Table 6.5** shows that there was very little change in the means obtained for the questionnaire items related to the question: *To what extent do you agree/disagree that school science has been helping you in the following areas?* The greatest increase was observed for the item *Using scientific results to draw a conclusion* ($M_b$ = 2.7 → $M_a$ = 3.2) and *Understanding the world around you* ($M_b$ = 3.3 and $M_a$ = 3.5). Although these aspects were not targeted directly through the learning intentions of the science awareness activities, it is significant to note that during scholastic year 2015-2016, the study group were exposed to a whole repertoire of lessons that may have had a positive effect on these aspects.

**Table 0.32: Comparison of means before and after piloting for questionnaire items related to the question *To what extent do you agree/disagree that school science has been helping you in the following areas?***

| **Questionnaire items** | **Mean Before $M_b$** | **Mean After $M_a$** |
|---|---|---|
| participating in political action | 1.9 | 1.8 |
| willingness to participate in political action as a reflective citizen | 2.7 | 2.4 |
| using scientific results to draw a conclusion` | **2.7** | **3.2** |
| negotiating possible solutions through democratic ways | 2.8 | 2.7 |
| presenting your opinions to others | 2.9 | 2.9 |
| questioning the things or issues around you | 3.0 | 2.9 |
| strengthening your values | **3.0** | **3.1** |
| distinguishing between what is right and what is wrong | 3.1 | 3.1 |
| understanding how scientists work | 3.3 | 3.3 |
| understanding the importance of science in your lives | 3.3 | 3.3 |
| understanding the world around you | **3.3** | **3.5** |
| listening to people with different views | 3.3 | 3.1 |
| taking care of your health | 3.5 | 3.2 |

Overall, changes in means were probably small because the averages were already high for several attributes mentioned before the pilot study itself. As to the persistent low results obtained for the two items that feature participation in political action, (*Participating in political action* and *Willingness to participate in political action as a reflective citizen*) results clearly indicate that more work has to be done, beyond that covered in this study, in raising awareness regarding the relationships between science, science education and citizenship. These results also indicate that the influence that the students had regarding their science education from previous school science or other experiences in relation to this aspect are perhaps stronger than the six isolated activities they had throughout this scholastic year. It may also show that experiences in school science before the age of 12 may have a greater impact on students' perception of the importance of school science than those at age 12 or later.

However, despite confounding numerical results, through the journal entries one could identify several instances where the students were able to see the significance of science education in the development of skills that are not traditionally associated with the subject.

Following the Botswana activity, where students had to work in groups, some students commented:

"You have to discuss with each other what we bring. At first it was kind of hard, to set everything together, the teacher helped us and everything was alright. We did have some problems about what we should do so that everyone would be doing something. So we helped each other to make it all better and nice. We did have some arguments but we coped with each other and had fun doing it." (Student 4)

"I learned how to research better on the web and to work better in groups." (Student 6)

The students also appreciated the role of science education in helping them to engage with and act upon global scientific issues especially those related to pollution and climate change. When asked whether their science lessons are preparing them to be part of the solution of this global problem the following were some typical comments:

"Yes, they are teaching me about what is wrong with the world and helping me to make a difference." (Student 5)

"Yes, because now I know how people treat the world" (Student 7)

"Yes, they are helping me because I never knew how big the problem was, especially in Malta. But now I realise and I am going to try my best to help the environment. I also learnt about some sources of pollution and their effects and what I can do to solve the problems." (Student 6)

## 6.3 Levels of science awareness achieved.

In this section, journal entries were analysed further to distinguish between students who achieved different levels of science awareness. Three such students were then probed further during interviews so that their profiles regarding their levels of science awareness could be more accurately defined.

### 6.3.1 Degrees of Awareness Achieved

Following all the activities, towards the end of the scholastic year, the students' journals were also analysed numerically according to a defined set of criteria indicated in **Table 6.6** in order to identify three students with different levels of science awareness. Students' level of awareness was gauged according to the total number of criteria they managed to target in the journal entries out of the sixteen included in the same table.

The level of science awareness attained by the respective students in the study group is shown in **Table 6.7**. It is interesting to note that all students obtained a score of 9 or higher out of the 16 that marked the maximum level of science awareness. The distribution of science awareness of the rest of the students according to their scores is shown in **Table 6.7**.

The student with the highest score (Student 9 - 15/16), one with a middle relative score (Student 6 - 12/16) and one with the lowest score (9/16 – Student 1) were then also interviewed individually regarding their journal entries. For the purpose of this study, these students will be referred to as Melissa, Charmaine, and Jael respectively. The questions used to structure the interview for each student are given in **Appendix K.**

**Table 0.33: Criteria used to distinguish between different levels of science awareness according to the students' journal entries.**

| Student Score /16 | | | |
|---|---|---|---|
| **Science Awareness Activity** | **Criterion 1** | **Criterion 2** | **Criterion 3** |
| Raising awareness about smoking | Relates the negative effects of smoking to science. | Is aware that there are many other skills and attitudes they need to work on if they must act upon science issues. | |
| The story of diamonds in Botswana | Disagrees with the statement – *A country becomes richer when diamonds are found.* | Explains why the statement in criterion 1 is debatable. | Mentions at least two skills or attitudes one needs to have in order to prepare for a presentation. |
| Cochlear implants | Recognises deafness as a personal and social issue related to science. | Mentions some skills needed by a patient before he/she decides to have a cochlear implant. | Identifies science education as important in such decisions. |
| Teen Science Café | Shows an awareness that scientists do not always correspond to the traditional image of scientists. | Mentions at least two factors that correspond to a more authentic image of science or a scientist. | |
| Climate change – Media Analysis | Recognises pollution as a problem created by the rich. | Identifies more than one key player in finding a solution to climate change. | Identifies science education as relevant for common citizens to combat climate change. |
| Fieldwork | Recognises conservation and the work of NGO's as related to science. | Identifies at least two skills or attitudes needed by a person who carries out work for Birdlife. | Identifies science education as relevant in the development of the skills and attitudes mentioned in 2. |

**Table 0.34: Distribution of students according to their journal scores**

| Journal Score (maximum = 16) | Number of students |
|---|---|
| 15 | 1 |
| 14 | 1 |
| 13 | 1 |
| 12 | 3 |
| 11 | 2 |
| 9 | 2 |

### 6.3.2 Examples of degrees of awareness

This section provides examples of how Melissa, Charmaine and Jael differed in their degrees of awareness and the use of metacognition. These differences are also compared to their general achievement during the Integrated Science lessons.

- **Melissa**

Out of the 10 students who participated in data collection, Melissa was the one who achieved the highest score of science awareness from her journal entries. Melissa achieved an exam mark of 73% both in her Half Yearly and Annual Integrated Science exams for the scholastic year 2015/6. The assessment marks for her coursework were 87% and 90% respectively. Overall, Melissa was a hard worker and always handed in complete work punctually. However, her verbal participation in class left much to be desired and she had to be constantly prompted to participate. It was also observed that she relied a lot on her friend (who was a higher achiever but who decided not to participate in data collection) especially when groupwork was assigned.

Melissa's profile obtained through her questionnaires showed that her mother/female guardian had a secondary whilst the father/male guardian had a post-secondary level of education. Her parents did not participate in any political activity and she had five out of the six home resources given in the questionnaire. She spoke mainly Maltese at home, had less than one science lesson per week during her last year of primary schooling and was planning to study one science subject in Form 3. She did not participate in any out-of-school activities related to science except for visiting a zoo, museum or aquarium. Even after the scholastic year 2015/6 she still disagreed that science education is helping her to become more willing to or participate in political action, to negotiate solutions through democratic ways and to strengthen her values. She scored higher means for all the indicators of science awareness at the end of the scholastic year as shown in **Table 6.8.**

**Table 0.35: Comparison of the average means for the main indicators of science awareness for Melissa before and after the piloting process.**

| Indicator of science awareness | Average mean at the beginning of the scholastic year ($M_b$) | Average mean at the end of the scholastic year ($M_a$) |
|---|---|---|
| Recognition of science in personal scientific issues | 2.12 | 2.38 |
| Recognition of science in social scientific issues | 2.19 | 2.69 |
| Recognition of science in global scientific issues | 2.25 | 2.92 |
| Acknowledgement of science-society association | 2.59 | 2.71 |
| Acknowledgement of competencies needed to deal with personal scientific issues | 2.60 | 3.10 |
| Acknowledgement of competencies needed to deal with social scientific issues | 2.43 | 2.86 |

Although during the interview Melissa stated that, in general, she still liked experiments and other lab activities best, she still regarded the journal as useful to think about what was being learnt as she herself explained during the interview:

*"jgħinek tifhem iktar x'int titgħallem, tidħol iktar fid-dettall u sakemm qegħda tikteb tinduna iktar x'int tagħmel."* (Melissa)

"It helps you to understand better what you are learning, you go into more detail and while you are writing, you realise what you are learning."

In spite of this, she still said that sometimes it was difficult to express herself clearly, especially because this was her first time using such a journal even when considering other subjects.

*"Iva, kif se naqbad nispjega ruħi....xorta nkun naf ġo moħħi imma biex niktibha..."*

"Yes, how to explain myself......I would know it in my mind but to write it...."

She stated that more prompts could have made the process easier. In fact, she was able to clarify and to add on to the metacognitive reflections she originally included in the journal when encouraged to do so during the interview. When asked to reflect on the statement *A country becomes richer when diamonds are found,* she had originally simply written that finding diamonds has its advantages but also many disadvantages. When asked to specify some disadvantages during the interview, she was able to refer to the creation of mines that destroy the land and to the excessive use of water during the process. However, when asked to mention other examples where scientific applications were actually a detriment to poor people, she was not able to do so.

Regarding scientists, she explained how the science awareness activity helped her realise the reality of these careers, how some, like in forensic science, can actually be gruesome and that they are very much different from how they are portrayed in the media. She also managed to explain why she thinks that scientists do not always agree with each other especially when they have conflicting results and thus are not able to decipher the best way forward. She could also recognise the fact that not all scientists are responsible especially when they try out new things without having an extensive awareness of the outcomes of the process.

When prompted by the teacher to reflect further about the attributes needed by an individual who is to have a cochlear implant, she was also able to add on to the list she had originally written.

Researcher: "Let's say you were in this situation and had to decide whether to have an implant or not. Imagine that your doctor asked you to decide. What would you do?"

Melissa: "I would look for information...Google for example and see what there is online..."

Researcher: "...and if I tell you that this does not always work?"

Melissa: "I would look for alternatives"

During the interview, Melissa was also able to add on to the list of stakeholders responsible to solve the problem of pollution and climate change. Originally, she had said that she also has a role in this process by using less energy. When prompted to think further about her responsibility she also referred to her taking action:

| | |
|---|---|
| *"tidħol f'timijiet bhal dawn (NGO's) biex tkompli tgħin iktar...ikun hemm iktar persuni min jgħin."* | "you become a member of such teams (NGO's) so that you help out more...there would be more people helping out." |

However, she also thought that science lessons were not preparing her to do so. They were just imparting knowledge and not even all the knowledge needed in preparation for such actions.

Melissa stated that she did not choose the three sciences to study at higher levels because she had other career aspirations that seemed to have been set earlier on in her life.

| | |
|---|---|
| *"...għax xtaqt immur naqra linja oħra. Meta kont żgħira kont tajba fin-numri u hekk, allura inħossni komda ma' dawk l-affarijiet."* | "...because I wished to go in another direction. When I was young, I used to be very good at numbers, so I feel more comfortable in those areas." |

During the interview, it was observed that Melissa could provide further insight into the journal entries she wrote during the year when prompted to do so.

- **Charmaine**

Charmaine's journal entries score showed that she obtained a relatively average level of science awareness. She achieved an exam mark of 68% in her Half Yearly and 63% in her Annual Integrated Science exam for the scholastic year 2015/6. The assessment marks for her coursework were 89% and 84% respectively. Although Charmaine's academic work was not of a quality as high as that of Melissa, she was more verbal than Melissa during class discussions, reflected extensively on what was covered during the lesson and was very enthusiastic about the science activities carried out in class.

Charmaine's profile obtained through her questionnaires showed that her mother/female guardian had a secondary whilst the father/male guardian had a post-secondary level of education. Her parents did not participate in any political activity and she had four out of the six home resources given in the questionnaire. She spoke mainly Maltese at home, had less than one science lesson per week during her last year of primary schooling and was planning to study one science subject in Form 3. Apart from visiting a museum, zoo or aquarium, she also sometimes read scientific articles, watched scientific documentaries and visited websites about science topics. Even after the scholastic year 2015/6 she still disagreed that science education is helping her to become more willing to or participate in political action. She scored higher means for all the indicators of science awareness at the end of the scholastic year except for her recognition of global scientific issues and her acknowledgement of competencies needed to deal with social scientific issues for which there was a very small decline as shown in Table 6.9.

**Table 0.36: Comparison of average means for the main indicators of science awareness for Charmaine before and after the piloting process.**

| **Indicator of science awareness** | **Average mean at the beginning of the scholastic year ($M_b$)** | **Average mean at the end of the scholastic year ($M_a$)** |
|---|---|---|
| Recognition of science in personal scientific issues | 2.75 | 3.4 |
| Recognition of science in social scientific issues | 2.40 | 2.60 |
| Recognition of science in global scientific issues | 2.83 | 2.72 |
| Acknowledgement of science-society association | 2.35 | 2.47 |
| Acknowledgement of competencies needed to deal with personal scientific issues | 3.30 | 3.31 |
| Acknowledgement of competencies needed to deal with social scientific issues | 3.29 | 3.14 |

When asked about what she liked during the lessons carried out during the past scholastic year, like Melissa, she also referred to experiments and to the fact that the lessons were not based on writing.

*li kellna ħafna qishom experiments u l-lessons mhux qisek toqgħod tiktbilna u rridu nikkupjaw għax hemm min jagħmel hekk. Imma toqgħod tagħmlilna l-activities u affarijiet hekk."*

"we conducted a number of activities and during the lessons we didn't stay copying because there are teachers who do that. But you stay doing activities and similar things."

She referred more extensively than Melissa to the lessons aimed at raising science awareness. She mentioned the activity related to climate change because she said she was struck by how extensive this global problem actually was and that it made her feel that she also has to be part of the solution. She also referred to the issue of cochlear implants and to the related discussion as she became more aware of the devastating effects that loud sounds may have.

Charmaine also stated that the questions she had to answer in her journal also helped her a lot to reflect on the lessons. Like Melissa, sometimes she had difficulty deciding what to write. She stated that the teacher cannot be of much help in this process as it is an individual journey.

Unlike Melissa, Charmaine was not able to explain the disadvantages of the extraction of diamond even when heavily prompted to do so by the researcher. However, she was able to explain further how the Botswana activity helped her to work better in team. In particular, she referred to the group dynamics where one had to learn to work even with classmates who are not close friends. She also referred to the handout provided by the teacher/researcher that helped them plan and distribute work so that everyone had a role in the group.

Through the interview she also showed that she was very much aware of the lack of agreement between different scientists regarding a particular issue, especially when they are experts from different fields who use different techniques and approaches. When asked to reflect on the interview question of whether she thinks that scientists are responsible people, unlike Melissa, she responded affirmatively. However, she still managed to identify scenarios where this is not the case when she was prompted further to do so.

Her written reflection about the qualities needed by a member of an environmental NGO, such as Birdlife, was very good. Charmaine is a more passionate person than Melissa and, in fact, during the interview she stated that she felt that she was able to do such work if she sets her mind to it although she felt that at this stage in her life there still were some drawbacks.

| | |
|---|---|
| *"li għadni żgħira u li qisni ma tantx nista' nagħmel daqshekk effett fuq ħaddieħor."* | "that I am still young and that I cannot very much affect others." |

The organisation of similar activities in schools might make one feel more prepared to engage in such matters.

As in the case of Melissa, Charmaine also stated that she didn't choose the three sciences because she didn't want to follow that career path. She also added that she thought that they were difficult, in particular because she did not like to study.

- **Jael**

According to the journal score, Jael's metacognitive reflections exhibited a lower level than those compiled by Melissa and Charmaine. Jael was absent for her Half Yearly exam and achieved an exam mark of only 33% in her Annual Integrated Science exam for the scholastic year 2015/6. The assessment marks for her coursework were 65% and 55% respectively. Jael behaved very well in class but her enthusiasm for learning in general was very low. She was absent for several days during each month, had to be reminded to hand in missing assignments and rarely participated in class discussions.

Jael's profile obtained through her questionnaires showed that she was not aware of her parents' level of education. Her parents did not participate in any political activity and she had three out of the six home resources given in the questionnaire. She spoke mainly Maltese at home, had less than one science lesson per week during her last year of primary schooling and was planning to study one science subject in Form 3. She did not participate in any out-of-school activities related to science except for visiting a zoo, museum or aquarium or buying books about science topics. Even after the scholastic year 2015/6, she still disagreed that science education is helping her to become more willing to or participate in political action. Her means for the the indicators of science awareness at the end of the scholastic year were either lower or just slightly higher than the original means except for her acknowledgement of the science-society association for which her Mean improved from 2.29 to 2.70. All the means are given in **Table 6.10**.

**Table 0.37: Comparison of the average means for the main indicators of science awareness for Jael before and after the piloting process.**

| **Indicator of science awareness** | **Average mean at the beginning of the scholastic year ($M_b$)** | **Average mean at the end of the scholastic year ($M_a$)** |
|---|---|---|
| Recognition of science in personal scientific issues | 2.62 | 2.50 |
| Recognition of science in social scientific issues | 2.53 | 2.62 |
| Recognition of science in global scientific issues | 2.90 | 2.92 |
| Acknowledgement of science-society association | 2.29 | 2.70 |
| Acknowledgement of competencies needed to deal with personal scientific issues | 3.20 | 2.80 |
| Acknowledgement of competencies needed to deal with social scientific issues | 2.57 | 2.70 |

Like Melissa and Charmaine, during the interview, Jael also mentioned experiments and activities such as those done during the topic Forensic Science as the ones that were particularly interesting. She also stated that although the journal helped her to reflect, sometimes she did not know what to write. The fact that it could be written in Maltese facilitated the process.

The probing required by Jael to clarify her journal entries was much greater than that required by Melissa and Charmaine. She was more prone to give short, yes or no answers that had to be followed rigorously by the researcher. For example, when asked to explain how scientists decide what to research, she stated that this decision was a question of interest. There was no mention of the effect that the Government, society, industry and society at large may have on such a choice. Only when further prompted by the researcher, as shown in the interview excerpt, did she realise that the research a scientist adopts may actually be imposed on the scientist in question.

| | |
|---|---|
| *"Ix-xjentisti jistudjaw oqsma differenti. Kif taħseb li jiddeċiedu x'għandhom jistudjaw? Per eżempju, wieħed mix-xjentisti kien espert fuq fishfarming. Għalfejn, per eżempju, taħseb li jistudja dik it-tip ta' ħuta u mhux oħra?"* | "Scientists study different fields. How do you think do they decide what to study? For example, one of the scientists was an expert on fishfarming. Why do you think, he studies a particular type of fish and not another?" (Researcher) |
| *"Għax ikun interessat f'dik il-ħuta?"* | "Is it because he is interested in that particular fish?" (Jael) |
| *"Taħseb li hemm xi affarijiet oħra li jwassluh biex jistudja ħuta u mhux oħra?"* | "Do you think there are other factors that determine whether he studies one particular fish and not another?" (Researcher) |
| *"Għax tkun iktar interessanti dik il-ħuta minn ħuta oħra."* | "Because that fish is more interesting than the other." (Jael) |
| *"....Ejja ngħidu li dan jaħdem mall-Gvern u nerġa' nsaqsik l-istess mistqosija!"* | "What if I tell you that this scientist works for the Government and again I ask you the same question!" (Researcher) |
| *"...għax igiegħluh jagħmel fuq dik il-ħuta?"* | "...because they make him study that fish?" (Jael) |

In contrast to the two students who scored higher levels of awareness, it was particularly interesting to note that in one of her journal reflections, Jael stated that she does not feel that she should be part of the solution to climate change. She underlined this belief further during the interview by stating that she is not interested in such matters. It should be left to those who work in such areas. The question of interest also featured when she was asked why she does not feel ready to take action in relation to other issues such as raising awareness against smoking. There seemed to be very little enthusiasm from her part to continue learning to gain the attributes needed to face and act upon such issues.

## 6.4 What about changes in attitudes?

Results from Phase 1 of this study had shown that there is a relationship between high levels of science awareness and more positive attitudes towards science. Since a slight improvement was observed in the science awareness of the study group during the scholastic year 2015/6, this was also expected to reflect in slightly more positive attitudes or judgements towards school science. In fact, **Table 6.8** shows this projected slight positive shift in all the questionnaire statements that featured attitudes towards school science before and after piloting of the science awareness activities.

**Table 0.38: Comparison of means before and after piloting process for questionnaire items related to *Attitudes to school science*.**

| Attitudes towards school science | Mean before | Mean after |
|---|---|---|
| School science is boring | 1.50 | 1.30 |
| We do too much science at school | 2.10 | 2.10 |
| I look forward to my science lessons | 3.30 | 3.40 |
| I would like to do more science at school | 2.80 | 2.90 |
| I like science better than most other subjects at school | 2.50 | 2.60 |
| School science is difficult | 2.40 | 2.00 |

There was also overall positive qualitative feedback. The following were some of the general comments given when the students were asked to reflect on the science education they received during their Form 2 Integrated science lessons. This positive vibe may also imply that the students were satisfied with the whole approach adopted during the scholastic year, not only that restricted to the science awareness activities:

"I think this year the science lessons were much more fun and I learned much more things." (Student 9)

"This year's science was different from that of last year because we did more experiments and went into more detail. I wish to say thank you for this year." (Student 2)

"This year was the best. I felt more free to ask questions. The teacher of this year was the best and I don't need to be shy around people now that I know them. The teacher's activities were fun and I learned a lot from her." (Student 4)

"This year's science was different from last year because this year we did games, discussions and groupwork and for me I loved it." (Student 8)

Again, although present, these slight positive shifts in attitudes indicate that at this age, as in the case of beliefs, attitudes towards school science have already become established and are difficult to change.

## 6.5 Challenges

Several ethical and other problems could be identified during the process of design and implementation of the activities. These problems could be identified from the interview transcripts of the students but in particular from the journal entries of the teacher/researcher. The following includes a comprehensive list of the difficulties the researcher and the students faced during this phase of this study:

- Although the researcher was given access to the group, initially the School Management Team seemed to be sceptical whether the researcher was going to manage the research project and still cover the current vast Integrated Science syllabus. However, careful planning minimised waste of time and at the end of the scholastic year all the topics covered by the other two science teachers who taught the other Form 2 students were also completed by the study group.
- The teacher/researcher had more experience in teaching Chemistry at higher forms rather than Integrated science and therefore the learning activities originally planned had to be adjusted to fit the level of the students in question once the teaching and learning process actually started as shown by the reflections below:

"During this week, I met the thirteen students that will form the study group. I am still in shock mode because they were much worse than I expected. I am used to teaching science specialist groups who are in general very eager to work. In contrast, the first impression I got was that these Form 2 students are quite distracted and engaging them during the lesson will be quite a task." (Teacher's journal- 2/10/2015)

"Things would have been much easier if I had taught Form 2 in previous years." (Teacher's journal - 16/11/2015)

- Metacognitive reflection was a new pedagogical approach for the teacher and students alike.

In fact, the students identified several issues they had to face when asked whether they had difficulties using their journal during their science lessons as shown below:

"It depended on the type of question. Sometimes it was difficult." (Charmaine)

In fact, this was the first time they used this type of journal. While Charmaine said that it is difficult for the teacher to help in this thinking process as it is an internal, individualised learning process, Melissa pointed out that answering would have been easier if the questions were explained in much more detail.

- Finding areas that could address science awareness in a syllabus that is highly content-laden was also quite a laborious process and sometimes involved also ethical considerations as exemplified by the case below:

"I am also preparing for the science awareness activity related to smoking. I gave up on the activity regarding Amyotropic Lateral Sclerosis, ALS since there were many ethical issues involved. I didn't want to get the school, which happened to be a Church school in any controversies since it seems that research in ALS uses human embryos and this is not approved by the Catholic Cchurch. Smoking is more related to the syllabus and is perhaps more relevant to the students since all of them have a relative or two who smoke and all of them have to one day decide whether or not to resist smoking." (Teacher's journal - 30/12/2015)

- Although the researcher informed the other Form 2 Integrated Science teachers about the work related to science awareness, this learning philosophy could not be imposed on them. Thus, sometimes, it may have seemed that the group taught by the researcher was perhaps doing things that were not being covered so laboriously by other teachers.

"The students are now questioning why we carried out the activity of Botswana when other science groups didn't. I hope it doesn't become an issue in Parents' Day. However, when I asked them they immediately replied that they learnt a lot. This resistance was expected and I read all about it. But when you are in the midst of it all, it is quite stressful and adds a lot of pressure especially when you are already overwhelmed with all the preparations such research work entails." (Teacher's journal - 16/11/2015)

"However, it is significant to note that none of the parents complained about the research project during Parents' Day. This perhaps shows that the science awareness activities seem to be part and parcel of the curriculum." (Teacher's journal - 14/12/2015)

- The activities were also perhaps more demanding in preparation than other traditional science lessons activities as they involved teachers of other subject areas and players from diverse areas in society and thus implied ongoing liaising, in particular regarding logistics, etc. As indicated by the statements below, sometimes it also meant that some activities were covered at different times than when the actual topic was covered in class.

"This week I planned an alternative activity regarding the topic Elements, Compounds and Mixtures. I decided to use the participation of the school in the CHOGM Malta 2015 activities as an opportunity to engage in a science awareness activity. Our school was coupled with Botswana which is an avid producer of diamonds. Since the CHOGM activities have to be covered in October, I have to do this activity before the topic is actually covered in class." (Teacher's journal - 5/10/2015)

"Such planning would have been much easier if the syllabus was not so specific but more thematic and choice of material was at the discretion of the teacher." (Teacher's journal - 5/10/2015)

"I will also be trying to link this activity to the Teen Science Café which will be organised in our school, with the help of Directorate of Quality and Standards in Education, DQSE to increase awareness re STEM careers. At first, I took this as a personal initiative. However, I decided to speak with the other Form 2 science teachers who are willing to collaborate and with the Guidance Teacher who usually prepares Form 2 students to choose their options. So actually we would be targeting two areas at the same time." (Teacher's journal - 11/1/2016)

"This week was an exemplar of how logistically difficult such activities might be. I invited a person who has cochlear implants through the Cochlear Implant Association. After everything had been arranged, we realised that the person in question was actually a parent of one of our students. Somehow, the name of the school was not mentioned during the arrangement. However, both the father and the daughter accepted that it is still ok to share this experience with the other students." (Teacher's journal - 4/4/2016)

## 6.6 Discussion – Phase 2

The profile of the students who took part in the pilot project together with their original level of science awareness corresponded very well with that of the representative sample of Form 2 students studied in 2012. This meant that the data obtained for the general population through the survey and discussion was also applicable to the group of students in this study.

Results showed that the students who took part in the second phase of this study had an original low level of science awareness in relation to several indicators used to feature science awareness in this study. This may be attributed to a number of factors including the low exposure to science in primary years, the boring teacher-centred activities used in science lessons, low participation in out-of-school activities related to science, less than average home resources, and the poor involvement of parents in political activities.

Following the activities, there were positive shifts in the science awareness indicators that were originally of a low level amongst the study group. Students could relate more the personal and social issues tackled in the classroom to science. They were also able to give more realistic perceptions of the work of scientists and the scientific enterprise. The political milieu in which the scientific enterprise is embedded was also given higher recognition. This phase of the research also verified students' high level of awareness in relation to recognising the attributes needed to engage with and act upon scientific issues. However, the effect of this pilot study in helping students recognise the importance of science education in helping them to participate in political action in relation to scientific issues was almost negligible. This shows that the students' previous learning experiences in science education or lack thereof might have had a stronger impact on their perceptions of the importance of science education in relation to this aspect than those desired by this pilot study.

In fact, although an increase in science awareness was recorded, this was very slight.. Obtaining a significant shift is a difficult process and thus may require such activities to be more frequent and to be sustained over longer periods of time. This suggests that science awareness should perhaps be tackled at earlier stages of science education, even in primary years. Mental models related to science have in fact been shown to develop as early as 6 to 7 years of age (Birr Moje *et al*., 2007; Newton & Newton, 1998). Interest in science, which is another psychological variable is also believed to start developing from a very young age even before middle school (Tai. *et al*. 2006).

The recording of metacognitive reflections in students' journals proved to be a suitable tool to provide a rough sketch for the assessment and documentation of science awareness or of the beliefs that students have about science and science education. However, students at all levels of science awareness, and academic ability, in general, felt that they needed further probing and help in documenting their journal entries. The interviews have shown that these skills of metacognitive reflection and writing can be greatly improved if both the teacher and the students are previously exposed to training in this aspect. The importance of training in the use of metacognition as a pedagogical tool in science education has also been referred to in literature (Adi & Nir, 2013). Furthermore, triangulation of data from metacognitive reflective writings with other sources, such as interviews, gives a better picture of students' beliefs.

The questionnaire results and even the journal entries have shown attitudes towards school science also became more positive throughout the scholastic years. This shows two important outcomes. First of all, this finding is in line with psychological theories, like the expectancy-value model (Fishbein, 1963), that presents a direct relationship between beliefs and attitudes. It also corresponds to national and international studies that show that attitudes towards science start to form very early on in life, are more positive during primary education and have already become established and start to decline between the ages of 11 and 14 (Baldacchino, 2010; Bennett & Hogarth, 2009; Borg, 2013).

The feedback from the three students interviewed at the end of Phase 2 may imply that raising science awareness and recording it through metacognitive reflection works best with those who are high achievers. Recording beliefs through metacognitive reflections also works best with those who usually are more academically able probably because they already unknowingly employ such processes to improve their work (Ben-David & Zohar, 2009).

It was also observed that students' science awareness, even when raised, can result in the desired behaviour when there are background factors, other than intelligence and academic ability that enhance the behavioural intention. The person who seemed to have the best individual attributes, such as the right personality, emotion and values to actually proceed to take action about scientific issues was actually Charmaine, the student whose metacognitive reflections in the journal showed a medium level of science awareness. Charmaine's belief systems fits in nicely with the value set "Green" identified by Haste (2004). This value set or cluster of beliefs "is about the environment, ethical issues concerned with animal experimentation, and concern about the pace of science and 'interfering with nature'. It also includes items relating to feeling effective about being involved with the community" (p. 11) At the other end of the continuum Jael can be said to be "Alienated from science" (*ibid.*) as she shows a lack of interest in science, lack of recognition that science can solve human problems and does not tolerate ambiguity but more into clear right or wrong answers.

Finally, this pilot project has shown that such science awareness activities can actually be implemented in schools in line with the Integrated Science curriculum. In fact, despite all the 'extra' activities carried out, the researcher still managed to cover all the other areas of the syllabus. However, there are several other challenges to overcome in the process such as the teaching philosophy of other science teachers, the questioning attitude of the Senior Management Team and perhaps also parents in relation to this "soft option" being targeted in science lessons etc. All in all,

> "Those teachers who promote involvement and develop action skills are "riding a tiger," but it is a tiger that may well have to be ridden if we really mean what we say about education for civic participation." (Hodson, 2010, p.205)

# Chapter 7. OVERALL DISCUSSION

This research has shown that it is possible to tackle science awareness, or the recognition of the importance of science and science education, as a concept in its own right and as separate to other educational outcomes of science education for non science specialists. Piloting of the learning activities in Phase 2 of this research showed that classroom activities based on metacognitive reflection can, to a degree, promote science awareness and could also be an opportunity to combat differences due to social bacground and to enhance the relevance of science education among youth. The research also delineated a number of factors that have an effect on the development of science awareness and which have significant implications for science education research and for science education in Malta.

## 7.1 Major Findings and Implications

In this section, the major research findings and their implications to teaching and science education are discussed.

### 7.1.1 Demarcating and Extending the Concept of 'Science Awareness'

This research, based on science awareness, was originally motivated by the book "The Myth of Scientific Literacy" (Shamos, 1995) who argued that definitions of scientific literacy that expected students to learn too much abstract content and skills were too complex to be achieved by the general student. He proposed that the objective of scientific literacy should be less ambitious, and focus more on functionality, which he referred to as *scientific awareness* and which can be probably achieved by the majority of students. Shamos's radical proposal, to put more emphasis on awareness and functionality in the quest of engaging more students to learn science was taken up and developed further in this research.

The concept of science awareness, as developed in this study, based solely on beliefs and excluding acquisition or demonstration of deeper knowledge or any other behavioural attributes, allows science awareness to be measured distinctly. Science awareness was conceptualised by amalgamating the psychological interpretations of active, attentive awareness that can be deliberately sustained (Brown & Ryan, 2003; Roeser & Peck, 2009), with a democratic, humanistic philosophy being promoted by science educators, both in Malta (MEE, 2012) and beyond (Barton & Tan, 2010; Hodson, 2003). Elements of awareness were usually directly and indirectly included in frameworks of scientific literacy (De Boer, 2000; Hurd, 1998; OECD, 2006; OECD, 2009; Shamos, 1995) but frequently overlapped with other attributes or competencies required. This rendered the measurement and development of this basal educational outcome as marginal in several studies. In fact, literature specifically focused on science awareness was very limited.

Through a thorough review of theoretical perspectives, the elementary phenomenon of *science awareness* was distinguished from two other commonly proposed educational targets, namely *scientific literacy* (Bybee, 1997: Hurd, 1998, NRC, 1996; OECD, 2006; OECD, 2009) and *science for citizenship* (Ratcliffe & Grace, 2003; Ryder, 2002). These two terms were used in this research to cap a multitude of other philosophically similar terms that are found in the vast literature tackling the science education of the general student.

More specific focus and clear separation of different educational targets allows the development of different pedagogies to achieve different educational outcomes appropriate to different stages of schooling in science as suggested by Fensham (2008). In fact, the demaraction of science awareness from other educational outcomes allows it specifically to be addressed at early stages of science education, mainly by pedagogies that enhance one's thinking about his or her awareness.

Additionally, setting different science educational outcomes in preparation for citizenship at different levels of engagement implies that more students with different abilities or interests in science are given the chance to succeed (MEEF, 2011b; MEE, 2012; Shamos, 1995). Science awareness was set at the wide base of the triangular hierarchical model proposed in this study that relates science awareness, scientific literacy and science for citizenship. It is obvious that more students will be able to reach this target as less cognitive input and attributes are needed than those to achieve the other educational outcomes. Though this may seemingly be a small achievement, it can still be regarded as being considerable when taking into account the students' individual maximum potentials.

### 7.1.2 Science Awareness in the Quest of Equity and Social Justice

The undesirable effects of an economically-driven society on the scientific enterprise and science education have been tackled quite extensively by science education philosophers (Bazzul & Siatras, 2011; Carter, 2010; Tobin, 2011). There is a growing tension between a democratic science education tradition (Kaptan & Timurlenk, 2012; Roth & Lee 2004) and neoliberalism that still infiltrates science and science education structures. Neoliberalism renders an undue emphasis on individual excellence (Carter, 2010), rigorous accountability at all levels in schools (Apple, 2006) in addition to a lesser degree of autonomy and responsibility among scientists as they are expected to work for the market (Carter, 2008) instead of pursuing questions of scientific relevance.

This research, in particular Phase 2, in deliberately focusing on raising students' recognition of: the political nature of science and science education; the uneven distribution of scientific applications; and their role in acting upon issues that are socially and globally significant contributes to the move of "radical science educators" (Apple, 2011) to bring about change in particular against the "wicked problem" of neoliberalism (Carter, 2011). As an educator, the researcher took up an active role to promote change rather than remain passive and by default support the dominant ideology (Hodson, 2013) that transcends science education. The piloting of the learning activities to raise science awareness and to identify associated challenges is a response to the argument articulated by Apple (2011) that democratic traditions do not infiltrate schools as they tend to remain too theoretical and do not address questions that teachers face in the classroom.

This research has also shown that targeting science awareness through school science can be used to combat social differences that are the result of a phenomenon strongly associated with neoliberalism, namely neoconservatism (Bencze & Carter, 2011; Carter, 2008). Results from Phase 1 of the study showed that students from Independent Schools, who come from socially privileged backgrounds, are also the ones who have the highest degree of science awareness as it is featured in this research. Similar comparatively positive results in achievement for Independent Schools also featured in SEC exams (MEE, 2013b), TIMSS (MEE, 2016b) and PISA (MEE, 2016a) results. Although at face value it may seem that everybody has the same opportunity to learn science in schools, if the development of science awareness is left up to sporadic acquisition through informal education, then there will be greater social differences as students from economically and culturally richer families are at an advantage because of their additional extraneous out-of-school opportunities within the family context. This is also in line with philosophical movements that support the recognition of scientific forms of social and formal capital in Bourdieu's conceptualisation of capital in the theory of social reproduction (Archer *et al*., 2015). Keeping science education detached from its everyday relevance and political aspect only allows those students, whose primary discourse matches the secondary discourse (Gee, 2003) used in school science, to engage with science. It is then difficult for the rest to bridge this gap unless they are specifically inspired to do so by science educators. Thus, science awareness is one of the determinants of whether students engage with science and choose a science related career.

This research has also shown that the effort to improve the recognition of the importance of science education for citizenship and to act for the common good has to be sustained more strongly than the effort realised in Phase 2 of this study. As in previous studies (Angell *et al.,* 2004; Osborne & Collins, 2001), it has been shown that even at age 12 students already strongly believe that science education is solely important to help them in their personal lives and to achieve their career goals. There should be a continued effort to enhance a socially responsible science education (Onwu, 2017), motivating students to latch out from 'narcissism' (Schreiner, 2006) and start appreciating the importance of science and science education for the common good, especially with regards to issues that are related to sustainability of the planet. Since such passiveness among youth has also been reported for citizenship and activism in general (Print, 2007), efforts to combat this sociological issue should go beyond school science and subject compartmentalisation (Davies, 2004) to encompass a broader educational framework specifically designed to augment students' awareness of their role in this participatory culture, that gives them the chance to take part, mainly through dialogic relationships in the social fabrication of meaning (Hull *et al*, 2010; Jenkins, 2006).

### 7.1.3 Levels of Science Awareness and Science Education in Malta

This research has also contributed to the development of an instrument to measure science awareness among students. The questionnaire measured different constructs allowing one to decipher in what aspects there was a lack of science awareness. Students demonstrated a low level of science awareness, particularly in relation to the recognition of the importance of science in personal, social and global issues. This was especially evident in situations that do not feature any relation to school science. In addition, Maltese twelve year olds do not tend to appreciate that some scientific applications may be far from beneficial, that social bodies and even citizens may actually control the progress of science and that science education is not only important to improve our individual quality of life but also to ensure the common good and sustainability of the planet.

These beliefs reflect the positivist philosophy that is mirrored in the frequent, transmissive teacher-centred science lessons that were reported in this research. These findings also suggest that school science, tackled in early secondary years and possibly before, is still very much detached from the realities of everyday lives and simply serve as theoretical foundation for higher, purely scientific courses. Extensive research in Malta and beyond has also attributed negative attitudes towards science to this emphasis on abstract science facts and transmissive teaching methods (Azzopardi, 2008; Baldacchino, 2010; Lindahl, 2003; Lyons, 2006; Osborne & Collins, 2003; Sultana, 2011). This calls for more student-centred approaches that are embedded in social and environmental issues (Onwu, 2017). These enhance relevance as they tend more towards what is more important for the student than what is important to the scientist (Malcolm *et al*., 2009).

While the recognition of scientific issues is low, results have shown that students are still interested in tackling these issues in the classroom. During the focus groups, the students showed a very positive response to the proposition of learning activities that feature frequently in literature to address the educational outcomes of scientific literacy and science for citizenship. These include authentic science learning experiences based on collaborations between schools and informal settings emphasising the strengths of each setting (Adams *et al.*, 2012), context-based education based on the "need-to-know" principle (Bulte *et al*. 2006; Pilot & Bulte, 2006) and decision-making in the field of Socioscientific Issues, SSI (Evagorou *et al*., 2012). In a science for citizenship unit in New Zealand (Chen & Chowie, 2013), while primary school students learnt about butterflies through reading, they also hunted, tagged and released butterflies and published the data collected. Such an activity was reported to have an enhanced interest and long-term engagement in science by giving the students a taste of 'being there' experience. It is clear that students see these learning activities as tackling what Kessels *et al*., (2006) calls the perceived heteremony of science subjects as they allow them to state their opinions, to get out of school, and are more relevant and highly applied.

This study has also shown that there is a need to underline the importance of science education prior to the early secondary years in Malta. The quantitative results have shown that the extent to which students are exposed to science during their primary years has a significant effect on their science awareness. The significance of Science and Technology during the Junior Years has also been underlined in major national policy education documents, such as the NCF (MEE, 2012) where it was proposed that it should make up 15% of the teaching and learning time. However, this is a far cry from what is presently (2017) being achieved, let alone from what was being done when the data for this research were collected (back in 2012/2013). More recently, it was also suggested that high-quality science instruction in schools should start at an earlier age to nurture interest among students with less supportive home environments (OECD, 2016).

Statistically significant differences were also found amongst students who planned to study a different number of science subjects in Form 3 with the degree of science awareness generally being higher among those choosing more science subjects to study during the following scholastic year. This makes sense in the light of previous research carried out in Malta by Mallia (2013) which showed that there is a strong relationship between socioeconomic status, measured by parents' level of education and cultural capital, and the number of science subjects studied in Form 3. These findings can thus be embedded in the same arguments discussed in the previous section for the high level of science awareness recorded for students attending Independent Schools who also usually come from socially privelegd backgrounds and that endow students with out-of-school opportunities that help them acquire a higher degree of science awareness.

Beyond schooling and social background, gender was also found to be an important aspect related to science awareness. Boys tend to be more able to decipher the hidden scientific element in personal, social and global issues. They also recognise more the risk and uneven distribution of scientific applications and are also more apt at recognising the importance of the Government, industrialists and citizens in the progress of scientific research. As in other studies (Azzopardi, 2008, Sjøberg & Schreiner 2010) girls have also been shown to see school science as more difficult and to have more preference for other subjects. In fact, PISA 2015 results have shown that less Maltese girls than boys are interested in pursuing a career in science (MEE, 2016a) corroborating previous research indicating that the number of females in science courses at the University of Malta is low when compared to other undergraduate courses (Micallef & Gatt, 2006).

From a global perspective, this difference has been attributed to social factors that may be affecting access at primary level (UNESCO, 2012). This is not a major problem in Malta as out-of-school students at this level are practically nil. In Malta, gender disparity in relation to sceince may therefore be more affected in this country by biases in classroom practices (Halai, 2011) that may be lacking in features that usually engage girls. Girls have been shown to be more interested in contexts of health and medicine, beauty and the human body, ethics, aesthetics, wonder and speculation while boys tend to be attracted more to the technical, mechanical, electrical, violent and explosive aspects. Girls are also more concerned about the environment than boys (Sjøberg & Schreiner, 2010). To address this gender gap, there should be more sustained focus on classroom initiatives that have been shown to engage girls more with science (Baker, 2013) and to promote equity (Kennedy & Sundberg, 2017). The former include student-centred instructional strategies, a curriculum that sustains girls' interests, early science instruction, focus on self-efficacy etc. The latter even include occupational options and educational pathway planning within the curriculum, examples of how science can improve the quality of living things, allowing students to monitor their own progress, etc. The learning activities used in the pilot project to raise science awareness featured several of these elements and, in fact, the group studied started to see science as less difficult following that scholastic year.

### 7.1.4 Raising Science Awareness

Since the learning activities in this research were implemented with a small number of students, any increase in science awareness detected should be interpreted with caution. Nevertheless, it was established that the levels of science awareness recorded through the journal were accurate as those students who demonstrated a low level of science awareness in their reflective journal were also the ones who manifested limited awareness during the interviews at the end of the scholastic year and did not improve on their mean scores in the questionnaire after the pilot study. In contrast, students scoring higher levels of science awareness through their journal scored higher means for all indicators of science awareness in the questionnaire at the end of the scholastic year and could elaborate further when probed by the teacher/researcher. Thus, the pedagogy of metacognitive reflection and the associated data collection methods used in the pilot study are useful to tackle science awareness and to also document the associated cognitive changes. They have also been shown to serve as practical instruments for enhancing and assessing beliefs related to science awareness during the course of an Integrated Science curriculum in Malta. This research also widened the use of metacognition in science education beyond the understanding of science concepts on which this research area has been largely focused (Zohar & Brazilai, 2013).

The pilot study has shown that heightened levels of science awareness do not necessarily result in behavioural intentions that lead to further engagement with science and citizen action. The student who exhibited the highest level of science awareness through her reflections in Phase 2 of this research (Melissa), did not feature as much passion and enthusiasm to take action in relation to scientific issues when compared to the student whose metacognitive reflections were not so well defined (Charmaine). Hodson (2010), in fact talks about these different dispositions to act in terms of variations in knowledge, self-esteem, values, commitment and emotional involvement. Beyond science awareness, more work has to be done to address these variations and to tackle what Ajzen & Fishbein (2008), in their theory of reasoned action and planned behaviour, call normative and control beliefs. In the formation of a behavioural intention, behavioural beliefs, (the students' beliefs about the consequences of engaging and taking action in relation to scientific issues) act in conjunction with beliefs about the normative expectations of others as well as beliefs with regards to the perceived ease or difficulty of performing this behaviour

As suggested by other national studies (Pace, 1996; Darmanin, 1996; Buhagiar, 2008; Debono, 2007), this research has also shown that subject specialisation should perhaps be deferred to an older age. Although an increase in science awareness was documented following the pilot study, these were not of a drastic magnitude. This shows that students' beliefs regarding the importance of science and science education are already strongly ingrained and most of the time seen only in the light of whether the wish to pursue a career in this area (Osborne & Collins, 2001). Additionally, students are being faced by the crucial decision of subject specialisation at a stage when they are not mature enough to decide on their own. They are consequently very much influenced by the opinions of relatives and significant others rather than the views and exposure they have acquired from their science education (Buhagiar, 2008; Debono, 2007).

This problem can also be addressed if students are exposed to more science and similar initiatives to promote science awareness prior to age 12. It is well known that in the early grades of school, language arts are dominant and even nationally, this leaves little room for other subjects such as science (Vassallo & Musumeci, 2012). There is thus a growing emphasis to integrate science inquiry with literacy activities in the early and primary years of schooling (Saul, 2004). Such an initiative has been the goal of the Science Literacy Project (SLT) (Purdue University, Indiana, U.S.) with a classroom and a classroom-home component targeted for kindergarten children. Research results have shown that children, even as early as kindergarten, who engaged in this project for longer periods of time reported higher overall motivational beliefs (Mantzicopoulos *et al*., 2008; Mantzicopoulos *et al*., 2013) as these activities communicate to the participants that science is worthwhile, exciting and not out of reach for them in addition to conveying a realistic idea of what science involves. Nolen (2001) also showed that the amount of time teachers allocate to activities communicates how much those tasks are valued and impact children's motivation.

Another important change observed following the pilot study was that students started to see science as a less difficult school subject. Previous studies have shown that the load of content tackled in science curricula renders the subject difficult and disenchanting for students (Azzopardi, 2008; Osborne & Collins, 2003). More emphasis in curricula on reflecting about learning rather than transmission of a lot of information helps students see science as a less difficult topic and will thus lead to more students being able to achieve the desired objectives. In all the activities, students were at the centre of all the discussions carried out. Their journal reflections also entailed them in being cognitively active and very much aware of their awareness of the topic and the context being tackled.

In summary, there is a need to address engagement in science from its very basis, from its cognitive strands, from the earliest possible years if we are to ensure that quality science education is really for all and that it will mould young people to become active to ensure sustainability of the planet.

## 7.2 Limitations of the Study

During the progress of this research, a number of factors have created a number of limitations on this study, in particular its methodological aspects as is outlined below:

- Data collection for this research was carried out between 2012 and 2016. During this time several changes took place in the educational system in Malta and which could have had an effect on the results recorded. To allow time for inputting and statistical analysis of data, the focus group discussions used to provide explanations of the questionnaire results were carried out one year after the numerical results were collected. Thus, the cohort of students who gave the focus group responses was different from those who answered the questionnaire. In addition, in State Schools they were the first cohort of Form 2 students who did not have to sit for the Junior Lyceum exam and thus were not channelled to different secondary schools according to academic abilities as the cohort who answered the questionnaire. Since school type was found to have an effect on science awareness, focus groups could not be carried out separately with students from Area Secondary and Junior Lyceums. Instead, they were carried out with a group of low and high achievers as identified by the School Management Teams.

- The questionnaire was distributed in Maltese with the majority of students.. Although the English version was used mainly with students from Independent Schools, data has shown that they are actually the ones who mainly speak in English. Although several precautions were taken to minimise the difference between the two questionnaires, the translation effect could not be completely eradicated. Such effects are also part of much more highly recognised studies such as ROSE and PISA where the instruments are administered in different languages across different countries.

- The researcher administered the majority of the questionnaires personally. This ensured that the researcher administered the questionnaire in the same way and explained any difficulties encountered consistently. However, there were a few schools whose SMT asked for the questionnaires to be administered by class teachers in the absence of the researcher. Although instructions were given to the readers, one cannot completely exclude differences in the way the administration of the questionnaire was handled.

- The science awareness learning activities were carried out in parallel to an Integrated Science curriculum over the course of a scholastic year. This implies that one cannot assign any changes in science awareness recorded solely and explicitly to the science awareness activities piloted. Other activities that were planned to address the more content-based areas of the curriculum might also have had an unintended effect on the beliefs and associated attitudes of the students.

- The teacher/researcher and the students who took part in the pilot study were using the techniques of metacognitive reflection intentionally for the first time during this study. Thus, one cannot exclude that such learning activities might have more positive effects if the students and the teacher/researcher were more trained to use these techniques in the classroom.

All in all, the study has raised several questions regarding science education in Malta, especially during the primary and early secondary years in particular with regards to the degree of exposure of students to school science at these levels and the ways it is taught. It has also provided possibilities for the introduction of new pedagogies that may intentionally help to engage more students in science as they are prepared to face complex scientific issues in their lives. A number of proposals for improvement in this field are discussed in the next section.

## 7.3 Recommendations

Through the issues that emerged from this research and the corresponding insights obtained, a number of recommendations with respect to school science and science education can be put forward.

- It is recommended that work on engaging more students in science, not only for the achievement of a career but also for its relevance in their everyday life should start prior to the early secondary stage. This research has confirmed other national and international findings, both in the cognitive (Haworth *et al*., 2008; Lindahl, 2007) and affective aspect (Baldacchino, 2010; Borg, 2013; Bennett & Hogarth, 2009; Camilleri, 1999; Gafa & Grima, 2000; Galton *et al.,* 2003; Osborne & Collins, 2003) of engagement to science, that have shown that beliefs and attitudes to science are already less optimistic at age 12. Primary science education and even early years (Gatt, 2012; Tunnicliffe, 2013) should be the focus of major policies aimed at engaging more students in science in the near future. If school science is not tackled seriously during these crucial years, then the formation of beliefs and attitudes regarding science and scientists are being left up to chance, or more specifically to the type of social background our students are born and raised in. This is also resulting in a lot of inequalities and reproduction of the *status quo* (MEE, 2016a; MEE 2016b).

- It is recommended that raising science awareness in the sense addressed in this study should extend beyond science classes to feature in the education of parents and significant others in the students' lives. Qualitative data, collected through this research, has shown that beyond schooling students engage in science conversations and activities mainly with close relatives with the topics discussed being about school science and options related to their science education. As other studies have shown (Buday *et al*., 2012; Maltese & Tai, 2011), it is evident that these conversations are having a strong effect on how students view science, science education and their future aspirations in the field. Parents should be more involved in their children's education, especially during the middle grades when this involvement seems to decline. This is sustained by Epstein (2008), who is the director of the *Centre of School, Family and Community Partnerships* and the National *Network of Partnership Schools* established at Johns Hopkins University. More parent involvement, attempting to transform them from 'adjuncts' to 'subjects' (Borg & Mayo, 2001) will also help to combat inequalities due to social background. A synthesis of 51 studies featuring The Impact of Parent and Community Involvement On Student Achievement, Effective Strategies to Connect Schools, Families and Community and Parent and Community Organising Efforts has shown that when parents play an active role, children achieve greater success as learners, regardless of socioeconomic status, ethnic/racial background, or the parents' own level of education (Henderson and Mapp, 2002).

- It is recommended to include learning activities that raise science awareness as part of an Integrated Science course in early secondary years in Malta. This research has shown that this is practically possible and does not result in shortcomings from the content traditionally included in these curricula.

- It is also recommended to differentiate between science courses beyond the early secondary years. This diversification of science curricula to achieve different goals was also recommended by Osborne & Dillon (2008). Phase 2 of this study has shown that at the end of Form 2 students have different behavioural intentions with regards to their science education. The traditional, fact-based science courses should remain for those students who need science for careers in this area. Basic science courses with a focus on the areas that will be personally used in everyday life and to train students to act on social and global scientific issues should also be provided. This is in line with the Core Science Programme proposed for secondary school science in *A Vision for Science Education in Malta* (MEEF, 2011b) and which, to date, has not been realised.

- Furthermore, one of the factors that can facilitate the development of such highly applied learning activities is that curricula are more thematic and less prescribed with more decisions being left up to the teachers' professional judgements in line with the needs and experiences of the students being addressed. If this is not allowed teachers become associated with technicians who deliver a standards-driven science curriculum that does not function well outside of school (Aikenhead *et al*., 2006). The Integrated Science curriculum (DQSE, 2014), upon which the learning activities for this research were planned, although addressing students with different academic abilities, included too much detail as to the exact content to be included in a particular area and even a formulation of the routes that should be taken to address these targets. The introduction of the Learning Outcomes Framework, LOF, with its emphasis on flexibility and which for Integrated Science is planned to start in the next couple of years would probably soften this problem, as is indicated in the introductory excerpt below:

  "The LOF will allow for flexibility in teaching and learning programmes in order to address specific needs and to build up strengths within the context of the learning communities in different colleges and schools. This concept of flexibility is promoted throughout the entire framework. While acknowledging that out-of-school factors such as poverty and social exclusion affect learner achievement, the LOF seeks to improve learners' learning experience by encouraging creativity,

> critical literacy, entrepreneurship and innovation at all levels. This will allow learners to reach their potential by connecting what they have learnt to their individual contexts. Consequently, this will help learners develop a positive attitude towards learning and a greater appreciation of its usefulness." (DQSE, 2017)

The proposals discussed have shown that more effort has to be focused by science education policy makers on engagement with science during the early years. More parental and familial active involvement is also recommended, especially in secondary schools where this seems to decline. Ideas for diversification of courses for science and non-science specialists are to be revisited with any proposed science curricula, allowing for more flexibility to allow teaching professionals to address the needs of all learners.

## 7.4 Suggestions for Further Research

This research on science awareness was restricted to 12-year old students in Malta. It would be interesting to employ longitudinal studies to investigate how this educational target changes from primary to higher levels of education both nationally and in other countries. Such research would also clearly indicate at which stage it is appropriate to tackle it and when the students are ready to move on to higher educational targets in the quest of science for citizenship.

In line with such longitudinal studies, further work can also be targeted at developing and piloting more learning activities similar to the ones carried out during this study with increased levels of sophistication as the students move from satisfactory levels of science awareness, as it is featured in this study, to becoming scientific literate and to eventually reach the ultimate aim of employing science for citizenship.

The concepts and application of meta-awareness and metacognitive reflection in targeting beliefs regarding science and science education have been tackled marginally in this study. More research could be specifically focused on this area to stretch the application of the use of metacognitive reflection and the associated increase in meta-awareness to areas beyond the acquisition of scientific concepts on which most of the research in the field of science education has been targeted.

## 7.5 Conclusion

As a teacher caught in the conundrum created by the curriculum, summative assessments, internal and external audits and parents' and students' expectations, it is very easy to end up being pushed by a strong economically-driven culture that puts the acquisition of individual excellence and competition above all else. This study has shown that science awareness is important for students' engagement with science and should be tackled in the early stages of education. With a lot of perseverance and good will, change is possible, if enough teachers live up to their professional status and take action to ensure that science education in our schools is based on democratic principles and leads to the common good and sustainability of our planet which are so crucial in this day and age.

## REFERENCES


AAAS, American Association for the Advancement of Science. (1993). *Benchmarks for Scientific Literacy*. New York: Oxford University Press.

Adams, J.D., Gupta, P. & De Felice, A. (2012). Schools and informal science settings: collaborate, co-exist or assimilate? *Cultural Studies of Science Education*, 7, 409-416.

Adi, B.D. & Nir, O. (2013). Teachers' Voices on Integrating Metacognition into Science Education. *International Journal of Science Education*, 35(18), 3161-3193.

Agar, M. & Mcdonald, J. (1995). Focus groups and ethnography. *Human Organisation,* 54, 78-86.

Aikenhead, G. (1996). Science education: border crossing into the subculture of science. *Studies in Science Education,* 27, 1-52.

Aikenhead, G. (2006). *Science Education for Everyday Life: Evidence-Based Practice*. New York: Teachers College Press.

Aikenhead, G., Barton Calabrese, A. & Chinn, P.W.U. (2006). Forum: Towards a Politics of Place-Based Science Education. *Cultural Studies of Science Education*, 1, 403-416.

Ainley, M. & Ainley, J. (2011). Student engagement with science in early adolescence: The contribution of enjoyment to students' continuing interest in learning about science. *Contemporary Educational Psychology,* 36, 4-12.

Ajzen, I. (1985). From intentions to actions: A theory of planned behaviour. In: Kuhl, J. & J. Beckman, J. (Eds.), *Actioncontrol: From cognition to behavior* (pp. 11–39). Heidelberg, Germany: Springer.

Ajzen, I. (1988). *Attitudes, personality, and behavior*. Chicago: Dorsey.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes,* 50, 179–211.

Ajzen, I., Driver, B. L., & Nichols, A. J.(1995). Identifying salient beliefs about leisure activities: Frequency of elicitation versus response latency. *Journal of Applied Social Psychology*, *25*, 1391–1410.

Ajzen, I., & Cote, N.G. (2008). Attitudes and the prediction of behaviour. *Attitudes and attitude change,* 289-311.

Albe, V. (2009). Students' positions and considerations of scientific evidence about a controversial
socioscientific issue. *Science and Education*, 17, 805–827.

Altrichter, H., Feldman, A., Posch, P. & Somekh, B. (2008). *Teachers investigate their work; An introduction to action research across the professions*. Routledge.

Anderson, D., Nashon, S., & Thomas, G.P. (2009). Evolution of research methods for probing and understanding metacognition. *Research in Science Education,* 39, 181-195.

Angell, C., Guttersrud, Ø., Henriksen, E. K., & Isnes, A. (2004). Physics: Frightful, but fun. Pupils' and teachers' views of physics and physics teaching. *Science Education*, *88*(5), 683-706.

Appiah, K. A. (2006). *Cosmopolitanism: Ethics in a world of strangers*. New York: W.W. NortonW.W. Norton.

Apple, M.W. (2006). *Educating the 'right' way*. New York: Routledge

Apple, M.W. (2011). Democratic education in neoliberal and neoconservative times. *International Studies in Sociology of Education*, 21 (1), 21-31.

Archer, L., Dawson, E., De Witt, J. Seakins, A. & Wong, B. (2015). "Science Capital": A Conceptual, Methodological and Empirical Argument for Extending Bourdieu Sian Notions of Capital Beyond the Arts, *Journal of Research in Science Teaching,* Vol. 52 (7), 922-948.

Archer, L., DeWitt, J., Osborne, J., Willis, B. & Wong, B. (2012). Science aspirations and family habitus: How families shape children's engagement and identification with science. *American Educational Research Journal,* 49(5), 881-908.

Aschbacher, P.R., Li,E. & Roth, E.J. (2010). Is science me? High schools students' identities, participation and aspirations in science engineering and medicine. *Journal of Research in Science Teaching,* 47, 564-582.

ASTA, Australian Science Teachers Association (2004). *The ASTA Science Awareness Raising Model.* An evaluation report prepared for the Department of Education, Science and Training. ASTA.

Azzopardi, C. (2008). *A Relevant Science Education in the 21st Century*. An unpublished Masters dissertation. University of Malta.

Azzopardi, R. (2004). *Maltese Secondary Level Students' Image of a Scientist*. An unpublished undergraduate dissertation, University of Malta.

Baker, D. (2013). What works: Using Curriculum and Pedagogy to increase Girls' Interest and Participation in Science. *Theory in Practice,* 52, 14-20.

Baker, D.R., Lewis, E.B., Purzer, S., Bueno Watts, N. & Lang, M. (2009). The communication in Science Inquiry Project (CISIP): A project to enhance scientific literacy through the creation of science classroom discourse communities. *International Journal of Science and Environmental Educaiton,* 4(3), 259-274

Bakhtin, M.M. (1981). Discourse in the novel (C. Emerson & M. Holquisi. Trans.) in M. Holquisi (Ed.), *The dialogic imagination* (pp.259 – 566) Austin: University of Texas Press.

Bakx, A., Bakker, A., Koopman, M. & Beijaard, D. (2016). Boundary crossing by science teacher researchers in a PhD program. *Teaching and Teacher Education,* 60, 76-87

Baldacchino, S. (2010). *The transition from integrated science to physics: the initial experience of Form 3 students*. An unpublished undergraduate dissertation. University of Malta.

Bamberger M.(2000) *Integrating Quantitative and Qualitative Research in Development Projects*. Washington DC: World Bank.

Barmby, P; Kind, P.M. & Jones, K. (2007). Developing Attitudes towards Science Measures. *International Journal of Science Education*, 29(7), 871-893.

Barmby, P; Kind, P.M. & Jones, K. (2008). Examining Changing Attitudes in Secondary School Science. *International Journal of Science Education* 30 (8), 1075–1093.

Bartholomew, H; Osborne, J.; & Ratcliffe, M. (2004). Teaching students "ideas-about-science": Five dimensions of effective practice. *Science Education*, 88(5), 655-682.

Barton, A.C. & Tan, E. (2010). "It Changed Our Lives": Activism, Science, and Greening the Community. *Canadian Journal of Science, Mathematics and Technology Education*, 10 (3), 207-222.

Bauman, Z. (1992). *Mortality, Immortality and other Life Strategies*. Stanford: Stanford University Press.

Bazzul, J. & Siatras, A. (2011). "Enough has yet to be said": Dialoguing neoliberal ideology, pedagogy, and subjectivity in science education. *Journal for Activism in Science and Technology Education,* 3(2), 2.

Beck, U. (1992). *Risk Society- Towards a New Modernity*. London: Sage Publications Limited.

Beck, U. (2000). *What is globalization?* Cambridge: Polity Press.

Beck, J.C., & Wade, M. (2004). *Got Game? How the Gamer Generation Is Reshaping Business Forever*. Cambridge: Harvard Business School Press.

Bell, J. (1993). *Doing Your Research Project*. Buckingham, Philadelphia: Open.

Ben-David, A. & Zohar, A. (2009). Contribution of meta-strategic knowledge to scientific inquiry learning. *International Journal of Science Education,* 31, 1657-1682.

Bencze, L. & Carter, L. (2011). Globalizing Students Acting for the Common Good. *Journal of Research in Science Teaching*, 48(6), 648-669.

Bennett, J. & Hogarth, S. (2009). Would you want to talk to a scientist at a party? High School Students' Attitudes to School Science and to Science. *International Journal of Science Education*, 31(14), 1975-1998.

Bergin, D.A. (1999). Influence on Classroom Interest. *Educational Psychologist,* 34, 87-98.

Birr Moje, E., Tucker-Raymond, E., Varelas, M. & Pappas, C.C. (2007). Giving oneself over to science – Exploring the roles of subjectivities and identities in learning science. *Cultural Studies in Education*, 2007(1), 593-601.

Black, R.W. (2005a). Access and Affiliation: The Literacy and Composition Practices of English Language Learners in an Online Fanfiction Community. *Journal of Adolescent & Adult Literacy*, 49 (2), 118-128.

Black, R.W. (2005b). Online fanfiction: What technology and Popular Culture Can Teach Us about Writing and Literacy Instruction. *New Horizons for Learning Online Journal*, 11 (2).

Boe, V.B., Henriksen, E.K., Lyons, T. & Schreiner, C. (2011). Participation in Science and Technology. *Studies in Science Education,* 47(1), 37-72.

Borg, J. (2004). *Secondary students' image of science presented in films.* An unpublished undergraduate dissertation. University of Malta.

Borg, S. (2013). "*It's not my Style." Students' Attitudes towards Science*. An unpublished undergraduate dissertation, University of Malta.

Borg, C., & Mayo, P. (2001). From'Adjuncts' to'Subjects': Parental involvement in a working-class community. *British Journal of Sociology of Education*, *22*(2), 245-266.

Bourdieu, P. (1984). *Distinction: A social critique of the judgement of taste* (Translated by R. Nice). London: Routledge and Kegan Paul, Ltd.

Bourdieu, P. (1986). Forms of capital. In J. Richardson (Ed.), *Handbook of theory and research for the sociology of education* (pp. 241–258).New York: Greenwood.

Brown, K.W. & Ryan, R.M. (2003). The benefits of being present: Mindfulness and its role in Psychological Well-Being. *Journal of Personality and Social Psychology,* 84(4), 822-848.

Bruner, J. (1996). *The Culture of Education*, London: Harvard University Press.

Bryman A. (1988). *Quantity and Quality in Social Research*. London: Routledge.

Buckingham, D. (2000). *The Making of Citizens: Young People, News and Politics*. London: Routledge.

Buday, S. K., Stake, J. E., & Peterson, Z. D. (2012). Gender and the choice of a science career: The impact of social support and possible selves. *Sex roles*, *66*(3-4), 197-209.

Buhagiar, J. (2008). *Factors and Influences affecting  Junior Lyceum students in choosing biology as an option*. An unpublished undergraduate dissertation. University of Malta.

Bulte, A.M.W, Westbroek, H.B., De Jong, O. & Pilot, A. (2006). A Research Approach to Designing Chemistry Education using Authentic Practices as contexts. *International Journal of Science Education,* 28(9), 1063-1086.

Bybee R.W. (1997). Towards an understanding of scientific literacy. In: W. Gräber & C. Bolte. (Eds.). *Scientific literacy. An international symposium* (pp. 37-68). Germany: Institut für die Pädagogik der Naturwissenschaften (IPN).

Bybee, R.W. (2008). Scientific Literacy, Environmental Issues, and PISA 2006: The 2008 Paul F-Brandwein Lecture. *Journal of Science, Education and Technology*, 17, 566–585.

Bybee, R.W. (2010). Advancing STEM Education: A 2020 Vision. *Technology and Engineering Teacher,* September, 2010.

Bybee, R.W. & McCrae, B. (2011). Scientific Literacy and Student Attitudes: Perspectives from
PISA 2006 Science. *International Journal of Science Education*. 33, (1), 7–26.

Cachia, M.C. (2014). *Determinants of school choice: Factors affecting Student Enrolment in Independent Schools in Malta*. An unpublished Master's dissertation. University of Malta.

Cakmakci, G., Tosun, O., Turgut, S., Orenler, S., Sengul, K. & Top, G. (2010). Promoting an Inclusive Image of Scientists among Students: Towards Research Evidence-Based Practice. *International Journal of Science and Mathematics Education*. 9, 627-655.

Calabrese Barton, A.M. (2012). Citizen(s') Science. A Response to "The Future of Citizen Science". *Democracy & Education*, 20(2), 1-4.

Camilleri, C. (1999). *Students' attitudes to science from primary to secondary*. An unpublished undergraduate dissertation. University of Malta

Camilleri, C.M. (2012). The development of Chiswick House School from the 20th century into the early 21st century. An unpublished undergraduate dissertation. University of Malta.

Camilleri, N. (2013) Budget 2014 – government proposes 250 measures. *Malta Independent,* 4 November. Available from: http://www.independent.com.mt/articles/2013-11-04/news/budget-2014-an-evening-of-numbers-and-proposals-3089694721/ [Accessed 3 Sep 2016].

Campbell, D.T. & Fiske, D.W. (1959). Convergent and discriminant validation by the multitraitmultimethod matrix. *Psychological Bulletin,* 56, 81–105.

Carey, M.A. (1994). The group effect in focus groups: planning, implementing and interpreting focus group research. In J. Morse (Ed.). *Critical Issues in Qualitative Research Methods,* pp. 225-241, Thousand Oaks, CA: Sage.

Carter, L. (2008). Globalization and Science Education. The Implications of Science in the New Economy. *Journal of Research in Science Teaching*, 45(5), 617-633.

Carter, L. (2010). Globalisation and science education; the case of Sustainability by the Bay. *Cultural Studies of Science Education,* 5, 275-291

Carter, L. (2011). Gathering in threads in the insensible global world: the wicked problem of globalisation and science education. *Cultural Studies of Science Education,* 6,1-12.

Carter, L. (2016). Neoliberalism and STEM Education. *Journal for Activist Science & Technology Education*, 7(1), 31-41.

Carter, L. & Dediwalage, R. (2010). Globalisation and Science Education: the case of Sustainability by the Bay. *Cultural Studies of Science Education*, 5: 275-291

Cassar, J. (2010). Citizens or consumers? *Youth identity in Malta.* An unpublished undergraduate dissertation. University of Malta.

Cassar, R. (1991). *Stress and the Junior Lyceum oriented student.* An unpublished undergraduate dissertation. University of Malta.

Castanho, M. (2005). Developing Students' Awareness of the Public Understanding of Science. A Matter of Survival? *Biochemistry and Molecular Biology Education,* 33, (3), 202-204.

Cech, E.A. (2014). Embed Social Awareness in Science Curricula. *Nature*, 505, 477-478.

Cerini, B., Murray, I., & Reiss, M. (2004). *Student review of the science curriculum.* London: Planet Science.

Chambers, D.W. (1983). Stereotypic images of the scientist: the Draw a Scientist Test. *Science Education,* 67(2), 255-265.

Chang, H. & Lee, H. (2013). College students' decision-making tendencies in the context of socioscientific issues (SSI). *Journal of Korean Association of Science Education*, 30(7), 887-900.

Chen, J. & Cowie, B. (2013). Developing 'Butterfly Warriors'; a Case Study or Science for Citizenship. *Research in Science Education*, 43, 2153-2177.

Chetcuti, D. (2009). *Primary Science: The views of Peripatetic Science Teachers and Key Administrators*. Mimeo.

Choi, K., Lee, H., Shin, N. and Kim, S.W. (2011). Re-conceptualisation of scientific literacy in South Korea for the 21st Century. *Journal of Research in Science Teaching,* 48(6), 670-697.

Christensen, N., Rundgren, S.N.C., & Zeidler, D.L. (2014). The relationship of discipline background to upper secondary students' argumentation on socioscientific issues. *Research in Science Education*, 44, 581-601.

Claussen S. & Osborne, J. (2013). Bourdieu's notion of cultural capital and its implication for the science curriculum, *Science Education*, 97(1), 58-79.

Cohen, L., Manion, L. & Reiss, M.J. (2000). *Research Methods in Education.* London: Routledge & Falmer.

Collucci-Gray, L.C.; Camino, E.; Barbiero, G. & Gray, D. (2006). From Scientific Literacy to Sustainability Literacy: An Ecological Framework for Education. *Wiley Periodicals, Inc. Sci. Ed* 90, 227– 252..

Conner, L. (2007). Cueing metacognition to improve researching and essay writing in a final year high school biology class. *Research in Science Education*, 37, 1-16.

Cooper, C.B. (2012). Links and Distinctions among Citizenship, Science and citizen science. *Democracy and Education,* 20 (2), 1-4.

Creswell, J.W. (2002). *Research Design: qualitative, quantitative and mixed method approaches*. (2nd. Ed.) California: Sage Publications.

Creswell, J.W., Fetters, M.D. & Ivankova, N.D. (2004). Designing a Mixed Methods Study in Primary Care. *Annals of Family Medicine*, 2, (1), 7-12.

Creswell J.W. & Plano Clark V.L. (2007). *Designing and Conducting Mixed Methods Research*. Thousand Oaks, CA: Sage.

Creswell, J. W., & Plano Clark, V. L. (2011). *Designing and conducting mixed-methods research* (2nd ed.) Thousand Oaks, CA: Sage.

Creswell, J.W. & Zhang, W. (2009). The Application of Mixed Methods Design to Trauma Research. *Journal of Traumatic Stress*, 22 (6), 612-621.

Dani, D. (2011). Sustainability as a Framework for Analyzing Socioscientific Issues. *International Electronic Journal of Environmental Education*, 1 (2), 113-128.

Darmanin, M. (1996). Closing options, Opening opportunities. In F. Ventura (Ed.), *Secondary Education in Malta: Challenges and Opportunities, 77-87*. Malta: MUT Publications.

Davies, I. (2004). Science and Citizenship Education. *International Journal of Science Education,* 26, (14), 1751–1763.

Dawson, V. & Venville, G. (2013). Introducing high school Biology students to argumentation about socioscientific issues. *Canadian Journal of Science, Mathematics and Technology Education*, 13(4), 356-372.

DeBoer, G.E. (2000). Scientific Literacy: Another Look at its Historical and Contemporary Meanings and its Relationship to Science Education Reform. *Journal of Research in Science Teaching,* 37(6), 582-601.

DeBoer, G.E. (2011). The globalisation of science education. *Journal of Research in Science Teaching,* 48 (6), 567-591.

Debono, C. (2006). *Subject Choice by second year students: to what extent is this choice influenced by future career aspirations*. University of Malta – Dip. Social Studies.

Debono, C. (2007). *A study of science/non science subject choice at post secondary level*. An unpublished undergraduate dissertation, University of Malta.

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum.

Degabriele, G. (2008). *Getting the right picture: helping secondary students adjust their preconceived ideas on the image of scientists and their work derived from media presentation.* An unpublished Masters dissertation. University of Malta.

Denzin, N.K. (1994). The art and politics of interpretation. In N.K. Denzin & Y.S. Lincoln (Eds.) *Handbook of qualitative research* (pp. 500-515). Thousand Oaks CA: Sage.

De Vaus, D.A. (1995). *Surveys in Social Research*. New South Wales: Allen & Unwin.

Dewey, J. (1933). *How we think*. Boston, D.C. Heath.

Dierks, P.O., Hoffler, T.N. & Parchmann, I. (2014). Profiling interest of students in science: Learning in school and beyond. *Research in Science and Technological Education,* 32(2), 97-114.

Dillon, J. T. (1994). *Using discussion in classrooms.* Buckingham: Open University Press.

Doyle L., Brady A. & Byrne G. (2009). An overview of mixed methods research. *Journal of Research in Nursing*, 14, 175–185.

DQSE, Directorate for Quality and Standards in Education Curriculum Management and eLearning Department. (2012). *Teaching Objectives and Learning Outcomes Form 2*. Available at: < http://curriculum.gov.mt/en/Curriculum/Form2/Documents/curric_f2/curric_f2_int_science_units.pdf> [Accessed 17 August 2013].

DQSE, Directorate for Quality and Standards in Education Curriculum Management and eLearning Department. (2014). *Handbook for the Teaching of Integrated Science*.

DQSE, Directorate for Quality and Standards in Education Curriculum Management and eLearning Department. (2017). *Learning Outcomes Framework. Science – Level 7 – Learning and Assessment Programme.*

Driver, R., Leach, J., Millar, R. and Scott, P. (1996) *Young People's Images of Science*. Buckingham: Open University Press.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education*, 84(3), 287–312.

Duggan, S. & Gott, R. (2002). What sort of science education do we really need? *International Journal of Science Education,* 24, (7), 661–679.

EC, European Commission. (2005). *Special Eurobarometer 224. Europeans, Science and Technology.* Directorate General Press and Communication.

EC, European Commission. (2008). *Flash Eurobarometer 238. Young people and Science*. The Gallop Organisation.

EC, European Commission. (2010). *Special Eurobarometer 340. Science and Technology*. Directorate General for Communication.

EC, European Commission. (2014). *Special Eurobarometer 419. Public Perceptions of Science, Research and Innovation.* Director General for Communication.

EC, European Commission. (2015*). Science Education for Responsible Citizenship.* Brussels: Directorate General for Research and Innovations.

Eccles J. S., Adler, T. F., Futterman, R., Goff, S. B., Kaczala, C. M., Meece, J. L., & Midgley, C. (1983). Expectancies, values, and academic behaviors. In J. T. Spence (Ed.), *Achievement and achievement motivation* (pp. 75–146). San Francisco, CA: W. H. Freeman.

Efklides, A. (2006). Metacognition and affect. What can metacognitive experiences tell us about the learning process? *Educational Research Review*, 1, 3-14.

Epstein, J. L. (2008). Improving family and community involvement in secondary schools. *The Education Digest*, *73*(6), 9.

Evagorou, M. (2011). Discussing a socioscientific issue in a primary school classroom: The case of
using a technology-supported environment in formal and nonformal settings. In T. Sadler
(Ed.), *Socio-scientific issues in the classroom* (pp. 133–160). London: Springer.

Evagorou, M., & Avraamidou, L. (2008). The role of technology in supporting the process of argument construction in science learning. *Educational Media International*, 45(1), 33–45.

Evagorou, M., Jimenez-Aleixandre, M.P. & Osborne, J. (2012). 'Should we kill the grey squirrels?' A Study Exploring Students' Justifications and Decision-Making, *International Journal of Science Education*, 34(3), 401-428.

Ezeh, M.E. (2015). Religion and Science for a Sustainable Environment. *International Journal of Arts and Sciences*, 8(1), 125-131

Falk, J. H. (Ed.). (2001). *Free-choice science education: How we learn science outside of school*. New York:Teachers College Press.

Falzon, A. (2003). *Implementing a primary science curriculum: identifying key factors for success*. An unpublished Master's dissertation, University of Malta.

Fensham, P.J. (2004). Increasing the Relevance of Science and Technology Education for All Students in the 21 st Century. *Science Education International,* 15 (1),7-27.

Fensham, P.J. (2008). *Science education Policy-Making: Eleven emerging issues*, Paris, UNESCO, 2008 at http://unesdoc.unesco.org/images/0015/001567/156700E.pdf (accessed 02/02/2010).

Fensham, P.J. (2014). Scepticism and Trust: two counterpoint essentials in science education for complex socio-scientific issues, *Cultural Studies of Science Education*, 9, 649-661.

Fenstermacher, G. (1994). The knower and the known: the nature of knowledge in research on teaching. In L. Darling-Hammond (Ed.) *Review of Research in Education*. Washington, DC: American Educational Researcher Association.

Fink, A. (1995). The Survey Handbook. Thousand Oaks, CA: Sage.

Fishbein, M. (1963). An investigation of the relationships between beliefs about an object and the attitude toward that object. *Human relations*, 16, 233-240.

Fishbein, M. (1967). Attitude and the prediction of behaviour in M. Fishbein (Ed.), *Readings in Attitude Theory and Measurement* , (pp.477-492), New York: Wiley.

Fishbein, M., & Ajzen, I. (1975). *Belief, Attitude, Intention, and Behavior: An Introduction to Theory and Research.* Reading, MA: Addison-Wesley.

Flavell, J.H. (1976). Metacognitive aspects of problem solving. In L. B. Resnick (Ed.), *The nature of intelligence* (pp. 231–236). Hillsdale, NJ: Erlbaum.

Flavell, J.H. (1979). Metacognition and cognitive monitoring. *American Psychologist,* 34, 906-911.

Flick, L. (1990). Scientists in residence program: Improving children's image of science and scientists. *School science and mathematics,* 90(3), 204-214.

Folch-Lyon, E. and Trost, J.F. (1981). Conducting focus group sessions. *Studies in Family Planning*, 12, 443-449.

Foong, C.C. & Daniel, E.G.S. (2013). Students' argumentation skills across two socio-scientific issues in a confucian classroom: is transfer possible? *International Journal of Science Education*, 35 (14), 2331-2355

Francis, L.J. & Greer, J.E. (1999). Measuring Attitude towards Science among Secondary School Students: the affective domain. *Research in Science and Technological Education*, 17, (2), 219-226.

Fredrickson, B.L. (2001). The role of positive emotions in positive psychology: The broaden-and-build theory of positive emotions. *American Psychologist*, 56, 218-226.

Fung, Y.Y.H. (2002). Drawing a scientists: What do we do and do not know after fifty years of drawings. *School Science and Mathematics*, 102, 335-345.

Funtowicz, S., & Ravetz, J. (1993). Science for the post-normal age. *Futures*, 25(7), 739–755.

Gable, R.K. & Wolfe, M.B. (1993). *Instrument Development in the Affective Domain.* Boston: Kluwer Academic Publishers.

Gafa, L. & Grima, A. (2000). *Attitudes towards science.* An unpublished undergraduate dissertation, University of Malta.

Galen, D. (2003). The concepts of "Self," "Person," and "I" in Western psychology and in Buddhism. In B. A.Wallace (Ed.), *Buddhism and science: Breaking new ground* (pp. 107–142). New York: Columbia University Press.

Galton, M.; Hargreaves, L.; & Pell, T. (2003). Progress in the middle years of schooling: Continuities and discontinuities at transfer. *Education*, 31(2), 9-18.

Gardner, P. L. (1995). Measuring attitudes to science: unidimensionality and internal consistency revisited, *Research in Science Education,* 25(3), 283–289.

Gatt, S. (2012). *CREATIVE LITTLE SCIENTISTS: Enabling Creativity through Science and Mathematics in Preschool and First Years of Primary Education.* Creative Little Scientists Consortium.

Gaydos, M.J. & Squire, K.D. (2012). Role playing games for scientific citizenship. *Cultural Studies in Science Education, 7, 821-844*

Gee, J.P. (2003). *Social Linguistics and Literacy. Ideologies in discourse.* New York: Routledge-Flamer.

Gee, J.P. (2004). *Situated Language and Learning: A Critique of Traditional Schooling*. New York: Routledge.

George, R. (2006). A Cross-domain Analysis of Change in Students' Attitudes toward Science and Attitudes about the Utility of Science. *International Journal of Science Education* 28,(6)571–589.

Giddens, A. (1990). *The consequences of modernity.* Stanford, CA: Stanford University Press.

Giddens, A. (1991). *Modernity and Self-Identity*. Self and Society in the Late Modern Age. Cambridge: Polity Press.

Girod, M., Rau, C., & Schepige, A. (2003). Appreciating the beauty of science ideas: Teaching for aesthetic understanding. *Science Education*, 87, 574 – 587.

Glynn, A. (2012). *Teachers' and Students' views of the 2012 Form 2 Integrated Science Curriculum*. An unpublished undergraduate dissertation. University of Malta.

Gonzales, P., Williams, T., Jocelyn, L., Roey, S., Kastberg, D., and Brenwald, S. (2008). *Highlights From TIMSS 2007:Mathematics and Science Achievement of U.S. Fourth- and Eighth-Grade Students in an International Context* (NCES 2009–001Revised). Washington, DC: National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education.

Goodrum, D., Hackling, M., & Rennie, L. (2001). *The Status And Quality Of Teaching And Learning Of Science In Australian Schools.* Canberra: Department of Education, Training and Youth Affairs.

Gough, A. (2011). (W)rapping relationships between science education and globalisation. *Cultural Studies of Science Education,* (2011), 6, 77-88.

Goulart, M. I. M. and Roth, W.M. (2006). Margin|centre: toward a dialectical view of participation. *Journal of Curriculum Studies*, 38(6), 679–700.

Graber, W.; Erdmann, T. & Schlieker, V. (2001). ParCIS: Aiming for Scientific Literacy through Self-Regulated Learning with the Internet. In: *Science and Technology Education: Preparing Future Citizens*. Proceedings of the IOSTE Symposium in Southern Europe (1st Paralimni, Cyprus, April29 – May 2, 2001).

Gray, S.A., Nicosia, K. & Jordan, R.C. (2012). Lessons Learned from Citizen Science in the Classroom, *Democracy and Education*, 20(2), 1-4.

Greene. J.C., Caracelli, V.J. & Graham, W.F. Toward a conceptual framework for mixed-method evaluation designs. *Educ Eval Policy Anal* (1989); 11 (3), 255–74.

Gregory, R.L. (1987). *The Oxford Companion to the Mind*. New York: Oxford University Press.

Halai, A. (2011). Equality or Equity: Gender Awareness issues in secondary schools in Pakistan. *International Journal of Educational Development,* 31(1), 44-49.

Hall, S.; Massey, D. & Rustin, M. After neoliberalism: Analysing the present. *Soundings* 53, April 2013, 8-22

Hansen, D.T. (2010). Cosmopolitanism and education: A view from the ground. *Teachers College Record,* 112 (1), 1-50.

Harlen, W. (2008). Science as a key component of the primary curriculum: a rationale with policy implications. *Perspectives on Education 1 (Primary Science)*, 2008,4–18.

Harvey, D. (2010). *The enigma of capital and the crisis of capitalism*. London: Oxford University Press.

Haste, H. (2004). *A Study of Values and Beliefs in relation to Science and Technology amongst 11-21 year olds.* London: Nestlé Social Research Programme.

Haworth, C.M.A.; Dale, P.S. & Plomin R. (2008). A Twin Study into the Genetic and Environmental Influences on Academic Performance in Science in 9-Year-Old Boys and Girls. *International Journal of Science Education* 30 (8), 1003-1025.

Henderson, A. T., & Mapp, K. L. (2002). A New Wave of Evidence: The Impact of School, Family, and Community Connections on Student Achievement. Annual Synthesis 2002. *National Center for Family and Community Connections with Schools*.

Hermes, J. (2006). *Citizenship in the Age of the Internet*. Downloaded from ejc.sagepub.com at Ebsco Electronic Journals Service (EJS) on April 30, 2011

Hicks, D. (1988) *Education for peace: Issues, principles and practice.* London: Routledge.

Hidi, S. & Renninger, K.A. (2006). The Four-Phase Model of Interest Development. *Educational Psychologist,* 41(2), 111-127.

Hidi, S., Renninger, K.A. & Krapp, A. (2004). Interest, a motivational variable that combines affective and cognitive functioning. In D.Y. Day & R.J. Sternberg (Eds.). *Motivation, emotion and cognition: Integrative perspectives on intellectual functioning and development*, (pp.89-115). Mahwah N.J.: Erlbaum.

Hili, P.Z. & Zammit, J. (1998). *Attitudes towards science: a study on Form 2 pupils.* An unpublished undergraduate dissertation. University of Malta.

Hodson, D. (1994). Seeking Directions for Change: the personalisation and politicisation of science education. *Curriculum Studies,* 2(1), 71-98.

Hodson, D. (2003). Time for Action: Science Education for an Alternative Future. *International Journal of Science Education*, 25 (6), 645 -670.

Hodson, D. (2010). Science Education as a Call to Action. *Canadian Journal of Science, Mathematics and Technology Education.* 10(3), 197-206.

Hodson, D. (2013). Don't be Nervous, Don't be Flustered, Don't be Scared. Be Prepared. *Canadian Journal of Science, Mathematics and Technology Education*, 13 (4), 313-331.

Holbrook, J. (1998). Operationalising scientific and technological literacy—a new approach to science teaching. *Science Education International,* 9(2), 13–19.

Holbrook, J. & Rannikmae, M. (2007). Nature of science education for enhancing scientific literacy. *International Journal of Science Education*, 29 (11), 1347-1362.

Holbrook, J. & Rannikmae, M. (2009). The Meaning of Scientific Literacy. *International Journal of Environmental and Science Education.* 4(3), 275-288.

Holstermann, N., Grube, D. & Bögeholz, S. (2010). Hands-on Activities and their influence on Students' Interest. *Research in Science Education*, 40, 743-757.

Howitt, C. & Rennie, L.J. (2008). *Scientists in Schools: Evaluation of the scientists in schools pilot project.* Perth: Curtin University of Technology.

Hull, G.A., Stornaiuolo, A. & Sahni, U. (2010). Cultural Citizenship and Cosmopolitan Practice: Global Youth Communicate Online. *English Education,* July 2010, 331 – 367.

Hurd, P.D. (1998). Scientific Literacy: New Minds for a Changing World. *Science Education,* 82, 407-416.

Iordanou, K. & Constantinou, C.P. (2014). Developing pre-service teachers' evidence-based argumentation skills on socio-scientific issues. *Learning and Instruction*, 34, 42-57.

Jackson, P. W. (1986). *The practice of teaching*. New York: Teachers College Press.

James, W. (1890). *The principles of psychology*. New York: Holt.

Jane, B., Fleer, M. & Gipps, J. (2007). *Changing children's views of science and scientists through school-based teaching*. Asia-Pacific Forum on Science Learning and teaching ,8(1), Article 11, 2 (June, 2007).

Jenkins, E. (1999). School science, Citizenship and the Public Understanding of Science. *International Journal of Science Education*, 21 (7), 703-710.

Jenkins, E. & Nelson, N.W. (2005). Important but not for me: students' attitudes toward secondary school science in England. *Research in Science and Technological Education*, 23, 41-57.

Jenkins, H. (2006). *Confronting the Challenges of Participatory Culture: Media Education for the 21st Century.* Chicago: John D. and Catherine T. MacArthur Foundation..

Jenkins, L.L. (2011). Using citizen science beyond teaching science content; a strategy for making science relevant to students' lives. *Cultural Studies of Science Education*, 6, 501-508.

Jensen, B.B. (2004). Environmental and Health Education viewed from an action-oriented perspective: a case from Denmark. *Journal of Curriculum Studies*, 36(4), 405-425.

Jianzhong, X., Coats, L.T., & Davidson, M.L. (2012). Promoting Student Interest in Science: The Perspectives of Exemplary African American Teachers, *American Educational Research Journal.* 49 (1), 124-154.

Jime´nez-Aleixandre, M.P., & Pereiro-Munoz, C. (2002). Knowledge producers or knowledge consumers? Argumentation and decision making about environmental management. *International Journal of Science Education*, 24(11), 1171–1190.

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed-methods research: A research paradigm whose time has come. *Educational Researcher,* 33(1), 14-26.

Kaptan, K. & Timurlenk, O. (2012). Challenges for Science Education, *Social and Behavioural Sciences,* 51(2012), 763-771.

Kemp, A.C. (2000). *Science Educator's View on the Goal of Scientific Literacy for All: An Interpretive Review of the Literature.* Paper presented at the Annual Meeting of the National Association for Science Teaching. April, 28, New Orleans, USA.

Kennedy, T. J., & Sundberg, C. (2017). International Perspectives and Recommendations on Equity and Gender: Development Studies in Science Education. In *Science Education: A Global Perspective* (pp. 295-311). Springer International Publishing.

Kessels, U.; Rau, M.; & Hannover, B. (2006). What goes well with Physics? Measuring and altering the image of science. *British Journal of Educational Psychology* (2006), 76, 761- 780.

Kim, M., Anthony, R., & Blades, D. (2014). Decision making through dialogue: a case study of analyzing preservice teachers' argumentation on socioscientific issues. *Research in Science Education*, 44. 903-926.

Kipnis, M. & Hofstein, A. (2008). The inquiry laboratory as a source for development of metacognitive skills. *International Journal of Science and Mathematics Education*, 6, 601-627.

Kitzinger, J. (1994). The mehodology of focus groups: the importance of interaction between research participants. *Sociology of Health and Illness,* 16(1), 103-121

Kleve, B. (2007). Mathematics teachers' interpretationsof the curriculum reform, L97 in Norway. An unpublished doctoral thesis, Agder University College, Norway.

Kleve, B. (2013). Social inequalities, meta-awareness and literacy in mathematics education. *Research in Mathematics Education*, 15(2), 197-198.

Kleve, B & Penne, S. (2012). Cross-curricularity in a literacy perspective: Contrast, confrontation and metalinguistic awareness. *International Journal of Educational Research*, 55, 48-56.

Klopfer, L.E. (1976). *A Structure for the Affective Domain in relation to Science Education.* Paper presented at the annual meeting of the National Association for Research in Science Teaching. (46th, Detroit, Michigan, March, 1973).

Koren, P. & Bar, V. (2009). Pupils' image of 'the Scientist' amongst two communities in Israel: A comparative study. *International Journal of Science Education,* 31 (18), 2485-2509.

Krapp, A. (2003). Interest and human development: An educational psychology perspective. *British Journal of Educational Psychology.* Monograph series II, 57-84.

Krapp, A. & Prenzel, M. (2011). Research on Interest in Science: Theories, methods and findings. *International Journal of Science Education,* 33(1), 27-50.

Krathwohl, D. R. (2009). *Methods of educational and social science research.* Long Grove, IL: Waveland Press.

Krummheuer, G. (1995). The ethnography of argumentation. In P. Cobb and H. Bauersfeld (eds) *Emergence of Mathematical Meaning* Hillsdale, NJ: Lawrence Erlbaum.

Kuhn, D. (1991). *The skills of argument*. Cambridge: Cambridge University Press.

Lakin, S. & Wellington, J.J. (1991). *Teaching the nature of science: a study of teachers' views of science and their implications for science education*. University of Sheffield.

Laszlo, E. (2001). *Macroshift: Navigating the transformation to a sustainable world.* San Francisco, CA: Berrett-Koehler

Laugksch, R.C. (2000). Scientific Literacy: A Conceptual Overview. *Science Education* 84, 71-94.

Lave, J. and Wenger, E. (1991). *Situated Learning: Legitimate Peripheral Participation*. Cambridge: Cambridge University Press.

Leary, M. R., & Tangney, J. P. (2003). The Self as an organizing construct in the behavioral and social sciences. In M. R. Leary & J. P. Tangney (Eds.), *Handbook of self and identity* (pp. 3–14). New York: Guilford.

Lederman, N.G. & Lederman, J.S. (2004). Revising Instruction to Teach Nature of Science. *Science Teacher*, 71(9), 36-39.

Lee, H., Yoo, J., Choi, K., Kim, S., Krajcik, J., Herman, B.C. & Zeidler, D.L. (2013). Socioscientific issues as a vehicle for promoting character and values for global citizens. *International Journal of Science Education*, 35:12, 2079-2113.

Lenhardt, A., & Madden, M. (2005). *Teen Content Creators and Consumers*. Washington, DC:
Pew Internet & American Life Project, November 2.

Levinson, R. (2010). Science education and democratic participation: an uneasy congruence? *Studies in Science Education*, 46(1), 69-119.

Lindahl, B. (2003). *Pupils' responses to school science and technology? A longitudinal study of pathways to upper secondary school*. A summary of a Ph.D. Theses, Kristianstad University, Sweden.

Lindahl, B. (2007). *A longitudinal study of students' attitudes towards science and choice of career.* Paper presented at the annual meeting of the National Association for Research in Science Teaching, New Orleans, LA.

Linn, M., Bell, P., & Davis, E. (2004). Specific design principles: Elaborating the scaffolded knowledge integration framework. In M. Linn, E. Davis, & P. Bell (Eds.), *Internet environments for science education* (pp. 315–339). New Jersey: Lawrence Erlbaum Associates.

Lutz, A., Dunne, J. D., & Davidson, R. J. (2007). Meditation and the neuroscience of consciousness. In P.D. Zelazo, M.Moscovitch, & E. Thompson (Eds.), *Cambridge handbook of consciousness* (pp. 499–554). New York: Cambridge University Press.

Lyons, T. (2006). Different Countries, Same Science Classes: Students experiences of school science in their own words. *International Journal of Science Education*, 28 (6), 591-913.

Macmillan Dictionary. Awareness - definition of awareness [document on the internet]. [accessed 2012 July 31st] Available from: http://www.macmillandictionary.com/dictionary/british/awareness

Malcolm, C., Gopal, N., Keane, M., & Kyle, W. C., Jr. (2009). Transformative action research: Issues and dilemmas in working with two rural South African communities. In K. Setati, R. Vithal, C. Malcolm, & R. Dhunpath (Eds.), *Researching possibilities in mathematics, science and technology education* (pp. 193–212). New York: Nova Science Publishers.

Mallia, R. (2013). Science Subject Choice and the Socioeconomic Status of pupils in Maltese Secondary Schools. *An unpublished undergraduate dissertation. University of Malta*.

Maltese, A.V. & Tai, R.H. (2010). Eyeballs in the Fridge: Sources of Early interest in science. *International Journal of Science Education*, 32(5), 669-685.

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. *Science Education*, *95*(5), 877-907.

Mantzicopoulos, P; Patrick, H. & Samarapungavan, A. (2008). Young childrens' motivational beliefs about learning science. *Early Childhood Research Quarterly*, 23, 378-394

Mantzicopoulos, P; Patrick, H. & Samarapungavan, A. (2013). Science Literacy in School and Home Contexts: Kindergarteners' Science Achievement and Motivation, *Cognition and Instruction,* 31(1), 62-119

Marks, R. & Eilks, I. (2008). Promoting Scientific Literacy Using a Sociocritical and Problem-oriented Approach to Chemistry Teaching: Concept, Examples, Experiences. *International Journal of Environmental and Science Education*, 4(3), 231-245.

Mathers, N., Fox, N. & Hunn, A. (1998). *Using Interviews in a Research Project*. *(Trent Focus Group)* [on-line]: http://www.trentfocus.org.uk/Resources/Using%20Interviews.pdf

Mathews, C.K. (2007). The News of Science, a Colloquium-style Course Designed to Promote Lifelong Scientific Awareness. *Biochemistry and Molecular Biology Education*, 35(2), 101–104.

McClaren, M. & Hammond, B. (2005). Integrating education and action in environmental education. In E.A. Johnson & M.J. Mappins (eds.), *Environmental education and advocacy: Changing perspectives of ecology and education* (267-291). Cambridge, England: Cambridge University Press.

McClune G. & Jarman, R. (2010). Critical Reading of Science-Based News Reports: Establishing a knowledge, skills and attitudes framework. *International Journal of Science Education* 32 (6), 727–752.

Mc Comas, W.F & Olson, J.K. (1998). The Nature of Science in International Science Education Standards Documents. In W.F. McComas (Ed.) *The Nature of Science in Science Education: Rationales and Strategies* (pp.41-52). Dordrecht: Kluwer.

McFarlane, D.A. (2013). Understanding the Challenges of Science Education in the 21st Century: New opportunities for Scientific Literacy. *International Letters of Social and Humanistic Sciences,* 4, 35-44

McMurty, J. (1999). *The cancer stage of capitalism.* London: Pluto.

MCST, Malta Council for Science and Technology. (2010). *The Malta Council for Science and |Technology Annual Report.* (available online) http://www.mcst.gov.mt/Media/136f7936-ca5f-48a1-a446-7a2995bd9052.pdf (accessed 04/09/2016)

MCST, Malta Council for Science and Technology. (2011). *The Malta Council for Science and |Technology Annual Report. Performance report and Financial Statements*. (available online) http://www.mcst.gov.mt/Media/ec5ee5ab-21a2-47e3-893b-6c8db6af2c04.pdf (accessed 04/09/2016)

MECYS, Ministry of Education, Culture, Youth and Sports. (2008). *Transition from Primary to Secondary Schools in Malta. A Review*. Floriana

MEE, Ministry for Education and Employment. (2012). *A National Curriculum Framework for All*. Malta: Salesian Press.

MEE, Ministry for Education and Employment. (2013a). TIMSS 2011. *Trends in International Mathematics and Science Study Malta Report.*

MEE, Ministry for Education and Employment. (2013b). *PISA 2009+ Programme for International Student Assessment Malta Report.*

MEE, Ministry of Education and Employment, (2016a), PISA 2015 National Report, Malta: Ministry of Education and Employment, (available online) https://researchanddevelopment.gov.mt/en/Documents/PISA%202009+%20Malta%20Report.pdf

MEE, Ministry of Education and Employment, (2016b), TIMSS 2015 National Report, Malta: Ministry of Education and Employment, (available online) https://curriculum.gov.mt/en/international_studies/Documents/TIMSS_2015_Malta_Report.pdf

MEEF, Ministry for Education, Employment and the Family. (2011a). *The National Curriculum Framework, 2011. Consultation Document 1*. Malta:Salesian Press.

MEEF, Ministry for Education, Employment and the Family. (2011b). *A Vision for Science Education in Malta, Consultation Document, 2011.* Malta: Salesian Press.

MEYE, Ministry for Education, Youth and Employment. (2005). *For All Children to Succeed. A New Network Organisation for Quality Education in Malta*. Malta: Salesian Press.

Micallef, C. & Gatt. S. (2006). *Gender preferences and science career choice.* Proceedings of the 3rd International Conference on Hands-on Science Science Education and Sustainable Development, Braga. 648-657.

Mifsud, J. (2012). *Language Practices in Science Education: Problems and Possible Solutions.* An unpublished undergraduate dissertation, University of Malta.

Millar, R. (2006). Twenty First Century Science: Insights from the Design and Implementation of a Scientific Literacy Approach in School Science. *International Journal of Science Education,* 28 (13), 1499-1521.

Millar, R., & Osborne, J. F. (Eds.). (1998). *Beyond 2000: Science Education for the Future*. London: King's College London.

Minstrell, J., & Van Zee, E. (Eds.). (2000). *Teaching in the inquiry-based science classroom. Washington*, DC: American Association for the Advancement of Science.

Morgan, D.L. (1988) *Focus Groups as Qualitative Research.* London: Sage.

Morgan, D. L. (1992). Designing focus group research. In M. A. Stewart, F. Tudiver, M. J. Bass, E. V. Dunn, & P. G. Norton (Eds.), Research methods for primary care, Vol. 2. Tools for primary care research (pp. 177-193). Thousand Oaks, CA, US: Sage Publications, Inc.

Morgan, D.L. (1996). Focus groups. *Annual Review of Sociology,* 22, 129-152.

Morgan, D.L., Zhao, P.Z. (1993). The doctor-caregiver relationship: managing the care of family members with Alzheimer's disease. *Qualitative Health Research.* 3, 133-164.

Morse, J. (1991). Approaches to qualitative–quantitative methodological triangulation. *Nursing Research*, 40, 120–123.

Mortimer, E., & Scott, P. (2003). *Meaning making in secondary science classrooms*. Maidenhead,
England: Open University Press.

Mueller, M., Tippins, D. & Bryan, L. (2012). The Future of Citizen Science. *Democracy & Education*, 20 (1), 1-12.

Murray, P. (2007). Citizen Education and Youth Participation in Democracy. *British Journal of Educational Studies*, 5,(3), 325-345.

Newman, I., & Benz, C.R. (1998). *Qualitative–quantitative research methodology: Exploring the interactive continuum*. Carbondale, IL: Southern Illinois University Press.

Newton L.D. & Newton, D.P. (1998). Primary children's conceptions of science and the scientist: Is the impact of a national curriculum breaking down the stereotypes? *International Journal of Science Education*, 14(3), 331-348.

Niglas, K. (2004). *The combined use of qualitative and quantitative methods in educational research* (Dissertations on social sciences). Tallinn: Tallinn Pedagogical University.

Nolen, S.B.. (2001). Constructing literacy in the kindergarten: Task structure. Collaboration and motivation. *Cognition and Instruction*, 18, 95-142.

Norris, S.P. & Phillips, L.M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education,* 87, 224-240.

NRC, National Research Council (1996). *National Science Education Standards*. Washington DC: The National Academy Press.

NRC, National Research Council. (2000). Inquiry and the national science education standards. Washington,DC: National Academy Press.

NSF, National Science Foundation (2014). *Science and Engineering Indicators.* Arlington VA: National Science Foundation (NSB 14-01).

Obidimalor Munro, R. (2006). *Young children's image of a scientist*. An unpublished undergraduate dissertation, University of Malta.

OECD, Organisation for Economic Cooperation and Development, (2003). *The PISA 2003 Assessment Framework Ð Mathematics, Reading, Science and Problem Solving Knowledge and Skills*. Paris: OECD.

OECD, Organisation for Economic Cooperation and Development, (2006). *Evolution of Student Interest in Science and Technology Studies*. Paris: OECD.

OECD, Organisation for Economic Cooperation and Development, (2009). *PISA 2009 Assessment Framework.* Paris: OECD.

Onwu, G. (2017). Towards a socially responsible science education. In *Science education: A Global Perspective* (pp.235-251). Springer, International Publishing.

OECD, Organisation for Economic Co-operation and Development. (2013). *PISA 2015 draft science framework*. France: OECD

OECD, Organisation for Economic Cooperation and Development, (2016). *PISA 2015 Results in Focus.* France: OECD

Onwuegbuzie, A.J., & Leech, N.L. (2005). Taking the 'Q' out of research: Teaching research methodology courses without the divide between quantitative and qualitative paradigms. *Quality & Quantity,* 39, 267–296.

Oon, P.T. & Subramaniam, R. (2014). On the Declining Interest in Physics amongst Students – From the perspective of teachers. *International Journal of Science Education,* 33(5), 727-746.

Oppenheim, A.N. (1992). *Questionnaire Design, Interviewing and Attitude Measurement.* London, UK: Pinter Publishers.

Ortlipp, M. (2008). Keeping and Using Reflective Journals in the Qualitative Research process. *The Qualitative Report,* 13, 695-705.

Osborne, J. & Collins, S. (2001). Pupils' Views of the Role and Value of the Science Curriculum: a Focus-Group Study. *International Journal of Science Education*, 23 (5), 441-467.

Osborne, J. & Collins, S. (2003). Attitudes towards Science: a Review of the Literature and its Implications. *International Journal of Science Education*, 25, (9), 1049-1079.

Osborne, J. & Dillon, J. (2008). *Science Education in Europe: Critical Reflections*. A report to the Nuffield Foundation.

Osborne, J., Ratcliffe, M., Collins, S., Millar, R., & Duschl, R. (2003). What 'ideas-about-science' should be taught in school science? A Delphi study of the 'Expert' community, *Journal of Research in Science Teaching*, 40(7), 692-720.

Osborne, J., S. Erduran, S. Simon, and M. Monk. (2001). Enhancing the quality of argument in school science. *School Science Review* 82 (301): 63–69.

Osborne, J., Erduran, S., & Simon, S. (2004). Enhancing the quality of argument in school science. *Journal of Research in Science Teaching*, 41(10), 994–1020

Pace, P. (ed.) (2000). *The State of Science Education in Malta.* Malta: The Malta Council for Science& Technology.

Palincsar, A.S. (1986). The role of dialogue in providing scaffolded instruction. *Educational Psychologist*, 21(1&2), 73-98.

Palincsar, A.S. (1998). Social constructivist perspectives on teaching and learning. *Annual Review of Psycholog,*. 49, 345-375.

Palincsar, A.S. & Brown, A.L. (1984). Reciprocal teaching of comprehension fostering and monitoring activities. *Cognition and Instruction*, 1,117-175.

Palincsar, A.S. & Brown, A.L. (1989) . Social constructivist perspectives on teaching and learning. *Annual Review of Psychology*, 49. 345-375.

Pell, T. & Jarvis, T. (2001). Developing attitude to science scales for use with children of ages from five to eleven years. *International Journal of Science Education*, 23(8), 847-862.

Peters, E.E. & Kitsantas, A. (2010). Self-regulation of student epistiemic thinking in science: the role of metacognitive prompts. *Educational psychology,* 30, 27-52.

Piaget, J. (1985). *The equilibrium of cognitive structures. The central problem of intellectual development.* Chicago, University of Chicago Press.

Pilot, A. & Bulte, A.M.W. (2006). Why do you "Need to know" context-based education? *International Journal of Science Education*, 28(9), 953-956.

Polit, D.F., & Hungler, B. P. (1999). *Nursing Research Principles and Methods.* (6th Ed.) Philadelphia: Lippincott.

Potvin, P. & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at K-12 levels: a systematic review of 12 years of educational research. *Studies in Science Education,* 50(1), 85-129.

Prain, V. (2012). Acting on Sustainability. *Research in Science Education*, 42, 149-154.

Print, M. (2007). Citizenship Education and Youth Participation in Democracy. *British Journal of Educational Studies,* 55(3), 325-345

Prokop, P., Prokop, M. & Tunnicliffe, S.D. (2007). Is biology boring? Student attitudes toward biology. *Journal of Biological Education,* 42(1), 36-39.

Pugh, K. J. (2002). Teaching for idea-based, transformative experiences in science: An investigation of the effectiveness of two instructional elements. *Teachers College Record*, 104, 1101 – 1137.

Pugh, K. J. (2004). Newton's laws beyond the classroom walls. *Science Education*, 88, 182 – 196.

Pugh, K. J., & Bergin, D. A. (2005). The effect of education on students' out-of-school experience. *Educational Researcher*, 34(9), 15 – 23.

Pugh, K. J., & Girod, M. (2007). Science, art and experience: Constructing a science pedagogy from Dewey's aesthetics. *Journal of Science Teacher Education*, 18, 9 – 27.

Pugh, K.J., Linnenbrink-Garcia, L., Koskey, K.K., Stewart, V. & Manzey, C. (2009). Motivation, Learning, and Transformative experience: A study of deep engagement in science. *Science Education,* 94, 1-28.

Punch, K.F. (1999). *Introduction to Social Research – Quantitative and Qualitative Approaches.* Wiltshire: Sage.

QCA, Qualifications and Curriculum Authority. (1998). *Education for citizenship and the teaching of democracy in schools. Final report of the Advisory Group on Citizenship*, 22 September, 1998. London: QCA

Ragin C.C., Nagel J. & White P. (2004). *Workshop on scientific foundations of qualitative research* (report from the National Science Foundation website). Available at: http://www.nsf.gov/pubs/2004/nsfo4219/nsfo4219.pdf (accessed 8 April 2006).

Ratcliffe, M & Grace, M. (2003). *Science Education For Citizenship: Teaching Socioscientific Issues.* London: Open University Press.

Ravetz, J. R. (1997). Simple scientific truths and uncertain policy realities: Implications for science education. *Studies in Science Education*, 30, 5-18.

Reiss, M & Tunnicliffe, S. (2001). What sorts of worlds do we live in nowadays? Teaching biology in a post-modern age. *Journal of Biological Education,* 35 (3), 125-129.

Reid, N. (2006). Thoughts on attitude measurement. *Research in Science and Technological Education.* 24 (1), 3-27.

Renninger, K.A. & Hidi, S. (2011). Revisiting the Conceptualization, Measurement, and Generation of Interest. *Educational Psychologist,* 46(3), 168-184.

Rocard, M. (2007). *Science Education Now: A Renewed Pedagogy for the Future of Europe*. Brussels: EC.

Rodrigues, S., Tytler, R., Darby, L., Hubber, P., Symington, D. & Edwards, J. (2007). The usefulness of a science degree. The "lost voices" of science-trained professionals. *International Journal of Science Education,* 29(11), 1411-1433.

Roeser, R.W. & Peck, S.C. (2009). An Education in Awareness: Self, Motivation and Self-Regulated Learning in Contemplative Perspective. *Educational Psychologist.* 44(2), 119-136

Roth, W.M. (2007). Toward a Dialectical Notion and Praxis of Scientific Literacy. *Journal of Curriculum Studies*, 39 (4), 377-398

Roth, W.M., Hwang, S., Goulart, M. I. M. and Lee, Y.-J. (2005). *Participation, Learning, and Identity: Dialectical Perspectives.* Berlin: Lehmanns Media.

Roth, W.M., & Lee, S. (2004). Science Education as/for Participation in the Community, *Science Education*, 88, 263-291.

Rusli, A. (2010). A Format for the Basic Science Lecture – Aiming at Science Awareness: Some Study Results. *Proceedings of the Third International Conference on Mathematics and Natural Science* ICMNS 2010, 579-586.

Rusli, A. (2012). Science and Scientific Literacy vs Science and Scientific Awareness through Basic Physics Lectures: A Study of Wish and Reality. *International Conference on Physics and its Applications* AIP Conf. Proc. 1454, 169-173 (2012).

Ryan, R.M. & Deci, E.L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, 55(1), 68-78.

Ryan, R.M. & Deci, E.L. (2008), A Self-Determination Theory Approach to Psychotherapy: The Motivational Basis for Effective Change. *Canadian Psychology,* 49(3), 186-193.

Ryder, J. (2002). School science education for citizenship: strategies for teaching about the epistemology of science. *Journal of Curriculum Studies*, 34(6), 637-658.

Sadler, T.D. (2009). Situated learning in science education: socio-scientific issues as contexts for practice. *Studies in Science Education*, 45 (1), 1-42.

Sadler, T. D., & Zeidler, D. L. (2004, April). *The significance of content knowledge for informal reasoning regarding socio-scientific issues: Applying genetics knowledge to genetic engineering issues.* Paper presented at the Annual meeting of the National Association for Research in science Teaching, Vancouver, BC.

Saferstein, B. (1995). *Focusing opinions: conversion, authority, and the (re) construction of knowledge.* Paper presented at the Annual meeting of the Americal Sociological Association, Washington, DC.

Sampson, V, Grooms, J. & Walker, J. (2010). Argument-Driven inquiry as a way to help students learn how to participate in scientific argumentation and craft written arguments: an exploratory study. *Science Education*, 95, 217-257

Santos, B. (2001). Nuestra America; Reinventing a Subaltern Paradigm of Recognition and Redistribution. *Theory into Practice*, 18, 185-217.

Santos, W.L.P. (2009). Scientific Literacy: A Freirean Perspective as a radical view of humanistic science education, *Science Education*, 93 (2), 361-382.

Santos, W.L.P. (2014). Debate of global warming as a socio-scientific issue: science teaching towards political literacy. *Cultural Studies of Science Education*, 9, 663-674

Saul, E. W. (2004). *Crossing Borders in Literacy and Science Instruction: Perspectives on Theory and Practice*. Newark: International Reading Association.

SCCC, Scottish Consultative Council on the Curriculum. (1996). *Science Education in Scottish Schools: Looking to the Future.* Broughty Ferry: Author.

Schiefele, U. (1991). Interest, learning and motivation. *Educational Psychologist,* 26, 299-323.

Schifferdecker, K.E. & Reed, V.A. (2009). Using mixed methods research in medical education: basic guidelines for researchers. *Medical Education,* 43, 637-644.

Schreiner, C. (2006). *Exploring a ROSE-garden. Norwegian youth's orientations towards science – seen as signs of late modern identities.* An unpublished doctoral dissertation, University of Oslo.

Schreiner, C. & Sjøberg, S. (2004). *Sowing the Seeds of Rose – Background, Rationale, Questionnaire Development and Data Collection for ROSE (The Relevance of Science Education) – a Comparative Study of Students' Views of Science and Science Education.* Department of Teacher Education and School Development, University of Oslo.

Schreiner, C. & Sjøberg, S. (2007). Science Education and Youth's Identity Construction – Two incompatible projects? In D. Corrigan, J. Dillon & R. Gunstone (Eds.) *The Re-emergence of values in the Science Curriculum* (pp.231-247). Rotterdam: Sense Publishers.

Selby, D. (1995). *Earthkind: A teacher's handbook on humane education*. Trentham: Trentham Books.

Senchina, D.S. (2010). Weaving Science and Civics through Interdisciplinary Courses. *Journal of College Science Teaching,* July/August, 2010, 44-51.

Sewell, W. H. (1999). The concept(s) of culture. In V. E. Bonnell and L. Hunt (eds), *Beyond the Cultural Turn: New Directions in the Study of Society and Culture* (pp.35-61). Berkeley: University of California Press.

Shamir, A., Zion, M., & Spector-Levi, O. (2008). Peer tutoring, metacognitive processes and multimedia problem-based learning: the effect of mediation training on critical thinking. *Journal of Science Education and Technology,* 17, 384-398.

Shamos, M.H. (1995). *The Myth of Scientific Literacy*. USA: Rutgers University Press.

Sharkawy, A. (2012). Exploring the potential of using stories about diverse scientists and reflective activities to enrich primary students' image of scientists and scientific work. *Cultural studies of science education,* 7, 307-340.

She, H.C. (1995). Elementary and Middle School Students' Image of Science and Scientists related to Current Science Textbooks in Taiwan. *Journal of Science Education and Technology,* 4(4), 283-294.

She, H.C. (1998). Gender and grade level differences in Taiwan's student stereotypes of science and scientists. *Research in Science and Technological Education*, 16, 125-135.

Silverstone, R. (2007). *Media & morality: on the rise of mediapolis*. UK: Cambridge.

Simon, S., Erduran, S., & Osborne, J. (2006). Learning to teach Argumentation: Research & Development in the Science classroom. *International Journal of Science Education*, 28 (2-3), 235-260.

Sjøberg, S. (2002). *Science for the children?* Report from the Science and Scientists-project (Acta Didactica 1/2002), Oslo, Norway; Department of Teacher Education and School Development, University of Oslo.

Sjøberg, S. & Schreiner, C. (2005). *Young People and Science: Attitudes, Values and Priorities: Evidence from the ROSE Project*. Keynote presentation at the European Union Science and Society Forum, Brussels, March, 2005. Also available at: http://www.ils.uio.no/forskning/rose

Sjøberg, S. & Schreiner, C. (2010). *The ROSE project. Overview and key findings*.

Smith, D.V., (2011). One brief, shining moment? The impact of neoliberalism on science curriculum in the compulsary years of schooling. *International Journal of Science Education*, 33 (9), 1273-1288.

Smith, M.W. (1995). Ethics in focus groups: a few concerns. *Qualitative Health Research.* 5, 478-486.

Solbes, J. & Traver, M. (2003). Against a negative image of science: History of science and the teaching of Physics and Chemistry. *Science and Education*, 12, 703-717.

Spektor-Levy, O., Eylon, B.S. & Scherz, Z. (2009). Teaching Scientific Communication skills in science studies: does it make a difference? *International Journal of Science and Mathematics Education*, 7, 875-903

Sperling, E. & Bencze, J.L. (2010). "More than particle theory: Citizenship through school science. *Canadian Journal of Science, Mathematics and Technology Education,* 10 (3), 255-266.

Spiteri, M. (2006). *The image of a scientist held by primary students in the junior years*. An unpublished undergraduate dissertation, University of Malta.

Spring, J. (2008). Research on globalization and education. *Review of Educational Research,* 78, 330-363

Steckler A., McLeroy K.R. & Goodman R.M. (1992). Toward integrating qualitative and quantitative methods: an introduction. *Health Education Quarterly,* 19, 1–8.

Stiglitz, J.E. (2003). *Globalization and its discontents*. New York: Norton.

Stewart, D. W., Shamdasani, P. N., & Rook, D. W. (2007). Applied Social Research Methods: Focus groups Thousand Oaks, CA: SAGE Publications Ltd

Stocklmayer, S. & Gilbert, J.K. (2002). New Experiences and Old Knowledge: towards a model for the personal awareness of science and technology. *International Journal of Science Education,* 24, (8), 835–858.

Sultana, A. (2011). *An investigation of the attitudes of secondary level students in Gozo (Malta) towards science education*. An unpublished undergraduate dissertation, University of Malta.

Suskie, L. (2009). *Assessing student learning: A common sense guide* (2nd ed.). San Francisco, CA: Jossey Bass.

Symington, S. & Tytler, R. (2004). Community leaders' views of the purposes of science in the compulsary years of schooling. *International Journal of Science Education*, 26 (11), 1403-1418.

Tai, R.T., Liu, C., Maltese, A.V. & Fan, X.T. (2006). Planning early for careers in science. *Science*, 312 (5777), 1143-1144.

Tashakkori A. & Teddlie C. (1998) *Mixed Methodology: Combining Qualitative and Quantitative Approaches*. Thousand Oaks, CA: Sage Publications Inc.

Tashakkori, A. & Teddlie, C. (2003). *Handbook of Mixed Methods in Social &. Behavioral Research*. Thousand Oaks: Sage

Taylor, L. (2007). The Language of Argumentation. Using debate to spark interest and learning in science. *The Science Teacher,* Summer 2013, 45-49.

Taylor, P., Lee, S.H. & Tal, T. (2006). Toward socio-scientific participation: changing culture in the science classroom and much more. *Cultural Studies in Science Education,* 1, 645-656

Teddlie, C. & Tashakkori, A. (2003). *Foundations of mixed methods research: Approaches in the social and behavioral sciences.* Thousand Oaks, CA: Sage.

Thomas, G.P. (1999). Student restraints to reform: Conceptual change issues in enhancing students' learning processes. *Research in Science Education,* 29, 89-109.

Tobin, K. (2011). Global reproduction and transformation of science education. *Cultural Studies of Science Education*, 6, 127-142.

Tomkins, S. & Tunnicliffe, S.D. (2007). Nature tables: Stimulating children's interest in natural objects. *Journal of Biological Education.* 41(4), 150-155.

Tomlin, R. & Villa, V. (1994). Attention in cognitive science and second language acquisition. *Studies in second language acquisition,* 16 (2), 183-203.

Toulmin, S. (1958). *The uses of argument*. Cambridge, England: Cambridge University Press.

Tunnicliffe, S.D. (2013). *Talking and Doing Science in the Early Years: A Practical Guide for Ages 2-7.* Routledge.

Tunnicliffe, S. & Reiss, M. (2000). Building a model of the environment: how do children see plants? *Journal of Biological Education,* 34(4), 172-177.

Turkmen, H. (2008). Turkish primary students' perceptions about scientists and factors affecting the image of the scientists. *Eurasia Journal of Mathematics, Science and Technology Education*, 4(1), 55-61.

UNESCO, United Nations Educational Scientific and Cultural Organisation, (2000). *Scientific and Technological Literacy for All.* New Dehli: UNESCO.

UNESCO, United Nations Educational Scientific and Cultural Organisation, (2001). *The training of trainers manual for promoting scientific and technological literacy for all.* Bangkok: UNESCO

UNESCO, United Nations Educational Scientific and Cultural Organisation, (2003). *Convention for the Safeguarding of the Intangible Cultural Heritage.* Paris: UNESCO.

UNESCO, United Nations Educational Scientific and Cultural Organisation, (2009). *Current Challenges in Science Education.* Paris: UNESCO.

UNESCO, United Nations Educational Scientific and Cultural organisation. (2012). *World atlas of gender equality in education.* Paris: UNESCO.

Vanderlinde, R. & Van Braak, J. (2010). The gap between educational research and practice: Views of teachers, school leaders, intermediaries and researchers. *British Educational Research Journal,* 36, 299-316.

Vassallo, C. (2010). Primary Science teaching in Malta: a study. An unpublished Master's dissertation. University of Malta.

Vassallo, C. & Musumeci, M. (2012, January). *Primary Science Teaching in Malta: A Study. Paper* presented at ASE Annual Conference, University of Liverpool, UK.

Vella, P.E. (2014). *Student Transition to University: Difficulties Experienced by Students following Science and Engineering Courses*. An unpublished undergraduate dissertation. University of Malta.

Vygotsky, L. (1986). *Thought and language.* Cambridge, MA: The MIT Press.

Wackernagel, M., Shulz, N. B., Diana, D., Callejas, L. A., Jenkins, M., Kapos, V., Monfreda, C., Loh, J., Myers, N., Norgaard, R., & Randers, J. (2002). *Tracking the ecological overshoot of the human economy*. Proceedings of the National Academy of Science of the United States of America, 99, 9266– 9271.

Watters, J.J. & Diezmann, C.M. (2013). Community Partnerships for Fostering Student Interest and Engagement in STEM. *Journal of STEM Education.* 14(2), 47-55.

Webb, N.M. (1989). Peer interaction and learning in small groups. *International Journal of Educational Research,* 13, 21-39

Weinstein, M. (2012). Schools/Citizen Science. A response to "The Future of Citizen Science". *Democracy and Education,* 20(1), 1-3

Wellington, J. (2001). What is science education for? *Canadian Journal of Science Mathematics and Technology Education,* 1:1, 23-38

Wertsch, J. V. (1991). *Voices of the mind: A sociocultural approach to mediated action*. Cambridge, MA: Harvard University

Wong, E. D., Pugh, K. J., & The Deweyan Ideas Group at Michigan State University. (2001). Learning science: A Deweyan perspective. *Journal of Research in Science Teaching*, 38, 317 – 336.

Wyss, V.L., Heulskamp, D. & Siebert, C.J. (2012). Increasing middle school student interest in STEM careers with videos of scientists. *International Journal of Environmental and Science Education,* 7(4), 501-522.

Yang, L.H.. (2010). Toward a deeper understanding of student interest of lack of interest in science. *Journal of College Science Teaching*, March/April 2010, 68-77.

Zahra, G.J. (2013). Neoliberalism, the EU and Science Education in the Maltese Curriculum. Available online: https://www.scribd.com/document/187558128/Neoliberalism-the-EU-and-Science-Literacy-Education-in-Malta

Zahra, G.J. (2015). Views of Science Education in Malta. *A Constructed Discourse between Academics of Science and Science Education.* An unpublished Master's dissertation, University of Malta.

Zeidler, D.L. & Keefer, M. (2003). The role of moral reasoning and the status of socioscientific issues in science education. In D. Zeidler (Ed.), *The role of moral reasoning and discourse on socioscientific issues in science education,* (pp.7-40). Dordrecht: Kluwer Academic Publishers.

Zeidler, D.L., Sadler, T.D., Simmons, M.L. & Howes, E.V. (2005). Beyond STS: A Research-Based Framework for Socioscientific Issues Education. *International Journal of Science Education*, 89, 357-377.

Zeidler, D., Walker, K., Ackett, W., & Simmons, M. (2002). Tangled up in views: beliefs in the nature of science and responses to socioscientific dilemmas. *Science Education*, 86(3), 343–367.

Zohar A. & Brasilai, S. (2013). A review of research on metacognition in science education: current and future directions. *Studies in Science Education,* 49(2), 121-169.

## APPENDICES A-K

# APPENDIX A QUESTIONNAIRE (ENGLISH)

The following is the questionnaire in the English language used to measure science awareness both during phase 1 and phase 2 of the study.

## M. PHIL. RESEARCH PROJECT: SCIENCE EDUCATION

Dear student,

In this booklet you will find questions about:

- you and your family and
- your views about science and science education

Please read each question carefully and answer as accurately as you can by ticking one box for each question. If you make a mistake when ticking a box, cross out or erase your mistake and mark the correct box.

**In this questionnaire, there are no right or wrong answers. Your answers should be the ones that are right for you.**

You may ask for help if you do not understand something or are not sure how to answer a question.

**Your answers will be combined with others to make totals and averages in which no individual can be identified. All your answers will be kept confidential.**

**THANK YOU! Your answers will be a great help.**

**Contact and ©: Claudette Azzopardi Tel. 27420753 Mob: 79283855**
**e-mail: cmif008@um.edu.mt**

## SECTION 1:YOUR VIEWS ABOUT SCIENCE

**A. To what extent do you agree that the following are related to science?**
*(Please tick only one box in each row)*

| | *Strongly disagree* | *Disagree* | *Agree* | *Strongly agree* |
|---|---|---|---|---|
| 1. whether to take the swine flu vaccine ................................ | ☐ | ☐ | ☐ | ☐ |
| 2. whether to breast-feed or bottle-feed a baby.................. | ☐ | ☐ | ☐ | ☐ |
| 3. choosing between a number of treatments for a deadly disease such as cancer................................................ | ☐ | ☐ | ☐ | ☐ |
| 4. whether to recycle waste......................................................... | ☐ | ☐ | ☐ | ☐ |
| 5. what type of food to buy.......................................................... | ☐ | ☐ | ☐ | ☐ |
| 6. what type of car to buy............................................................ | ☐ | ☐ | ☐ | ☐ |
| 7. whether to install a solar water heater............................... | ☐ | ☐ | ☐ | ☐ |
| 8. the type of transport to use................................................... | ☐ | ☐ | ☐ | ☐ |

**B. To what extent do you agree that the following are related to science?**
*(Please tick only one box in each row)*

| | *Strongly disagree* | *Disagree* | *Agree* | *Strongly agree* |
|---|---|---|---|---|
| 1. whether an area should be built or developed.................... | ☐ | ☐ | ☐ | ☐ |
| 2. whether pollution from a particular source, e.g. a power station, is a risk to health................................ | ☐ | ☐ | ☐ | ☐ |
| 3. where to set up wind farms to produce | ☐ | ☐ | ☐ | ☐ |

electricity from wind energy..................................................

4. whether those who destroy the environment should be made to pay........................................................ ☐ ☐ ☐ ☐

5. the type of power station to install e.g. gas power station or oil power station....................... ☐ ☐ ☐ ☐

6. the laws to control hunting of birds.................................. ☐ ☐ ☐ ☐

7. the laws to protect the habitat of rare animals............. ☐ ☐ ☐ ☐

8. where to build a landfill...................................................... ☐ ☐ ☐ ☐

9. the type of landfill to build................................................ ☐ ☐ ☐ ☐

10. whether fish farming is having a negative effect on the marine environment.................................................. ☐ ☐ ☐ ☐

11. whether alcoholic drinks should be prohibited for young people............................................... ☐ ☐ ☐ ☐

12. the type of transport systems to introduce................... ☐ ☐ ☐ ☐

13. the level of risk presented by slow changes, e.g. coastal erosion............................................................. ☐ ☐ ☐ ☐

14. the level of risk presented by fast changes, e.g. earthquakes, hurricanes............................................... ☐ ☐ ☐ ☐

15. the type of methods of waste disposal............................ ☐ ☐ ☐ ☐

16. how to control the spread of infectious diseases........... ☐ ☐ ☐ ☐

**C. To what extent do you agree that the following are related to science?**
*(Please tick only one box in each row)*

| | *Strongly disagree* | *Disagree* | *Agree* | *Strongly agree* |
|---|---|---|---|---|
| 1. Cloning of human beings........................................................ | ☐ | ☐ | ☐ | ☐ |
| 2. Getting rid of nuclear waste.................................................. | ☐ | ☐ | ☐ | ☐ |
| 3. Air pollution.......................................................................... | ☐ | ☐ | ☐ | ☐ |
| 4. Greenhouse gases and their effects on the climate.......................................................................... | ☐ | ☐ | ☐ | ☐ |
| 5. Competition between food against fuel production.......................................................................... | ☐ | ☐ | ☐ | ☐ |
| 6. Abortion.................................................................................. | ☐ | ☐ | ☐ | ☐ |
| 7. Population control e.g. China's one child policy................... | ☐ | ☐ | ☐ | ☐ |
| 8. Use of pesticides and the destruction of the ozone layer........................................................... | ☐ | ☐ | ☐ | ☐ |
| 9. Pandemics e.g. AIDS, swine flu, bird flu............................. | ☐ | ☐ | ☐ | ☐ |
| 10. Extinction of species............................................................ | ☐ | ☐ | ☐ | ☐ |
| 11. Exploration of space............................................................ | ☐ | ☐ | ☐ | ☐ |
| 12. Ecological balance.............................................................. | ☐ | ☐ | ☐ | ☐ |

**D. To what extent do agree with the following statements?**
*(Please tick only one box in each row)*

| | Strongly disagree | Disagree | Agree | Strongly agree |
|---|---|---|---|---|
| 1. The latest scientific applications are more risky than ever before | ☐ | ☐ | ☐ | ☐ |
| 2. The effects of science applications are always known exactly | ☐ | ☐ | ☐ | ☐ |
| 3. The effects of science applications are always safe | ☐ | ☐ | ☐ | ☐ |
| 4. Scientists often disagree with each other | ☐ | ☐ | ☐ | ☐ |
| 5. All scientists are responsible people | ☐ | ☐ | ☐ | ☐ |
| 6. We should always trust scientists | ☐ | ☐ | ☐ | ☐ |
| 7. The scientific method always leads to correct answers | ☐ | ☐ | ☐ | ☐ |
| 8. What scientists research is determined by politicians and industrialists | ☐ | ☐ | ☐ | ☐ |
| 9. Only scientists can find solutions for scientific issues such as global warming. | ☐ | ☐ | ☐ | ☐ |
| 10. Common citizens can control the progress of science | ☐ | ☐ | ☐ | ☐ |
| 11. Scientists often need to work with other experts e.g. economists | ☐ | ☐ | ☐ | ☐ |
| 12. People like me and my family have little chance to influence scientists | ☐ | ☐ | ☐ | ☐ |

13. The Government can control any dangerous developments in science........................................................... ☐ ☐ ☐ ☐

14. Science helps protect our planet for future generations.................................................................. ☐ ☐ ☐ ☐

15. Everyone benefits equally from the progress of science.... ☐ ☐ ☐ ☐

16. Science serves the rich at the expense of the poor............ ☐ ☐ ☐ ☐

17. Science can help solve social problems e.g. poverty.............. ☐ ☐ ☐ ☐

**The following question refers to this case based on a true story:**

*Paul* was recently paralysed when a heavy structure fell on him. Since then, he has been receiving stem cell treatment overseas to help him regain the use of his legs and he is getting better. Stem cell treatment is quite a new research area, is not available worldwide and not all experts agree about its benefits.*

*(*Real person's identity has been withdrawn)*

**E. State the extent to which you agree that the following are/were important for Paul* to improve his quality of life:**
*(Please tick only one box in each row)*

| | Strongly disagree | Disagree | Agree | Strongly agree |
|---|---|---|---|---|
| 1. knowing how his body works | ☐ | ☐ | ☐ | ☐ |
| 2. knowing about the curing effects of stem cells | ☐ | ☐ | ☐ | ☐ |
| 3. knowing where to look for reliable information about stem cell research | ☐ | ☐ | ☐ | ☐ |
| 4. comparing and evaluating the results obtained by different doctors/researchers | ☐ | ☐ | ☐ | ☐ |
| 5. analysing why different doctors/researchers obtained different results | ☐ | ☐ | ☐ | ☐ |
| 6. evaluating whether the risks of the treatment outweigh the benefits | ☐ | ☐ | ☐ | ☐ |
| 7. being able to listen to the views of others | ☐ | ☐ | ☐ | ☐ |
| 8. showing interest in scientific research | ☐ | ☐ | ☐ | ☐ |
| 9. being willing to take action to collect money for his treatment | ☐ | ☐ | ☐ | ☐ |
| 10. his school science education | ☐ | ☐ | ☐ | ☐ |

**The following question refers to this case:**

*The Malta Environment and Planning Authority on Monday, 5th December 2011 approved the use of heavy fuel oil over gas-oil as the main fuel for the Delimara power station extension. The people who live in the South of Malta did not agree with this decision as they argue that in contrast to gas-oil the burning of heavy fuel oil causes a lot of air pollution especially soot emissions.*

**F. State your level of agreement with the following statements:**
*(Please tick only one box in each row)*

Citizens who do not agree with this decision should:

| | *Strongly disagree* | *Disagree* | *Agree* | *Strongl agree* |
|---|---|---|---|---|
| 1. accept such a decision as good and final as it was taken by experts..... | ☐ | ☐ | ☐ | ☐ |
| 2. only speak up if the decision affects them personally..... | ☐ | ☐ | ☐ | ☐ |
| 3. write about the issue in newspapers, blogs etc..... | ☐ | ☐ | ☐ | ☐ |
| 4. take part in demonstrations to stop the project ..... | ☐ | ☐ | ☐ | ☐ |
| 5. take part in television debates regarding the issue..... | ☐ | ☐ | ☐ | ☐ |
| 6. collect useful data from different sources to understand the issue better..... | ☐ | ☐ | ☐ | ☐ |
| 7. collect signatures for a petition and present it to the relevant authorities..... | ☐ | ☐ | ☐ | ☐ |

**G. To what extent do you agree/disagree that school science has been helping you in the following areas?** *(Please tick only one box in each row)*

| | *Strongly disagree* | *Disagree* | *Agree* | *Strong agree* |
|---|---|---|---|---|
| 1. Understanding the world around you...................................... | ☐ | ☐ | ☐ | ☐ |
| 2. Understanding how scientists work. ........................................ | ☐ | ☐ | ☐ | ☐ |
| 3. Using scientific results to draw a conclusion........................ | ☐ | ☐ | ☐ | ☐ |
| 4. Distinguishing between what is right and wrong................... | ☐ | ☐ | ☐ | ☐ |
| 5. Taking care of your health........................................................ | ☐ | ☐ | ☐ | ☐ |
| 6. Understanding the importance of science in your lives........................................................................ | ☐ | ☐ | ☐ | ☐ |
| 7. Questioning the things or issues around you ........................ | ☐ | ☐ | ☐ | ☐ |
| 8. Participating in political action................................................ | ☐ | ☐ | ☐ | ☐ |
| 9. Presenting your opinions to others.......................................... | ☐ | ☐ | ☐ | ☐ |
| 10. Listening to people with different views............................... | ☐ | ☐ | ☐ | ☐ |
| 11. Negotiating possible solutions through democratic ways.............................................................. | ☐ | ☐ | ☐ | ☐ |
| 12. Willingness to participate in political action as a reflective citizen.............................................................. | ☐ | ☐ | ☐ | ☐ |
| 13. Strengthening your values e.g. human rights, tolerance, prudence towards the environment etc............... | ☐ | ☐ | ☐ | ☐ |

## SECTION 2: ABOUT YOU

**A. Are you female or male?**

Male ☐ Female ☐

**B. What type of school do you attend?**

Junior Lyceum ☐ Independent School ☐

Area Secondary ☐ Church School ☐

**C. What language do you speak most of the time?** (*Please tick only one box*)

Maltese ☐ English ☐ Other ☐

**D. How many science lessons did you have in the last year of primary schooling?**

No lessons ☐ Less than once a week ☐

Once a week ☐ More than once a week ☐

**E. What mark did you obtain in your last Integrated Science exam?**

less than 25 ☐ between 25 and 50 ☐

between 50 and 75 ☐ between 75 and 100 ☐

**F. How many science subjects/areas do you think you will choose to study in Form 3 (or Form 4)?** *(Please tick only one box)*

1 ☐ 2 ☐ 3 ☐

**G. How often do you carry out the following during your science lessons?**

(*Please tick only one box in each row)*

| | Never | Sometimes | Regularly | Very Often |
|---|---|---|---|---|
| 1. Discussion | ☐ | ☐ | ☐ | ☐ |
| 2. Listening to the teacher | ☐ | ☐ | ☐ | ☐ |
| 3. Watching the teacher do an experiment | ☐ | ☐ | ☐ | ☐ |
| 4. Doing an experiment yourself | ☐ | ☐ | ☐ | ☐ |
| 5. Working with friends | ☐ | ☐ | ☐ | ☐ |
| 6. Field work | ☐ | ☐ | ☐ | ☐ |
| 7. Reading or writing notes | ☐ | ☐ | ☐ | ☐ |
| 8. Community work | ☐ | ☐ | ☐ | ☐ |
| 9. Trying to solve a problem | ☐ | ☐ | ☐ | ☐ |

**H. How often do you carry out the following out-of-school activities?**

(*Please tick only one box in each row)*

| | Never | Sometimes | Regularly | Very Often |
|---|---|---|---|---|
| 1. Read science articles in newspapers | ☐ | ☐ | ☐ | ☐ |
| 2. Watch scientific documentaries | ☐ | ☐ | ☐ | ☐ |
| 3. Borrow or buy books about science topics | ☐ | ☐ | ☐ | ☐ |
| 4. Visit websites about science topics | ☐ | ☐ | ☐ | ☐ |
| 5. Listen to radio programmes about science | ☐ | ☐ | ☐ | ☐ |
| 6. Attend a science club | ☐ | ☐ | ☐ | ☐ |
| | ☐ | ☐ | ☐ | ☐ |

7. Visit a museum, zoo or aquarium................................

**I. To what extent do you agree with the following statements about science?**
*(Please tick only one box in each row)*

| | Strongly disagree | Disagree | Agree | Strongly agree |
|---|---|---|---|---|
| 1. Science is important for society.................................... | ☐ | ☐ | ☐ | ☐ |
| 2. Science makes our lives healthier, easier and more comfortable.......................................... | ☐ | ☐ | ☐ | ☐ |
| 3. I will use science in may ways when I am an adult........ | ☐ | ☐ | ☐ | ☐ |
| 4. Science is not useful in my everyday life........................ | ☐ | ☐ | ☐ | ☐ |
| 5. Science interferes with nature........................................ | ☐ | ☐ | ☐ | ☐ |
| 6. Scientific discoveries do more harm than good............ | ☐ | ☐ | ☐ | ☐ |
| 7. Science has ruined the environment.............................. | ☐ | ☐ | ☐ | ☐ |
| 8. Science is very important for a country's development.................................................................. | ☐ | ☐ | ☐ | ☐ |

**J. To what extent do you agree with the following statements about your science lessons?** *(Please tick only one box in each row)*

| | Strongly disagree | Disagree | Agree | Strongly agree |
|---|---|---|---|---|
| 1. School science is boring................................................... | ☐ | ☐ | ☐ | ☐ |
| 2. We do too much science at school.................................. | ☐ | ☐ | ☐ | ☐ |
| 3. I look forward to my science lessons............................. | ☐ | ☐ | ☐ | ☐ |
| 4. I would like to do more science at school...................... | ☐ | ☐ | ☐ | ☐ |
| 5. I like science better than most other subjects at school.................................................... | ☐ | ☐ | ☐ | ☐ |
| 6. School science is difficult................................................ | ☐ | ☐ | ☐ | ☐ |

## SECTION 3: YOUR FAMILY AND YOUR HOME

*In this section you will be asked some questions about your family and your home. Some of these questions are about your mother and father or those persons who are like a mother or father to you — for example, guardians, step-parents, foster parents, etc.*

**A. What is the highest level of schooling completed by your mother/female guardian?**

Primary ☐ Secondary ☐

Post-secondary ☐ Tertiary ☐

**B. Is your mother/female guardian active in any one or more of the following:**
*(Please tick only one box in each row)*

| | Yes | No |
|---|---|---|
| Local council........................................ | ☐ | ☐ |
| Political party........................................ | ☐ | ☐ |
| NGO (e.g. Birdlife, Friends of the Earth, Greenpeace)........................ | ☐ | ☐ |
| Trade Union........................................ | ☐ | ☐ |

**C. What is the highest level of schooling completed by your father/male guardian?**

Primary ☐ Secondary ☐

Post-secondary ☐ Tertiary ☐

**D. Is your father/male guardian active in any one or more of the following:**

*(Please tick only one box in each row)*

| | Yes | No |
|---|---|---|
| Local council ............ | ☐ | ☐ |
| Political party ............ | ☐ | ☐ |
| NGO (e.g. Birdlife, Friends of the Earth, Greenpeace) ............ | ☐ | ☐ |
| Trade Union ............ | ☐ | ☐ |

**E. Which of the following are in your home?**

*(Please tick only one box in each row)*

| | Yes | No |
|---|---|---|
| Computer/ Lap top/ i-pad ............ | ☐ | ☐ |
| An internet link ............ | ☐ | ☐ |
| An atlas or globe ............ | ☐ | ☐ |
| More than 50 books ............ | ☐ | ☐ |
| A microscope ............ | ☐ | ☐ |
| A telescope ............ | ☐ | ☐ |

# APPENDIX B QUESTIONNAIRE (Maltese)

The following is the translated version of the questionnaire in Maltese used as a quantitative measure of science awareness.

## PROĠETT TA' RIĊERKA TAL- M. PHIL:

## EDUKAZZJONI XJENTIFIKA

Għażiż student,

F'dan il-ktejjeb ser issib mistoqsijiet dwar:

- il-familja tiegħek u inti stess u
- l-opinjonijiet tiegħek dwar ix-xjenza u l-edukazzjoni xjentifika

Jekk jogħġbok aqra sew kull mistoqsija u wieġeb bl-aktar mod preċiż possibbli billi timmarka kaxxa waħda għal kull mistoqsija. Jekk tagħmel żball meta timmarka kaxxa, aqta' jew ħassar l-iżball tiegħek u mmarka l-kaxxa t-tajba.

**F'dan il-kwestjonarju, m'hemm l-ebda tweġiba tajba jew ħażina. It-tweġibiet tiegħek għandhom ikunu dawk li huma tajbin għalik.**

Tista' titlob l-għajnuna jekk ma tifhimx xi ħaġa jew m'intix ċert kif twieġeb xi mistoqsija.

**It-tweġibiet tiegħek ser jiġu magħquda ma' oħrajn biex jinħadmu l-ammonti totali u medji li permezz tagħhom ebda individwu ma jkun jista' jiġi identifikat. It-tweġibiet kollha tiegħek ser jinżammu kunfidenzjali.**

**GRAZZI! It-tweġibiet tiegħek ser ikunu ta' għajnuna kbira.**

**Ikkuntattja u ©: Claudette Azzopardi Tel. 27420753 Mob: 79283855**
**posta elettronika: cmif008@um.edu.mt**

## TAQSIMA 1: L-OPINJONIJIET TIEGĦEK DWAR IX-XJENZA

**A. Kemm taqbel li dawn li ġejjin huma relatati max-xjenza?**
*(Jekk jogħġbok immarka kaxxa waħda minn kull ringiela)*

| | *Ma naqbel xejn* | *Ma naqbilx* | *Naqbel* | *Naqbel ħafna* |
|---|---|---|---|---|
| 1. jekk tieħux il-vaċċin tas-*swine flu*........ | ☐ | ☐ | ☐ | ☐ |
| 2. jekk treddgħax jew tisqi lit-tarbija permezz ta' *bottle*.... | ☐ | ☐ | ☐ | ☐ |
| 3. L-għażla bejn numru ta' trattamenti għal mard fatali bħall-kanċer........ | ☐ | ☐ | ☐ | ☐ |
| 4. jekk tirriċiklax l-iskart........ | ☐ | ☐ | ☐ | ☐ |
| 5. x'tip ta' ikel tixtri........ | ☐ | ☐ | ☐ | ☐ |
| 6. x'tip ta' karozza tixtri........ | ☐ | ☐ | ☐ | ☐ |
| 7. jekk tinstallax *solar water heater*........ | ☐ | ☐ | ☐ | ☐ |
| 8. it-tip ta' trasport li tuża........ | ☐ | ☐ | ☐ | ☐ |

**B. Kemm taqbel li dawn li ġejjin huma relatati max-xjenza?**
*(Jekk jogħġbok immarka kaxxa waħda minn kull ringiela)*

| | *Ma naqbel xejn* | *Ma naqbilx* | *Naqbel* | *Naqbel ħafna* |
|---|---|---|---|---|
| 1. jekk żona partikolari għandiex tinbena jew tiġi żviluppata........ | ☐ | ☐ | ☐ | ☐ |
| 2. jekk it-tniġġis minn sors partikolari, eż. *power station*, huwiex ta' riskju għas-saħħa........ | ☐ | ☐ | ☐ | ☐ |
| 3. fejn jiġu stabbiliti impjanti tar-riħ għall-produzzjoni ta' elettriku mill-enerġija tar-riħ........ | ☐ | ☐ | ☐ | ☐ |

4. jekk dawk li jħassru l-ambjent għandhomx ikunu mġiegħla jħallsu........................................ ☐ ☐ ☐ ☐

5. it-tip ta' *power station* li għandha tiġi installata eż. *power station* tal-gass jew taż-żejt............................ ☐ ☐ ☐ ☐

6. il-liġijiet għall-kontroll tal-kaċċa tat-tjur........................ ☐ ☐ ☐ ☐

7. il-liġijiet għall-protezzjoni tal-ħabitat tal-annimali rari.............................................................. ☐ ☐ ☐ ☐

8. fejn tinbena miżbla............................................................... ☐ ☐ ☐ ☐

9. it-tip ta' miżbla li għandha tinbena.................................. ☐ ☐ ☐ ☐

10. jekk il-*fish farming* hux qed ikollu effett negattiv fuq l-ambejnt marittimu...................................................... ☐ ☐ ☐ ☐

11. jekk ix-xorb alkoħoliku għandux ikun ipprojbit għaż-żgħażagħ............................................ ☐ ☐ ☐ ☐

12. it-tip ta' sistemi tat-trasport li għandu jkun introdott................................................................. ☐ ☐ ☐ ☐

13. il-livell ta' riskju ppreżentat minn bidliet li jseħħu bil-mod, eż. erożjoni kostali.................................. ☐ ☐ ☐ ☐

14. il-livell ta' riskju ppreżentat minn bidliet li jseħħu malajr, eż. terremoti, uragani................................ ☐ ☐ ☐ ☐

15. it-tip ta' metodi użati għar-rimi tal-iskart...................... ☐ ☐ ☐ ☐

16. kif tkun ikkontrollata l-firxa ta' mard infettiv................ ☐ ☐ ☐ ☐

**C. Kemm taqbel li dawn li ġejjin huma relatati max-xjenza?**
*(Jekk jogħġbok immarka kaxxa waħda minn kull ringiela)*

| | *Ma naqbel xejn* | *Ma naqbilx* | *Naqbel* | *Naqbel ħafna* |
|---|---|---|---|---|
| 1. L-ikklownjar ta' persuni umani | ☐ | ☐ | ☐ | ☐ |
| 2. Il-qerda ta' skart nukleari | ☐ | ☐ | ☐ | ☐ |
| 3. It-tniġġis tal-arja | ☐ | ☐ | ☐ | ☐ |
| 4. Il-gassijiet serra u l-effetti tagħhom fuq il-klima | ☐ | ☐ | ☐ | ☐ |
| 5. Il-kompetizzjoni bejn il-produzzjoni tal-ikel u l-*fuel* | ☐ | ☐ | ☐ | ☐ |
| 6. L-abort | ☐ | ☐ | ☐ | ☐ |
| 7. Il-kontroll tal-popolazzjoni eż. il-politika ta' tarbija waħda taċ-Ċina | ☐ | ☐ | ☐ | ☐ |
| 8. L-użu ta' pestiċidi u l-qerda tal-*ozone layer* | ☐ | ☐ | ☐ | ☐ |
| 9. Mard pandemiku eż. AIDS, *swine flu, bird flu* | ☐ | ☐ | ☐ | ☐ |
| 10. L-estinzjoni ta' speċi | ☐ | ☐ | ☐ | ☐ |
| 11. L-esplorazzjoni tal-ispazju | ☐ | ☐ | ☐ | ☐ |
| 12. Il-bilanċ ekoloġiku | ☐ | ☐ | ☐ | ☐ |

**D. Kemm taqbel mad-dikjarazzjonijiet li ġejjin?**

*(Jekk jogħġbok immarka kaxxa waħda minn kull ringiela)*

| | *Ma naqbel xejn* | *Ma naqbilx* | *Naqbel* | *Naqbel ħafna* |
|---|---|---|---|---|
| 1. L-applikazzjonijiet xjentifiċi l-aktar reċenti huma aktar riskjużi minn qatt qabel........................................ | ☐ | ☐ | ☐ | ☐ |
| 2. L-effetti tal-applikazzjonijiet xjentifiċi huma dejjem magħrufa eżatt.............................................................................. | ☐ | ☐ | ☐ | ☐ |
| 3. L-effetti tal-applikazzjonijiet xjentifiċi huma dejjem mingħajr periklu............................................................... | ☐ | ☐ | ☐ | ☐ |
| 4. Ix-xjentisti spiss ma jaqblux ma' xulxin................................. | ☐ | ☐ | ☐ | ☐ |
| 5. Ix-xjentisti huma persuni responsabbli................................ | ☐ | ☐ | ☐ | ☐ |
| 6. Għandna dejjem nafdaw ix-xjentisti..................................... | ☐ | ☐ | ☐ | ☐ |
| 7. Il-metodu xjentifiku dejjem iwassal għal tweġibiet korretti.................................................................................. | ☐ | ☐ | ☐ | ☐ |
| 8. X'riċerka jagħmlu x- xjentisti hija determinata minn politiċi u industrijalisti........................................................... | ☐ | ☐ | ☐ | ☐ |
| 9. Huma biss ix-xjentisti li jistgħu jsibu soluzzjonijiet għal kwistjonijiet xjentifiċi bħal *global warming* ........................... | ☐ | ☐ | ☐ | ☐ |
| 10. Ċittadini komuni jistgħu jikkontrollaw il-progress tax-xjenza................................................................................ | ☐ | ☐ | ☐ | ☐ |
| 11. Ix-xjentisti spiss jeħtieġ li jaħdmu ma' esperti oħra eż. ekonomisti........................................................ | ☐ | ☐ | ☐ | ☐ |
| 12. Persuni bħali u bħall-familja tiegħi ftit jistgħu jinfluwenzaw ix-xjentisti......................................................... | ☐ | ☐ | ☐ | ☐ |

13. Il-Gvern jista' jikkontrolla kwalunkwe żviluppi perikolużi fix-xjenza.......................................................................
14. Ix-xjenza tgħin biex nipproteġu l-pjaneta tagħna għal ġenerazzjonijiet futuri.......................................................
15. Kulħadd jibbenefika l-istess mill-progress xjentifiku...........
16. Ix-xjenza sservi lis-sinjuri għad-detriment tal-fqar.............
17. Ix-xjenza tista' tgħin biex jiġu riżolti problemi soċjali eż. il-faqar.......................................................

**Il-mistoqsija li jmiss tirreferi għal dan il-każ li hu bbażat fuq storja vera:**

*Paul* safa' paralizzat reċentement meta waqqħet fuqu struttura tqila. Minn dakinhar hu beda jirċievi trattament ta'* stem cells *barra mill-pajjiż biex jgħinu jikseb lura l-użu ta' saqajh u l-kondizzjoni tiegħu qed titjieb. It-trattament bl-*istem cells *huwa qasam ta' riċerka pjuttost ġdid, mhux disponibbli fid-dinja kollha u l-esperti mhux kollha jaqblu dwar il-benefiċċji tiegħu.* *(*L-identità vera tal-persuna mhix żvelata)*

E. **Indika sa fejn taqbel li dawn li ġejjin huma/kienu importanti għal Paul* biex itejjeb il-kwalità tal-ħajja tiegħu:**

*(Jekk jogħġbok immarka kaxxa waħda minn kull ringiela)*

| | *Ma naqbel xejn* | *Ma naqbilx* | *Naqbel* | *Naqbel ħafna* |
|---|---|---|---|---|
| 1. ikun jaf kif jaħdem il-ġisem tiegħu........................................ | ☐ | ☐ | ☐ | ☐ |
| 2. ikun jaf dwar l-effetti tal-kura tal-*istem cells*............................................................................ | ☐ | ☐ | ☐ | ☐ |
| 3. ikun jaf fejn ifittex biex isib informazzjoni affidabbli dwar riċerka tal-*istem cells*....................................................... | ☐ | ☐ | ☐ | ☐ |
| 4. iqabbel u jevalwa r-riżultati miksuba minn tobba/riċerkaturi differenti....................... .................. | ☐ | ☐ | ☐ | ☐ |
| 5. janalizza għala tobba/riċerkaturi differenti kisbu riżultati differenti......................................................... | ☐ | ☐ | ☐ | ☐ |
| 6. jevalwa jekk ir-riskji tat-trattament jissuperawx il-benefiċċji......................................................... | ☐ | ☐ | ☐ | ☐ |
| 7. ikun kapaċi jisma' l-opinjonijiet ta' oħrajn............................... | ☐ | ☐ | ☐ | ☐ |
| 8. juri interess f'riċerka xjentifika................ ............................ | ☐ | ☐ | ☐ | ☐ |
| 9. ikun lest li jieħu azzjoni biex jiġbor il-flus għat-trattament tiegħu................................................. | ☐ | ☐ | ☐ | ☐ |
| 10. l-edukazzjoni xjentifika skolastika tiegħu............................... | ☐ | ☐ | ☐ | ☐ |

**Il-mistoqsija li jmiss tirreferi għal dan il-każ:**

*L-Awtorità Maltija tal-Ambjent u l-Ippjanar nhar it-Tnejn 5 ta' Diċembru 2011 approvat l-użu ta'* heavy fuel oil *minflok* gas-oil *bħala l-*fuel *ewlieni għall-estensjoni tal-power station ta' Dellimara. In-nies li jgħixu fin-Nofsinhar ta' Malta ma jaqblux ma' din id-deċiżjoni u argumentaw li meta mqabbel mal-*gas-oil, *l-użu ta'* heavy fuel oil *jikkawża tniġġis kbir tal-arja speċjalment l-emissjonijiet tan-nugrufun.*

**F. Indika l-livell ta' qbil mad-dikjarazzjonijiet li ġejjin:**
*(Jekk jogħġbok immarka kaxxa waħda minn kull ringiela)*

Iċ-ċittadini li ma jaqblux ma' din id-deċiżjoni għandhom:

| | *Ma naqbel xejn* | *Ma naqbilx* | *Naqbel* | *Naqbel ħafna* |
|---|---|---|---|---|
| 1. jaċċettaw din id-deċiżjoni bħala tajba u finali peress li ttieħdet minn esperti............ | ☐ | ☐ | ☐ | ☐ |
| 2. jitkellmu biss jekk id-deċiżjoni tolqothom personalment............ | ☐ | ☐ | ☐ | ☐ |
| 3. jiktbu dwar il-kwistjoni f'gazzetti, blogs eċċ............ | ☐ | ☐ | ☐ | ☐ |
| 4. jieħdu sehem f'dimostrazzjonijiet biex iwaqqfu l-proġett............ | ☐ | ☐ | ☐ | ☐ |
| 5. jieħdu sehem f'dibattiti televiżivi dwar il-kwistjoni............ | ☐ | ☐ | ☐ | ☐ |
| 6. jiġbru informazzjoni utli minn sorsi differenti biex jifhmu l-kwistjoni aħjar............ | ☐ | ☐ | ☐ | ☐ |
| 7. jiġbru firem għal petizzjoni u jippreżentawha lill-awtoritajiet relevanti............ | ☐ | ☐ | ☐ | ☐ |

*G.* **Kemm taqbel/ma taqbilx li x-xjenza fl-iskola kienet ta' għajnuna fl-oqsma li ġejjin?** *(Jekk jogħġbok immarka kaxxa waħda minn kull ringiela)*

| | *Ma naqbel xejn* | *Ma naqbilx* | *Naqbel* | *Naqbel ħafna* |
|---|---|---|---|---|
| 1. Biex tifhem id-dinja ta' madwarek | ☐ | ☐ | ☐ | ☐ |
| 2. Biex tifhem kif jaħdmu x-xjentisti | ☐ | ☐ | ☐ | ☐ |
| 3. Biex tuża riżultati xjentifiċi sabiex tasal għal konklużjoni | ☐ | ☐ | ☐ | ☐ |
| 4. Biex tiddistingwi bejn it-tajjeb u l-ħażin | ☐ | ☐ | ☐ | ☐ |
| 5. Biex tieħu ħsieb saħħtek | ☐ | ☐ | ☐ | ☐ |
| 6. Biex tifhem l-importanza tax-xjenza f'ħajjtek | ☐ | ☐ | ☐ | ☐ |
| 7. Biex issaqsi dwar l-affarijiet ta' madwarek | ☐ | ☐ | ☐ | ☐ |
| 8. Biex tipparteċipa f'azzjoni politika | ☐ | ☐ | ☐ | ☐ |
| 9. Biex tippreżenta l-opinjonijiet tiegħek lil oħrajn | ☐ | ☐ | ☐ | ☐ |
| 10. Biex tisma' lil persuni b'opinjonijiet differenti | ☐ | ☐ | ☐ | ☐ |
| 11. Biex ikunu nnegozjati soluzzjonijiet possibbli permezz ta' metodi demokratiċi | ☐ | ☐ | ☐ | ☐ |
| 12. Biex tkun lest tipparteċipa f'azzjoni politika bħala ċittadin li tirrifletti | ☐ | ☐ | ☐ | ☐ |
| 13. Biex issaħħaħ il-valuri tiegħek eż. id-drittijiet tal-bniedem, it-tolleranza, il-prudenza lejn l-ambjent eċċ. | ☐ | ☐ | ☐ | ☐ |

## TAQSIMA 2: INFORMAZZJONI DWAREK

**A. Inti ta' sess maskili jew femminili?**

Maskil ☐ Femminili ☐

**B. X'tip ta' skola tattendi?**

Junior Lyceum ☐ Skola Indipendenti ☐

Area Secondary ☐ Skola tal-Knisja ☐

**C. Kemm kien ikollok lezzjonijiet tax-xjenza fl-aħħar sena tal-edukazzjoni primarja?**

Xejn ☐ Inqas minn darba fil-ġimgħa ☐

Darba fil-ġimgħa ☐ Iktar minn darba fil-ġimgħa ☐

**D. B'liema lingwa titkellem ħafna mill-ħin?** *(Jekk jogħġbok immarka kaxxa waħda)*

Malti ☐ Ingliż ☐ Oħra ☐

**E. X'kienet il-marka li ksibt fl-aħħar eżami tal-*Integrated Science*?**

inqas minn 25 ☐ bejn 25 u 50 ☐

bejn 50 u 75 ☐ bejn 75 u 100 ☐

**F. Kemm taħseb li ser tagħżel suġġetti/oqsma tax-xjenza fil-Form 3 (jew Form 4)?** *(Jekk jogħġbok immarka kaxxa waħda)*

1 ☐ 2 ☐ 3 ☐

**G. Kemm isiru ta' spiss dawn li ġejjin waqt il-lezzjoni tax-xjenza tiegħek?**

*(Jekk jogħġbok immarka kaxxa waħda minn kull ringiela)*

| | *Qatt* | *Kultant* | *Regolarment* | *Ta' spiss ħafna* |
|---|---|---|---|---|
| 1. Diskussjoni | ☐ | ☐ | ☐ | ☐ |
| 2. Tisma' u tagħti każ lill-għalliem | ☐ | ☐ | ☐ | ☐ |
| 3. Tara lill-għalliem iwettaq esperiment | ☐ | ☐ | ☐ | ☐ |
| 4. Tagħmel esperiment inti stess | ☐ | ☐ | ☐ | ☐ |
| 5. Taħdem mal-ħbieb | ☐ | ☐ | ☐ | ☐ |
| 6. *Field Work* | ☐ | ☐ | ☐ | ☐ |
| 7. Taqra jew tikteb noti | ☐ | ☐ | ☐ | ☐ |
| 8. Xogħol fil-komunità | ☐ | ☐ | ☐ | ☐ |
| 9. Tipprova ssolvi problema | ☐ | ☐ | ☐ | ☐ |

**H. Kemm tagħmilhom ta' spiss dawn l-attivitajiet li ġejjin?**

*(Jekk jogħġbok immarka kaxxa waħda minn kull ringiela)*

| | *Qatt* | *Kultant* | *Regolarment* | *Ta' spiss ħafna* |
|---|---|---|---|---|
| 1. Taqra artikli tax-xjenza f'gazzetti | ☐ | ☐ | ☐ | ☐ |
| 2. Tara dokumentarji xjentifiċi | ☐ | ☐ | ☐ | ☐ |
| 3. Tissellef jew tixtri kotba dwar suġġetti xjentifiċi | ☐ | ☐ | ☐ | ☐ |
| 4. Tidħol f'websajts dwar suġġetti xjentifiċi | ☐ | ☐ | ☐ | ☐ |
| 5. Tisma' programmi tar-radju dwar ix-xjenza | ☐ | ☐ | ☐ | ☐ |
| 6. Tattendi klabb tax-xjenza | ☐ | ☐ | ☐ | ☐ |

| | | | | |
|---|---|---|---|---|
| 7. Iżżur mużew, żu jew akkwarju.................................. | ☐ | ☐ | ☐ | ☐ |

**I. Kemm taqbel mad-dikjarazzjonijiet li ġejjin dwar ix-xjenza?** *(Jekk jogħġbok immarka kaxxa waħda minn kull ringiela)*

| | *Ma naqbel xejn* | *Ma naqbilx* | *Naqbel* | *Naqbel ħafna* |
|---|---|---|---|---|
| 1. Ix-xjenza hija importanti għas-soċjetà........................ | ☐ | ☐ | ☐ | ☐ |
| 2. Ix-xjenza tagħmel ħajjitna aktar b'saħħitha, aktar faċli u aktar komda.......................... ..................... | ☐ | ☐ | ☐ | ☐ |
| 3. Jien ser nuża x-xjenza b'diversi modi meta nsir adult | ☐ | ☐ | ☐ | ☐ |
| 4. Ix-xjenza mhix utli għall-ħajja tiegħi ta' kuljum.......... | ☐ | ☐ | ☐ | ☐ |
| 5. Ix-xjenza tinterferixxi man-natura.............................. | ☐ | ☐ | ☐ | ☐ |
| 6. L-iskoperti xjentifiċi jagħmlu aktar ħsara milli ġid..... | ☐ | ☐ | ☐ | ☐ |
| 7. Ix-xjenza qerdet l-ambjent............................................ | ☐ | ☐ | ☐ | ☐ |
| 8. Ix-xjenza hija importanti ħafna għall-iżvilupp ta' pajjiż.................................................................... | ☐ | ☐ | ☐ | ☐ |

**J. Kemm taqbel mad-dikjarazzjonijiet li ġejjin dwar il-lezzjonijiet tax-xjenza?** *(Jekk jogħġbok immarka kaxxa waħda minn kull ringiela)*

| | *Ma naqbel xejn* | *Ma naqbilx* | *Naqbel* | *Naqbel ħafna* |
|---|---|---|---|---|
| 1. Ix-xjenza fl-iskola hija monotona................................. | ☐ | ☐ | ☐ | ☐ |
| 2. Nagħmlu wisq xjenza fl-iskola......................................... | ☐ | ☐ | ☐ | ☐ |
| 3. Jien inkun qed nistenna b'ħerqa kbira l-lezzjonijiet tax-xjenza..................................................... | ☐ | ☐ | ☐ | ☐ |
| 4. Jien nixtieq li nagħmlu aktar xjenza fl-iskola............... | ☐ | ☐ | ☐ | ☐ |
| 5. Jien nippreferi x-xjenza minn ħafna suġġetti oħra fl-iskola.......................................... | ☐ | ☐ | ☐ | ☐ |

6. Ix-xjenza fl-iskola hija diffiċli......................................... ☐ ☐ ☐ ☐

**TAQSIMA 3: IL-FAMILJA TIEGĦEK U D-DAR TIEGĦEK**

*F'din it-taqsima ser tiġi mistoqsi xi mistoqsijiet dwar il-familja tiegħek u d-dar tiegħek. Uħud minn dawn il-mistoqsijiet huma dwar ommok u missierek jew dwar dawk il-persuni li huma bħal ommok u missierek għalik – pereżempju, kustodji, step-parents, foster parents, eċċ.*

**A. X'inhu l-ogħla livell ta' skola li ommok/il-kustodja femminili tiegħek laħqet?**

Primarju ☐ Sekondarju ☐

Post-sekondarju ☐ Terzjarju ☐

**B. Ommok/il-kustodja femminili tiegħek hija attiva f'xi waħda jew aktar minn dawn li ġejjin:** *(Jekk jogħġbok immarka kaxxa waħda minn kull ringiela)*

| | *Iva* | *Le* |
|---|---|---|
| Kunsill Lokali............................................................................ | ☐ | ☐ |
| Partit Politiku............................................................................ | ☐ | ☐ |
| NGO (eż. Birdlife, Friends of the Earth, Greenpeace)........................... | ☐ | ☐ |
| Trade Union.............................................................................. | ☐ | ☐ |

**C. X'inhu l-ogħla livell ta' skola li missierek/il-kustodju maskili tiegħek laħaq?**

Primarju ☐ Sekondarju ☐

☐ ☐

Post-sekondarju Terzjarju

**D. Missierek/il-kustodju maskili tiegħek huwa attiv f'xi waħda jew aktar minn dawn li ġejjin:**

*(Jekk jogħġbok immarka kaxxa waħda minn kull ringiela)*

| | *Iva* | *Le* |
|---|---|---|
| Kunsill Lokali | ☐ | ☐ |
| Partit Politiku | ☐ | ☐ |
| NGO (eż. Birdlife, Friends of the Earth, Greenpeace) | ☐ | ☐ |
| Trade Union | ☐ | ☐ |

**E. Liema minn dawn li ġejjin issibhom f'darek?**

*(Jekk jogħġbok immarka kaxxa waħda minn kull ringiela)*

| | *Iva* | *Le* |
|---|---|---|
| Kompjuter/ Laptop/ i-pad | ☐ | ☐ |
| Link tal-internet | ☐ | ☐ |
| Atlas jew globu | ☐ | ☐ |
| Aktar minn 50 ktieb | ☐ | ☐ |
| Mikroskopju | ☐ | ☐ |
| Teleskopju | ☐ | ☐ |

## APPENDIX C: Permission of the Directorate for Quality and Standards in Education, DQSE to distribute the questionnaire in State Schools for Phase 1 of this study.

DIRETTORAT GĦAL
KWALITA' U STANDARDS FL-EDUKAZZJONI
FURJANA VLT 2000
MALTA

DIRECTORATE FOR
QUALITY AND STANDARDS IN EDUCATION
FLORIANA VLT 2000
MALTA

**Request for Research in State Schools**

A. (Please use BLOCK LETTERS)

Surname: AZZOPARDI Name: CLAUDETTE

I.D. Card Number: 570779M

Telephone No: 27420753 * Mobile No: 79283855 *

Address: 44, FLAT 2, MELWOOD PARK, TRIQ ANĠLU GATT

Locality: MOSTA Post Code: MST 4025

E-mail Address: cmif008@um.edu.mt

Faculty: EDUCATION Course: M. PHIL. Year Ending: 2016

Title of Research: RAISING THE LEVEL OF SCIENCE AWARENESS AMONG EARLY SECONDARY STUDENTS

Aims of research: ☐ Long Essay ☑ Dissertation ☐ Thesis ☐ Publication

Time Frame: THIRD TERM (SCHOLASTIC YEAR 2011-2012) Language Used: ENGLISH / MALTESE

Description of methodology: SURVEY - QUESTIONNAIRE

School/s where research is to be carried out: SECONDARY SCHOOLS - ONE GIRLS' SCHOOL AND ONE BOYS' SCHOOL / per college

Years / Forms: 2 Age range of students: 12

*** Telephone and mobile numbers will only be used in strict confidence and will not be divulged to third parties.**

**I accept to abide by the rules and regulations re Research in State Schools and to comply with the Data Protection Act 2001.**

**<u>Warning to applicants</u> - Any false statement, misrepresentation of concealment of material fact on this form or any document presented in support of this application may be grounds for criminal prosecution.**

Signature of applicant: C. Azzopardi Date: 4/2/2012

**B. Tutor's Approval** (where applicable)

The above research work is being carried out under my supervision.

Tutor's Name: Dr. Suzanne Gatt Signature: ____________

Faculty: Education Faculty Stamp: ____________

**C. Directorate for Quality and Standards in Education - Official Approval**

The above request for permission to carry out research in State Schools is hereby approved according to the official rules and regulations, subject to approval from the University of Malta Ethics Committee.

Raymond Camilleri
Director, RDD

Director Date: 17 / 02 /2012 Official Stamp
(Research and Development Department)

**Conditions for the approval of a request by a student to carry out research work in State Schools**

Permission for research in State Schools is subject to the following conditions:

1. The official request form is to be accompanied by a copy of the questionnaire and / or any relevant material intended for use in schools during research work.

2. The original request form, showing the relevant signatures and approval, must be presented to the Head of School.

3. All research work is carried out at the discretion of the relative Head of School and subject to their conditions.

4. Researchers are to observe strict confidentiality at all times.

5. The Directorate for Quality and Standards in Education reserves the right to withdraw permission to carry out research in State Schools at any time and without prior notice.

6. Students are expected to restrict their research to a minimum of students / teachers / administrators / schools, and to avoid any waste of time during their visits to schools.

7. As soon as the research in question is completed, the Directorate for Quality and Standards in Education assumes the right to a full copy (in print/on C.D.) of the research work carried out in State Schools. **Researchers are to forward the copies to the Assistant Director, International Research, Directorate for Quality and Standards in Education.**

8. Researchers are to hand a copy of their Research in print or on C.D. to the relative School/s.

9. In the case of video recordings, researchers have to obtain prior permission from the Head of School and the teacher of the class concerned. Any adults recognisable in the video are to give their explicit consent. Parents of students recognisable in the video are also to be requested to aprove that their siblings may be video-recorded. Two copies of the consent forms are necessary, one copy is to be deposited with the Head of School, and the other copy is to accompany the Request Form for Research in State Schools. Once the video recording is completed, one copy of the videotape is to be forwarded to the Head of School. The Directorate for Quality and Standards in Education reserves the right to request another copy.

10. The video recording's use is to be limited to this sole research and may not be used for other research without the full consent of interested parties including the Directorate for Quality and Standards in Education.

**APPENDIX D: Permission of the Secretariat for Catholic Education to distribute the questionnaire in Church Schools for Phase 1 of the study.**

**MALTESE EPISCOPAL CONFERENCE**
**Secretariat for Catholic Education**

The Head
All Church Schools

20th February 2012

Ms Claudette Azzopardi, currently reading a PhD (Science) at the University of Malta, hereby requests permission to conduct questionnaires with form 2 students.

The Secretariat for Catholic Education finds no objection for Ms Claudette Azzopardi to carry out the stated exercise subject to adhering to the policies and directives of the school concerned.

Fr Charles Mallia
Archbishop's Delegate for Church Schools

Secretariat for Catholic Education, 16, The Mall Floriana, FRN 1472. Tel: 27790060
E-mail: charles.mallia@maltadiocese.org

## APPENDIX E: Consent Forms for distribution of the questionnaire during Phase 1 of this study.

44  Flat 2 Melwood Park
Triq Anglu Gatt
Mosta MST4025
31st January 2012

The Head
«Company_Name»
«Address_Line_1»

Dear Sir/Madam,

I am a Ph.D. student at the University of Malta currently working on a research project to enhance science awareness amongst early secondary students. In this study, science awareness is being articulated as a recognition of the ways science pervades our lives and the competencies, values and attitudes needed to engage with science-based life situations.

The first session of data collection will be during the third term of this scholastic yea during which an anonymous questionnaire will be distributed to a sample of Form 2 students in Maltese schools. Currently the necessary permissions are being sought to implement the first part of the project.

I am writing this letter to ask your consent to carry out this research in your school. Subject to your approval, an anonymous questionnaire will be distributed by me or a research assistant to **one Form 2 class** of mixed ability students. The questionnaire will take approximately the **duration of one lesson**.

Whilst hoping for your support for this research, I hope to hear from you soon.

Yours sincerely,

Claudette Azzopardi

P.S. Kindly fill in the attached form and return in the self-addressed envelope by **15 th February**

# CONSENT FORM – STATE SCHOOLS

I, the undersigned, Head of School of _______________________________________________ (name of school/college) **am willing/ am not willing** to allow my school to participate in the research project – *Raising the level of Science Awareness among Early Secondary Students*.

I understand that during the course of this project the students' responses will be kept strictly confidential and that none of the data released in this study will identify them by name or any other data, descriptions, or characterizations. Furthermore, I understand that I may discontinue my school's participation in this project at any time.

I fully understand that this research is being conducted for constructive educational purposes and that my signature gives my consent for one Form 2 class from my school to fill in an anonymous questionnaire subject to approval of this tool by the *Directorate for Quality and Standards in Education* (DQSE) and of *The University Research Ethics Committee* (UREC).

Signature ________________________________________ Date ________________________

Rubber School Stamp:

## FORMOLA TA' KUNSENS

Jien, il-ġenitur ta' ________________________________________ naċċetta li binti timla' kwestjonarju dwar l-edukazzjoni xjentifika li qiegħed jinġabar bħala parti mill-proġett ta' riċerka *Raising the level of science awareness among early secondary students.* Nifhem li t-tifla mhix mistennija tikteb isimha fuq dan il-kwestjonarju u li kull informazzjoni li tinġabar se tintuża biss għal skopijiet ta' riċerka.

Firma tal-ġenitur ________________________________________

Data ________________________________

F'każ ta' diffikulta' ċempel fuq 79283855 jew ibgħat e-mail fuq cmif008@um.edu.mt indirizzat lil Claudette Azzopardi (Riċerkatriċi – Universita' ta' Malta).

## FORMOLA TA' KUNSENS

Jien, il-ġenitur ta' ________________________________________ naċċetta li binti timla' kwestjonarju dwar l-edukazzjoni xjentifika li qiegħed jinġabar bħala parti mill-proġett ta' riċerka *Raising the level of science awareness among early secondary students.* Nifhem li t-tifla mhix mistennija tikteb isimha fuq dan il-kwestjonarju u li kull informazzjoni li tinġabar se tintuża biss għal skopijiet ta' riċerka.

Firma tal-ġenitur ________________________________________

Data ________________________________

F'każ ta' diffikulta' ċempel fuq 79283855 jew ibgħat e-mail fuq cmif008@um.edu.mt indirizzat lil Claudette Azzopardi (Riċerkatriċi – Universita' ta' Malta).

**APPENDIX F: Permission granted by the University Research Ethics Committee (University of Malta) to distribute the questionnaire during Phase 1 of this study.**

## UNIVERSITY OF MALTA

**Request for Approval of Human Subjects Research**
Please type. Handwritten forms will not be accepted
You may follow this format on separate sheets or use additional pages if necessary.

| | |
|---|---|
| FROM: *(name, address for correspondence)*<br>Claudette Azzopardi<br>44, Flat 2, Melwood Park<br>Triq Anglu Gatt<br>Mosta MST4025 | PROJECT TITLE:<br><br>RAISING THE LEVEL OF SCIENCE AWARENESS AMONG EARLY SECONDARY STUDENTS |
| TELEPHONE: 27420753/ 79283855 | |
| E-MAIL<br>cmif008@um.edu.mt | |
| COURSE AND YEAR:<br>Master of Philosophy in Education (2010) | |
| DURATION OF ENTIRE PROJECT:<br><br>from 2010 to 2016 | FACULTY SUPERVISOR'S NAME:<br><br>Dr. Suzanne Gatt,<br>Senior Lecturer,<br>Primary Science & Environmental Education |

ANTICIPATED FUNDING SOURCE: n/a
*(include grant or contract number if known)*

1. Please give a brief summary of the purpose of the research, in non-technical language.

The main target of this research is to enhance the level of science awareness of Form 2 students attending Maltese schools. In this study, science awareness is being articulated as a recognition of: the extent to which science pervades our lives; the knowledge, competencies, attitudes and values needed to engage with science-based life situations; and the importance of the role of science education in the development of these attributes.

At this stage, permission is being sought for the first stage of this research project- that of obtaining a measure of level of scientific awareness among early secondary level students. This is to be achieved through a questionnaire which will be distributed amongst a representative sample of Form 2 secondary students. The questionnaire is based on the criteria for scientific awareness mentioned above.

2. Give details of procedures that relate to subjects' participation
(a) How are subjects recruited? What inducement is offered? *(Append copy of letter or advertisement or poster, if any.)*

Subjects are being recruited by contacting the Heads of schools (refer to attached letter) and asking for access to a class of Form 2 students who can fill in the aforementioned questionnaire
In order to not disturb students' learning as much as possible, classes where free lessons are present will be asked to do the questionnaire during their free lesson.
The students filling in the questionnaire will be a representative sample (worked out beforehand) of Form 2 students in all types of schools - State, Church and Independent- in Malta.

Schools have been contacted and Heads of Schools have already agreed to support the collection of data.

(b) Salient characteristics of subjects—number who will participate, age range, sex, institutional affiliation, other special criteria:

The subjects of this study will be 400 Form 2 students representative of the population of Form 2 students in Maltese schools in terms of gender and the type of school they attend as shown by the figures below:

| | State | Church | Independent | Total |
|---|---|---|---|---|
| Boys | 110 | 72 | 16 | 198 |
| Girls | 117 | 64 | 21 | 202 |
| | | | | 400 |

P.T.O.

(c) Describe how permission has been obtained from cooperating institution(s)—school, hospital, organization, prison, or other relevant organization. *(Append letters.)* Is the approval of another Research Ethics Committee required?

Permission was obtained from the respective Heads of Schools through a request letter through which they were asked to sign a consent form approving participation of their school in this study. Each school to be included in the data collection has provided a consent (attached to this application).
Approval from DQSE and Curia were also obtained.

The approval of another Research Ethics Committee is not required for this project.

(d) What do subjects do, or what is done to them, or what information is gathered? (Append copies of instructions or tests or questionnaires.) How many times will observations, tests, etc., be conducted? How long will their participation take?

Information will be gathered through a questionnaire including close-ended items only. It will take approximately three quarters of an hour for the students to fill in. The items included in the questionnaire are all related to scientific issues, probing practices and values and attitudes. (see questionnaire in attachment)

(e) Which of the following data categories are collected? Please indicate 'Yes' or 'No'.

| | | |
|---|---|---|
| Data that reveals – race or ethnic origin | | No |
| | political opinions | No |
| | ~~religious~~ or philosophical beliefs | Yes |
| | trade union memberships | No |
| | health | No |
| | sex life | No |
| | genetic information | No |

3. How do you explain the research to subjects and obtain their informed consent to participate? (If in writing, append a copy of consent form.) If subjects are minors, mentally infirm, or otherwise not legally competent to consent to participation, how is their assent obtained and from whom is proxy consent obtained? How is it made clear to subjects that they can quit the study at any time?

n/a

4 .Do subjects risk *any* harm—physical, psychological, legal, social—by participating in the research? Are the risks necessary? What safeguards do you take to minimize the risks?

There is no known physical, psychological, legal or social harm associated with participation in this research.

5. Are subjects deliberately deceived in *any* way? If so, what is the nature of the deception? Is it likely to be significant to subjects? Is there any other way to conduct the research that would not involve deception, and, if so, why have you not chosen that alternative? What explanation for the deception do you give to subjects following their participation?

This research does not involve deliberate deception of the subjects.

6. How will participation in this research benefit subjects? If subjects will be "debriefed" or receive information about the research project following its conclusion, how do you ensure the educational value of the process? *(Include copies of any debriefing or educational materials)*

The research subjects will not benefit directly as part of the research study.
It is however hoped that the research results will help develop teaching pedagogies which will be of benefiit for other students.

TERMS AND CONDITIONS FOR APPROVAL IN TERMS OF THE DATA PROTECTION ACT

- Personal data shall only be collected and processed for the specific research purpose.
- The data shall be adequate, relevant and not excessive in relation to the processing purpose.
- All reasonable measures shall be taken to ensure the correctness of personal data.
- Personal data shall not be disclosed to third parties and may only be required by the University or the supervisor for verification purposes. All necessary measures shall be implemented to ensure confidentiality and, where possible, data shall be anonymised.
- Unless otherwise authorised by the University Research Ethics Committee, the researcher shall obtain the consent from the data subject (respondent) and provide him with the following information: The researcher's identity and habitual residence, the purpose of processing and the recipients to whom personal data may be disclosed. The data subject shall also be informed about his rights to access, rectify, and where applicable erase the data concerning him.

I, the undersigned hereby undertake to abide by the terms and conditions for approval as attached to this application.

I, the undersigned, also give my consent to the University of Malta's Research Ethics Committee to process my personal data for the purpose of evaluating my request and other matters related to this application. I also understand that, I can request in writing a copy of my personal information. I shall also request rectification, blocking or erasure of such personal data that has not been processed in accordance with the Act.

Signature: C. Azzopardi

| APPLICANT'S SIGNATURE: | FACULTY SUPERVISOR'S SIGNATURE |
|---|---|
| *I hereby declare that I will not start my research on human subjects before UREC approval* | I have reviewed this completed application and I am satisfied with the adequacy of the proposed research design and the measures proposed for the protection of human subjects. |
| C. Azzopardi | |
| DATE 24/2/2012 | DATE 24/2/2012 |

***Return the completed application to your faculty Research Ethics Committee***

6

***To be completed by Faculty Research Ethics Committee***

We have examined the above proposal and advise

**Acceptance** **Refusal** **Conditional acceptance**

For the following reason/s:

Signature [signature] Date 9th March 2012.

***To be completed by University Research Ethics Committee***

We have examined the above proposal and grant

**Acceptance** **Refusal** **Conditional acceptance**

For the following reason/s:

Signature [signature] Date 30/3/2012

## APPENDIX G: Instructions to readers of questionnaire when researcher was not available during distribution of the questionnaire.

Ph.D. Research: Raising the Level of Science Awareness among Early Secondary Students.

**Instructions to reader**

Kindly read through the questionnaire while the students tick the answers. It will take approximately 40 mins when read at a moderate pace.

You may answer any difficulties the students may have as long as they are language –based.

Kindly refrain from explaining scientific terms e.g. *extinction of species* or *cloning*. Statements including technical terms which the students fail to understand should not be answered. This missing data will be considered to be one of the indicators of a lack of science awareness.

Thanks and regards,
Claudette Azzopardi

**APPENDIX H: Permissions granted to carry out the focus groups during Phase 1 of this study.**

ED4/0357/13
OK

## UNIVERSITY OF MALTA

## UNIVERSITY RESEARCH ETHICS COMMITTEE

***Check list to be included with UREC proposal form***

Please make sure to tick **ALL** the items. Incomplete forms will not be accepted.

| | | YES | NOT APP. |
|---|---|---|---|
| 1a. | Recruitment letter / Information sheet for subjects, in English | ✓ | |
| 1b. | Recruitment letter / Information sheet for subjects, in Maltese | ✓ | |
| 2a | Consent form, in English, signed by supervisor, and including your contact details | ✓ | |
| 2b | Consent form, in Maltese, signed by supervisor, and including your contact details | ✓ | |
| 3a | In the case of children or other vulnerable groups, consent forms for parents/ guardians, in English | ✓ | |
| 3b | In the case of children or other vulnerable groups, consent forms for parents/ guardians, in Maltese | ✓ | |
| 4a | Tests, questionnaires, interview or focus group questions, etc, in English | ✓ | |
| 4b | Tests, questionnaires, interview or focus group questions, etc, in Maltese | ✓ | |
| 5a | Other institutional approval *for access to subjects*: Health Division, Directorate for Quality and Standards in Education, Department of Public Health, Curia... | ✓ | |
| 5b | Other institutional approval *for access to data*: Registrar, Data Protection Officer Health Division/Hospital, Directorate for Quality and Standards in Education, Department of Public Health... | | ✓ |
| 5c | Approval from person *directly responsible for subjects*: Medical Consultants, Nursing Officers, Head of School... | ✓ | |

| | |
|---|---|
| Received by Faculty office on | 06/03/2013 |
| Discussed by Faculty Research Ethics Committee on | 13/03/2013 |
| Discussed by university Research Ethics Committee on | 19/4/2013 |

1

## UNIVERSITY OF MALTA

**Request for Approval of Human Subjects Research**

Please type. Handwritten forms will not be accepted

You may follow this format on separate sheets or use additional pages if necessary.

| | |
|---|---|
| FROM: *(name, address for correspondence)*<br>Claudette Azzopardi<br>44, Flat 2, Melwood Park<br>Triq Anglu Gatt<br>Mosta MST4025 | PROJECT TITLE:<br><br>RAISING THE LEVEL OF SCIENCE AWARENESS AMONG EARLY SECONDARY STUDENTS |
| TELEPHONE: 27420753/ 79283855 | |
| E-MAIL<br>cmif008@um.edu.mt | |
| COURSE AND YEAR:<br>Master of Philosophy in Education (2010) 3rd year | |
| DURATION OF ENTIRE PROJECT:<br><br>from 2010 to 2016 | FACULTY SUPERVISOR'S NAME:<br><br>Prof. Suzanne Gatt,<br>Senior Lecturer,<br>Primary Science & Environmental Education |

ANTICIPATED FUNDING SOURCE: n/a

*(include grant or contract number if known)*

1. Please give a brief summary of the purpose of the research, in non-technical language.

The main target of this research is to enhance the level of science awareness of Form 2 students attending Maltese schools. In this study, science awareness is being articulated as a recognition of: the extent to which science pervades our lives; the knowledge, competencies, attitudes and values needed to engage with science-based life situations; and the importance of the role of science education in the development of these attributes.

In the first phase of this research project, a questionnaire was used to obtain a measure of scientific awareness among early secondary students. The instrument was based on the criteria of science awareness mentioned above. Through this proposal, permission is being sought for the second stage of this research project- that of obtaining a deeper insight into the factors that enhance or preclude the development of science awareness among Form 2 students. This is to be achieved through a number of focus groups with Form 2 student subtypes who have been shown to have significantly different levels of science awareness

2. Give details of procedures that relate to subjects' participation

(a) How are subjects recruited? What inducement is offered? *(Append copy of letter or advertisement or poster, if any.)*

Subjects are being recruited by contacting the Heads of schools (refer to attached letter) and asking for access to a seven Form 2 students to participate in a focus group discussion. In order to not disturb students' learning as much as possible, the focus group discussion will be carried out by the researcher during a free period.

Schools have been contacted and Heads of Schools have already agreed to support the collection of data.

2

(b) Salient characteristics of subjects—number who will participate, age range, sex, institutional affiliation, other special criteria:

The quantitative results have shown that the main factors that have a significant effect on science awareness are gender and the type of school. Consequently, the focus groups will be done with girls and boys coming from state, church and independent schools respectively. In order to include these student subtypes, 8 focus groups will be carried out with each focus group consisting of a discussion with seven Form 2 students. The focus groups will be conducted in 2 boys' state schools, 2 girls' state schools, a boys' church school, a girls' church school and two independent schools.

(c) Describe how permission has been obtained from cooperating institution(s)—school, hospital, organization, prison, or other relevant organization. *(Append letters.)* Is the approval of another Research Ethics Committee required?

Permission was obtained from the respective Heads of Schools through a request letter through which they were asked to sign a consent form approving participation of their school in this study. Each school to be included in the data collection has provided a consent (attached to this application).
Approval from DQSE and Curia were also obtained.

The approval of another Research Ethics Committee is not required for this project.

(d) What do subjects do, or what is done to them, or what information is gathered? (Append copies of instructions or tests or questionnaires.) How many times will observations, tests, etc., be conducted? How long will their participation take?

Information will be gathered through a one-time, semi-structured focus group discussion with seven students from the afore-mentioned school types. Each discussion will take approximately three quarters of an hour during which the subjects will be audio recorded. The questions that will shape the discussion have been attached to this application.

(e) Which of the following data categories are collected? Please indicate 'Yes' or 'No'.

| | | |
|---|---|---|
| Data that reveals – race or ethnic origin | | No |
| | political opinions | No |
| | ~~religious~~ or philosophical beliefs | Yes |
| | trade union memberships | No |
| | health | No |
| | sex life | No |
| | genetic information | No |

3. How do you explain the research to subjects and obtain their informed consent to participate? (If in writing, append a copy of consent form.) If subjects are minors, mentally infirm, or otherwise not legally competent to consent to participation, how is their assent obtained and from whom is proxy consent obtained? How is it made clear to subjects that they can quit the study at any time?

n/a

4 .Do subjects risk *any* harm—physical, psychological, legal, social—by participating in the research? Are the risks necessary? What safeguards do you take to minimize the risks?

There is no known physical, psychological, legal or social harm associated with participation in this research.

5. Are subjects deliberately deceived in *any* way? If so, what is the nature of the deception? Is it likely to be significant to subjects? Is there any other way to conduct the research that would not involve deception, and, if so, why have you not chosen that alternative? What explanation for the deception do you give to subjects following their participation?

This research does not involve deliberate deception of the subjects.

6. How will participation in this research benefit subjects? If subjects will be "debriefed" or receive information about the research project following its conclusion, how do you ensure the educational value of the process? *(Include copies of any debriefing or educational materials)*

The research subjects will not benefit directly as part of the research study.
It is however hoped that the research results will help develop teaching pedagogies which will be of benefiit for other students.

TERMS AND CONDITIONS FOR APPROVAL IN TERMS OF THE DATA PROTECTION ACT

- Personal data shall only be collected and processed for the specific research purpose.
- The data shall be adequate, relevant and not excessive in relation to the processing purpose.
- All reasonable measures shall be taken to ensure the correctness of personal data.
- Personal data shall not be disclosed to third parties and may only be required by the University or the supervisor for verification purposes. All necessary measures shall be implemented to ensure confidentiality and, where possible, data shall be anonymised.
- Unless otherwise authorised by the University Research Ethics Committee, the researcher shall obtain the consent from the data subject (respondent) and provide him with the following information: The researcher's identity and habitual residence, the purpose of processing and the recipients to whom personal data may be disclosed. The data subject shall also be informed about his rights to access, rectify, and where applicable erase the data concerning him.

I, the undersigned hereby undertake to abide by the terms and conditions for approval as attached to this application.

I, the undersigned, also give my consent to the University of Malta's Research Ethics Committee to process my personal data for the purpose of evaluating my request and other matters related to this application. I also understand that, I can request in writing a copy of my personal information. I shall also request rectification, blocking or erasure of such personal data that has not been processed in accordance with the Act.

Signature: C. Amperoli

| APPLICANT'S SIGNATURE: | FACULTY SUPERVISOR'S SIGNATURE |
|---|---|
| *I hereby declare that I will not start my research on human subjects before UREC approval* | I have reviewed this completed application and I am satisfied with the adequacy of the proposed research design and the measures proposed for the protection of human subjects. |
| C. Amperoli | |
| DATE 5/ 3/ 2013 | DATE |

***Return the completed application to your faculty Research Ethics Committee***

***To be completed by Faculty Research Ethics Committee***

We have examined the above proposal and advise

**Acceptance** **Refusal** **Conditional acceptance**

For the following reason/s:

Signature [signature] Date 20th March 2013.

***To be completed by University Research Ethics Committee***

We have examined the above proposal and grant

**Acceptance** **Refusal** **Conditional acceptance**

For the following reason/s:

Signature [signature] Date 18/4/2013

7

## Ph.D. Research in Science Education – Information for parents/students

Towards the end of the scholastic year 2011-2012, data was collected from schools in Malta and Gozo by means of a questionnaire aimed at gauging the level of science awareness among Form 2 students. This quantitative data gathering was the first out of three stages of a doctoral research project entitled *Raising the Level of Science Awareness Among Early Secondary Students*. This research is being conducted by **Claudette Azzopardi**, under the supervision of **Prof. Suzanne Gatt, University of Malta**. The three phases of the study consist of:

1. gauging the level of science awareness of early secondary students through quantitative data collected by means of a questionnaire;
2. identifying the factors that enhance or hinder science awareness through focus groups discussions; and
3. using the findings from stages 1 and 2 above in action research aimed at developing learning strategies that can be used to raise the level of science awareness.

In this study, science awareness is being defined in terms of students' beliefs or perceptions of the importance of science and science education in their personal, social and global lives. It can thus be considered to be part of the general effort being made recently by the science education community to prepare all students to become functional citizens in relation to science-oriented issues or decisions. This research will also benefit students as it is expected to lead to improved practices in science lessons especially during the early secondary years.

Currently, students are being recruited to help out in the second phase of this study where a number of group discussions will be carried out with Form 2 students in several schools. These focus groups will be carried out during the third term of the scholastic year 2012/2013, will be guided by the researcher and will take approximately the duration of one lesson. The students will be audio recorded during the discussion for transcription purposes. Kindly fill in the attached consent forms should you wish to participate in the study. Your participation is greatly appreciated.

**Riċerka dwar l-Edukazzjoni Xjentifika (Ph.D.) –**

**Informazzjoni għall-ġenituri/istudenti**

Lejn l-aħħar tas-sena skolastika 2011-2012, inġabret informazzjoni permezz ta' kwestjonarju dwar il-livell ta' *science awareness* ta' l-istudenti tal-Form 2 li jattendu skejjel f'Malta u Għawdex. Din kienet l-ewwel minn tliet fażijiet tal-proġett ta' riċerka: *Raising the Level of Science Awareness Among Early Secondary Students.* Din ir-riċerka qegħda ssir minn **Claudette Azzopardi**, taħt is-superviżjoni ta' **Prof. Suzanne Gatt, Universita` ta' Malta.** Fit-tieni parti tal-proġett, se jsiru diskussjonijiet ma' gruppi żgħar ta' studenti tal-Form 2 biex jigu identifikati b'mod iktar ċar dawk il-fatturi li jżidu, jew inaqqsu, l-livell ta' *science awareness* ta' l-istudenti. Fit-tielet u l-aħħar fażi ta' din ir-riċerka, se jiġu ppjanati numru t'attivitajiet immirati biex itejbu l-livell ta' *science awareness* ta' studenti tal-Form 2.

F'dan l-istudju, *science awareness* qiegħda tiġi definita bħala l-perċezzjonijiet li l-istudenti għandhom dwar l-importanza tax-xjenza u l-edukazzjoni xjentifika fil-ħajja personali, soċjali u globali tagħhom. Dan il-proġett jista' jigi kkunsidrat bħala parti mill-isforz li qiegħed isir mill-edukaturi tax-xjenza biex l-istudenti kollha jkunu kapaċi jiffunzjonaw bħala ċittadini meta jiltaqgħu ma' kwistjonijiet, jew meta jridu jagħmlu deċiżjonijiet ta' xejra xjentifika. Din ir-riċerka se tkun ukoll ta' benefiċċju għall-istudenti għax mistennija li twassal għal prattiċi aħjar ta' tagħlim waqt il-lezzjonijiet tax-xjenza.

Bħalissa, qegħda ssir talba biex studenti jieħdu sehem fit-tieni fażi ta' dan il-proġett fejn se jsiru numru ta' diskussjonijiet fi gruppi ma' studenti tal-Form 2 f'diversi skejjel. Dawn id-diskussjonijiet se jsiru fit-tielet term tas-sena skolastika 2012-2013, se jigu mmexxija mir-ricerkatriċi u se jieħdu madwar lezzjoni. L-ilħna ta' l-studenti se jigu rrekordjati waqt id-diskussjoni. Jekk jogħġbok imla l-formoli ta' kunsens mibgħutin ma' din l-informazzjoni jekk tixtieq tipparteċipa f'dan l-istudju. Il-kontribut tiegħek se jkun ta' għajnuna kbira. Grazzi!

5Ċ

**CONSENT FORM - HEAD OF SCHOOL**

Ph.D. RESEARCH PROJECT:

*Raising the Level of Science Awareness Among Early Secondary Students*

RESEARCHER: Claudette Azzopardi, University of Malta

(E-mail:cmif008@um.edu.mt, Mob:79283855 )

I, the undersigned, Head of School of ______________________________

(name of school/college) **am willing** to allow my school to participate in the research project – *Raising the level of Science Awareness among Early Secondary Students.*

I understand that during the course of this project the students' responses will be kept strictly confidential and that none of the data released in this study will identify them by name or any other data, descriptions, or characterizations. Furthermore, I understand that I may discontinue my school's participation in this project at any time.

I fully understand that this research is being conducted for constructive educational purposes and that my signature gives my consent for seven Form 2 students to be audio recorded during a focus group discussion subject to approval by their parents/guardians.

Signature ______________________________ Date ____________________

(HEAD OF SCHOOL)

Signature ______________________________ Date ____________________

(RESEARCHER)

**CONSENT FORM - STUDENT**

Ph.D. RESEARCH PROJECT:

*Raising the Level of Science Awareness Among Early Secondary Students*

RESEARCHER: Claudette Azzopardi, University of Malta

(E-mail:cmif008@um.edu.mt, Mob:79283855 )

I, the undersigned, ______________________________ (name of student) **am willing** to participate in the doctoral research project – *Raising the level of Science Awareness among Early Secondary Students.*

I understand that during the course of this project my responses will be kept strictly confidential and that none of the data released in this study will identify me by name or any other data, descriptions, or characterizations. Furthermore, I understand that I may discontinue my participation in this project at any time.

I fully understand that this research is being conducted for constructive educational purposes and that my signature gives my consent to be audio recorded during a group discussion about science and science education.

Signature ______________________________ Date ______________

(STUDENT)

Signature C. Azzopardi Date 6/3/2013

(RESEARCHER)

Signature ______________________________ Date 6/3/2013

(SUPERVISOR)

**FORMOLA TA' KUNSENS – STUDENT**

PROĠETT TA' RIĊERKA:

*Raising the Level of Science Awareness Among Early Secondary Students*

RIĊERKATRIĊI: Claudette Azzopardi, Universita' ta' Malta

(E-mail:cmif008@um.edu.mt, Mob:79283855 )

Jien, ______________________________, hawn taħt ismi iffirmat, nagħti kunsens biex niehu sehem fi proġett ta' riċerka bl-isem ta': *Raising the level of Science Awareness among Early Secondary Students.*

Nifhem li t-tweġibiet tiegħi se jintużaw biss għal skopijiet ta riċerka u li bl-ebda mod ma nista' niġi identifikat/a individwalment. Jien nista' meta rrid, mingħajr ma nagħti raġuni, ma nkomplix nieħu sehem aktar f'dan l-istudju.

Nifhem li din ir-riċerka qed issir biex ikun hemm titjib fis-sistema edukattiva u għalhekk qiegħed/qegħda nagħti l-kunsens biex nieħu sehem f'diskussjoni dwar ix-xjenza u l-lezzjonijiet tax-xjenza waqt li leħni jiġi rrekordjat.

Firma ______________________ Data ______________

(STUDENT)

Firma C. Azzopardi Data 6/3/2013

(RIĊERKATRIĊI)

Firma ______________________ Data 6/3/2013

(SUPERVISOR)

**CONSENT FORM - PARENT/GUARDIAN**

Ph.D. RESEARCH PROJECT:

*Raising the Level of Science Awareness Among Early Secondary Students*

RESEARCHER: Claudette Azzopardi, University of Malta

(E-mail:cmif008@um.edu.mt, Mob:79283855 )

I, the undersigned, parent/guardian of

________________________________________ (name of student) **am willing** to allow my son/daughter to participate in the doctoral research project – *Raising the level of Science Awareness among Early Secondary Students.*

I understand that during the course of this project my son's/daughter's responses will be kept strictly confidential and that none of the data released in this study will identify them by name or any other data, descriptions, or characterizations. Furthermore, I understand that I may discontinue my son's/daughter's participation in this project at any time.

I fully understand that this research is being conducted for constructive educational purposes and that my signature gives my consent for my son/daughter to be audio recorded during a group discussion about science and science education.

Signature ______________________________ Date __________________

(PARENT/GUARDIAN)

Signature C. Azzopardi Date 6/3/2013

(RESEARCHER)

Signature [signature] Date 6/3/2013

(SUPERVISOR)

5.C

**FORMOLA TA' KUNSENS – ĠENITUR/KUSTODJU**

PROĠETT TA' RIĊERKA:

*Raising the Level of Science Awareness Among Early Secondary Students*

RIĊERKATRIĊI: Claudette Azzopardi, Universita' ta' Malta

(E-mail:cmif008@um.edu.mt, Mob:79283855 )

Jien, hawn taħt ismi iffirmat, nagħti kunsens biex it-tifel/tifla tiegħi ______________________________ (isem it-tifel/tifla) jieħu/tieħu sehem fi proġett ta' riċerka bl-isem ta': *Raising the level of Science Awareness among Early Secondary Students*.

Nifhem li t-tweġibiet tat-tifel/tifla tiegħi se jintużaw biss għal skopijiet ta riċerka u li bl-ebda mod ma jista'/tista' tiġi identifikat/a individwalment. Jien nista' meta rrid, mingħajr ma nagħti raġuni, ma nħallix lit-tifel/tifla jkompli jieħu sehem aktar f'dan l-istudju.

Nifhem li din ir-riċerka qed issir biex ikun hemm titjib fis-sistema edukattiva u għalhek qiegħed/qegħda nagħti l-kunsens biex ibni/binti jieħu/tieħu sehem f'diskussjoni dwar ix-xjenza u l-lezzjonijiet tax-xjenza waqt li leħnu/leħinha jiġi irrekordjat.

Firma ____________________ Data ____________

(ĠENITUR/KUSTODJU)

Firma C. Azzopardi Data 6/3/2013

(RIĊERKATRIĊI)

Firma ____________________ Data ____________

(SUPERVISOR)

**RAISING THE LEVEL OF SCIENCE AWARENESS AMONG**

**EARLY SECONDARY STUDENTS**

MISTOQSIJIET GĦAL WAQT DISKUSSJONI FI GRUPP

1. Inti togħġbok ix-xjenza? Għaliex?
2. Taħseb li x-xjenza hija mportanti? Għaliex?
3. Kemm taqbel li dawn huma relatati max-xjenza? *(jekk żona partikolari għandiex tinbena jew tiġi żviluppata* jew *esplorazzjoni ta' l-ispazju)* Għaliex? X'tifhem bi xjenza?
4. Taħseb li x-xjentisti kollha huma nies responsabbli? Għaliex?
5. Temmen li kulħadd igawdi l-istess mill-progress xjentifiku?
6. Qatt tipparteċipa f'konverżazzjoni dwar ix-xjenza? Jekk iva, ma' min? Dwar xiex?
7. Qatt tipparteċipa f'attivitajiet barra mill-iskola relatati max-xjenza? Ta' liema tip? Ma' min?
8. Taħseb li-xjenza mgħallma fl-iskola hija diffiċli? Għaliex?
9. Kemm –il suġġett xjentifiku qed tippjana li tagħżel fit-tielet sena sekondarja? Liema fatturi wassluk għal din id-deċiżjoni?
10. X'tip t'attivitajiet tagħmlu waqt il-lezzjonijiet tax-xjenza? Liema metodu ta' tagħlim taħseb li huwa l-aktar attrajenti?
11. Kemm temmen li ċ-ċittadini komuni jistgħu jinfluwenza lill-politici f'deċiżjonijiet ta' natura xjentifika?
12. Xi kwalitajiet għandha bżonn persuna biex tagħmel dan?
13. Taħseb li l-edukazzjoni xjentifika tista' tgħinek sabiex issir ċittadin aktar attiv? Għaliex? Kif? B'liema meżżi?

14. Immaġina li l-lezzjonijiet tax-xjenza tiegħek ikunu jinkludu attivitajiet relatati ma' suġġetti jew deċiżjonijiet ta' natura xjentifika, bħal per eżempju: dibattiti; proġetti fil-komunita'; analiżi tal-midja; tagħlim dwar kif tista' tinfluwenza lin-nies li jfasslu l-politika; narrazzjonijiet t'esperjenzi personali; eċċ. Temmen li permezz t'attivitajiet bħal dawn l-edukazzjoni xjentifika tkun aktar attrajenti? Għaliex?

**RAISING THE LEVEL OF SCIENCE AWARENESS AMONG**

**EARLY SECONDARY STUDENTS**

FOCUS GROUP QUESTIONS

1. Do you like science? Why?
2. Do you think science is important? Why?
3. To what extent do you agree that the following are related to science? (*whether an area should be built or developed* or *exploration of space)* Why? What do you understand by science?
4. Do you think that all scientists are responsible people? Why?
5. Do you think that everyone benefits equally from scientific progress?
6. Do you ever participate in a conversation related to science? If yes, with whom? About what?
7. Do you ever participate in out-of-school activities related to science? What type? With whom?
8. Do you consider school science to be difficult? Why?
9. How many science subjects do you plan to choose in Form 3? What influenced your decision?
10. What type of learning activities do you have during your science lessons? Which kind of teaching methods do you find most attractive?
11. To what extent do you think that common citizens may influence decisions taken by politicians in relation to scientific issues?
12. Which qualities does one need in order to do this?
13. Do you think that science education can help you to become more active citizens? Why? How? By what means?

14. Immaġina li l-lezzjonijiet tax-xjenza tiegħek ikunu jinkludu attivitajiet relatati ma' suġġetti jew deċiżjonijiet ta' natura xjentifika, bħal per eżempju: dibattiti; proġetti fil-komunita'; analiżi tal-midja; tagħlim dwar kif tista' tinfluwenza lin-nies li jfasslu l-politika; narrazzjonijiet t'esperjenzi personali; eċċ. Temmen li permezz t'attivitajiet bħal dawn l-edukazzjoni xjentifika tkun aktar attrajenti? Għaliex?

U

**RAISING THE LEVEL OF SCIENCE AWARENESS AMONG**

**EARLY SECONDARY STUDENTS**

MISTOQSIJIET GĦAL WAQT DISKUSSJONI FI GRUPP

1. Inti togħgbok ix-xjenza? Ghaliex?
2. Taħseb li x-xjenza hija mportanti? Għaliex?
3. Kemm taqbel li dawn huma relatati max-xjenza? (*jekk żona partikolari għandiex tinbena jew tiġi żviluppata* jew *esplorazzjoni ta' l-ispazju)* Ghaliex? X'tifhem bi xjenza?
4. Taħseb li x-xjentisti kollha huma nies responsabbli? Għaliex?
5. Temmen li kulħadd igawdi l-istess mill-progress xjentifiku?
6. Qatt tipparteċipa f'konverżazzjoni dwar ix-xjenza? Jekk iva, ma' min? Dwar xiex?
7. Qatt tipparteċipa f'attivitajiet barra mill-iskola relatati max-xjenza? Ta' liema tip? Ma' min?
8. Taħseb li-xjenza mgħallma fl-iskola hija diffiċli? Ghaliex?
9. Kemm –il suġġett xjentifiku qed tippjana li tagħżel fit-tielet sena sekondarja? Liema fatturi wassluk għal din id-deċiżjoni?
10. X'tip t'attivitajiet tagħmlu waqt il-lezzjonijiet tax-xjenza? Liema metodu ta' tagħlim taħseb li huwa l-aktar attrajenti?
11. Kemm temmen li c-cittadini komuni jistghu jinfluwenza lill-politici f'deċiżjonijiet ta' natura xjentifika?
12. Xi kwalitajiet għandha bżonn persuna biex tagħmel dan?
13. Taħseb li l-edukazzjoni xjentifika tista' tgħinek sabiex issir ċittadin aktar attiv? Ghaliex? Kif? B'liema meżżi?

…pproved under usual
…tions

14. Imagine that your science lessons would include activities that feature issues or decisons with a scientific background, such as: debates; community-based projects; media analysis; mentoring in lobbying policy makers; sharing of personal experiences; etc. Do you think that through such activities science education would be more attractive? Why?

DIRETTORAT GĦAL
KWALITA' U STANDARDS FL-EDUKAZZJONI
FURJANA VLT 2000
MALTA

DIRECTORATE FOR
QUALITY AND STANDARDS IN EDUCATION
FLORIANA VLT 2000
MALTA

**Request for Research in State Schools**

A. (Please use BLOCK LETTERS)

Surname: AZZOPARDI Name: CLAUDETTE

I.D. Card Number: 570779 M

Telephone No: 27420753 * Mobile No: 79283855 *

Address: 44, FLAT 2, MELWOOD PARK, TRIQ ANĠLU GATT

Locality: MOSTA Post Code: MST 4025

E-mail Address: mifsudclaudette@hotmail.com

Faculty: EDUCATION Course: Ph.D. Year Ending: 2016

Title of Research: RAISING THE LEVEL OF SCIENCE AWARENESS AMONG EARLY SECONDARY STUDENTS

Aims of research: □ Long Essay □ Dissertation ☑ Thesis □ Publication

Time Frame: 2010 – 2016 Language Used: ENGLISH / MALTESE

Description of methodology: FOCUS GROUPS

School/s where research is to be carried out:

4 SECONDARY SCHOOLS – 2 BOYS' / 2 GIRLS'

~~Years~~ / Forms: 2 Age range of students: 12 – 13

*** Telephone and mobile numbers will only be used in strict confidence and will not be divulged to third parties.**
**I accept to abide by the rules and regulations re Research in State Schools and to comply with the Data Protection Act 2001.**
**<u>Warning to applicants</u> - Any false statement, misrepresentation of concealment of material fact on this form or any document presented in support of this application may be grounds for criminal prosecution.**

Signature of applicant: C. Azzopardi Date: 21/2/2013

**B. Tutor's Approval** (where applicable)

The above research work is being carried out under my supervision.

Tutor's Name: Prof Suzanne Cott Signature: [signature]

Faculty: Education Faculty Stamp: UNIVERSITY OF MALTA Faculty of Education MSIDA MALTA

**C. Directorate for Quality and Standards in Education - Official Approval**

The above request for permission to carry out research in State Schools is hereby approved according to the official rules and regulations, subject to approval from the University of Malta Ethics Committee. Approved on condition that voluntary informed consent is given by parents whose children will be interviewed.

[signature] Date: 22 / 02 / 2013

Director
(Research and Development Department)

Raymond Camilleri
Director, RDD

Official Stamp

**Conditions for the approval of a request by a student to carry out research work in State Schools**

Permission for research in State Schools is subject to the following conditions:

1. The official request form is to be accompanied by a copy of the questionnaire and / or any relevant material intended for use in schools during research work.

2. The original request form, showing the relevant signatures and approval, must be presented to the Head of School.

3. All research work is carried out at the discretion of the relative Head of School and subject to their conditions.

4. Researchers are to observe strict confidentiality at all times.

5. The Directorate for Quality and Standards in Education reserves the right to withdraw permission to carry out research in State Schools at any time and without prior notice.

6. Students are expected to restrict their research to a minimum of students / teachers / administrators / schools, and to avoid any waste of time during their visits to schools.

7. As soon as the research in question is completed, the Directorate for Quality and Standards in Education assumes the right to a full copy (in print/on C.D.) of the research work carried out in State Schools. **Researchers are to forward the copies to the Assistant Director, International Research, Directorate for Quality and Standards in Education.**

8. Researchers are to hand a copy of their Research in print or on C.D. to the relative School/s.

9. In the case of video recordings, researchers have to obtain prior permission from the Head of School and the teacher of the class concerned. Any adults recognisable in the video are to give their explicit consent. Parents of students recognisable in the video are also to be requested to aprove that their siblings may be video-recorded. Two copies of the consent forms are necessary, one copy is to be deposited with the Head of School, and the other copy is to accompany the Request Form for Research in State Schools. Once the video recording is completed, one copy of the videotape is to be forwarded to the Head of School. The Directorate for Quality and Standards in Education reserves the right to request another copy.

10. The video recording's use is to be limited to this sole research and may not be used for other research without the full consent of interested parties including the Directorate for Quality and Standards in Education.

S.C.

## Statement of Consent

I hereby give my consent to the Directorate for Quality and Standards in Education to process and record personal and sensitive data being given herewith in order to be able to render me with the service I am applying for.
I fully understand that:

a) by opting out my application cannot be processed;

b) authorised personnel who are processing this information may have access to this data in order to supply me with the service being applied for;

c) edited information, that would not identify me, may be included in statistical reports.

I know that I am entitled to see the information related to me, should I ask for it in writing.
I am aware that for the purpose of the Data Protection Act, the Data Controller for this Directorate is:
The Directorate for Quality and Standards in Education
Floriana, VLT 2000

**I have read and understood this statement of consent myself** ✓

**This statement of consent was read and explained to me** ____

Signature: C. Angeli ID number: 570779 M (Data subject)

Signature: ____ ID number: ____ (Reader if applicable)

Date: 21/2/2013

### Data Protection Policy

The Data Protection Act, 2001 regulated the processing of personal data held electronically and in manual form. The Directorate for Quality and Standard in Education is set to fully comply with the Data Protection Principles as set out in the Act.

a) The Directorate will hold information you supply in accordance to your request to carry out research in State Schools and / or Directorates' documents.

b) The information you give may be disclosed to other Departments of the Directorate for Quality and Standards in Education, who may also have access to your data.

**Your rights:**
You are entitled to know what information the Directorate holds and processes about you and why; who has access to it; how it is kept up to date; what the Directorate is doing to comply with its obligations under the Data Protection Act, 2001.

The Data Protection Act, 2001 sets down a formal procedure for dealing with data subject access requests which the Ministry of Education, Culture, Youth and Sport follows.

All data subjects have the right to access any personal information kept about them by the Directorate either on computer or in manual files. Requests to access to personal information by data subjects must be made in writing and addressed to the Data Controller of the Ministry of Education, Culture, Youth and Sport. An identification document such as a photocopy of the Identity Card, photocopy of passport etc. of the data subject making the request must be submitted with the request. Such identification material will be returned to the data subject.

The Directorate aims to comply as quickly as possible with requests for access to personal information and will ensure that it is provided within reasonable time, the reason will be explained in writing to the data subject making the request.

All data subjects have the right to request that their information be amended, erased or not used in the event the data is incorrect.

# APPENDIX I Learning Activities (Phase 2)

The following are detailed descriptions of the activities used to raise science awareness in Phase 2 of the study during scholastic year 2015-2016.

## Raising science awareness through the topic Healthy Living 1 (DQSE, 2014)

Subject: Integrated Science Form 2

Unit code and title: **SCI 8.1 HEALTHY LIVING (I)**

Strand 1: Life Processes

In addition to the descriptions of the digestive, circulatory and respiratory systems, this topic also includes an emphasis on the importance of a balanced diet and the negative effects of smoking on the lungs both of which are highly relevant for 12 year olds as they face peer and social pressure regarding these issues. The issue of smoking was chosen as it was the theme that had just been tackled by a group of Maltese students in relation to a local-based science competition organised by NSTF (National Student Travel Foundation).

**Objectives for syllabus topic Healthy Living 1**

The teacher will:
guide students to identify the basic food substances and their use and describe the importance of a balanced diet.
illustrate the digestive system and guide students to describe the process of digestion.
illustrate the structure of the lungs, guide students to describe the breathing process and the production of energy from food (respiration).
illustrate the blood circulatory system.

**Objectives (science awareness)**

In the light of the concept of science awareness developed in this study, at the end of this activity the students were expected to recognise that:
smoking is a science-based personal and social issue.
a range of knowledge, skills and attitudes are needed in order to be able to act and raise awareness against smoking.
such competencies can be achieved through science education.

**Previous knowledge:**
At the beginning of this lesson, the students were able to:
Link lungs to breathing
Describe the structure of the lungs
Explain the role of the rib cage and the diaphragm in the breathing process
Relate smoking to lung disease

**Introduction**
The students were shown a lung model smoking a cigarette so that students can reflect on the negative effects that this may have on the lungs.

**Development**:

The negative effects of nicotine, tar etc. were explained briefly through a PowerPoint.
The students were then informed how the model of the lungs and other investigations were actually used by a group of boys attending a secondary school in Malta to raise awareness about smoking. They also won the NSTF competition in 2015 and participated in Science in the City in October 2015. Their Facebook page, together with the hands bands they issued with the help of the Health Promotion Unit were also shown.


These resources, together with reflective prompts by the teacher, the students were asked to reflect and discuss how the students used competencies they acquired through their science education to organise this awareness campaign against smoking.

**Assessment**:

Following this activity, the students were asked to answer the following question in their journal:

*Do you think that smoking is related to science?*

*The students who prepared the project Don't smoke – it's no joke were able to:*
*Describe the negative effects of smoking on the lungs,*

*Design experiments to be able to show these negative effects on smoking.*
*Set up stands in science competitions, exhibitions and fairs to show their experiments to others and to raise awareness about smoking.*
*Set up a Facebook page and produce leaflets and bands together with the Health Promotion Unit which they can distribute to raise more awareness about smoking.*

*Which of the above do you think you are able to do right now?*

*List the things that may be stopping you from being able to do the others.*

## Raising science awareness through the topic Elements, Compounds and Mixtures I and II (DQSE, 2014)

Subject: Integrated Science Form 2
Unit code and title: **SCI 8.3 and 8.4 ELEMENTS, COMPOUNDS AND MIXTURES I AND II**
Strand 1: Materials and their Properties

**The objectives of the syllabus for this topic are to:**

guide students to explore that materials are made up of elements and describe what elements are.
illustrate some examples of elements and guide students to understand how elements are sorted out in the periodic table.
guide students to identify examples of mixtures.
guide students to understand what compounds are.
guide students to explore examples of chemical changes and present them as word equations.

In September 2015, the school teaching staff were informed by the school SMT that the school will be participating in the CHOGM (Commonwealth, Heads of Government Meeting) Malta 2015 activities organised for schools. Every school was twinned with another Commonwealth country with Malta being twinned to Botswana.

In the light of these school based activities, it was decided to tackle the extraction of the element carbon in the form of diamond in Botswana. The extraction of this element is a very hot social scientific issue in Botswana. The recent discovery of diamond in had a great positive impact on the economy. However, since a lot of water was used in the process, this extraction is also having its negative repercussions on water availability in such a hot, dry country.

**Objectives (science awareness)**

In the light of the concept of science awareness developed in this study, at the end of this activity the students were expected to recognise:
that the extraction of minerals is a social scientific issue with several pros and cons.
the competencies needed to work in a group and to give a good presentation in relation to scientific issues.
that such competencies can be achieved through science education.

**Introduction**
Int this activity, the students were asked to work in groups in order to come up with a short presentation related to the extraction of diamond in Botswana. They were also expected to present material, such as a chart or a model as part of an exhibition related to CHOGM activities that was set up in the Education Department, Floriana.

**Development**:

The students were first given some information regarding this activity in relation to CHOGM. The students were then shown two videos: one to show how diamond was discovered in Botswana and its effects on the economy, and one addressing the negative side of this matter. Some keywords were also addressed at this stage.

The students were then divided into 3 groups of 3 and one group of 4 to address the following areas of this project:

*What is diamond?* (Chemistry)

*The story of extracting diamond in Botswana*. (history)

*The process of extracting and refining diamond in Botswana*.

*Diamond Hopes and Diamond Blues*. (2 students addressed advantages and the other two disadvantages)

The students were allowed to group themselves to make sure that they can work well with the other group members.

The students were then given a handout *Planning our work* which together with further scaffolding by the teacher was intended to help them plan the project. Time was also given for the students to discuss how they were going to work as a group and to fill in any necessary details on the handout.

During the time assigned for preparation (which was around three weeks), a few minutes were dedicated in subsequent lessons, to help students reflect on the challenges they were facing while preparing for the presentation. Prompts by the teacher helped them reflect on how they may solve these issues.

The material prepared was presented and was followed by a class discussion during which the students were prompted to reflect about the pros and cons of extracting diamonds.

**Assessment**:

Following this activity, the students will be asked to answer the following question in their journal:

*Please answer the following questions in relation to the activity about diamond in Botswana.*

*List some of the things you need to know how to do in order to prepare for a presentation about a particular topic.*

*A country becomes richer when diamonds are found. Comment.*

## Raising science awareness through the topic Light and Sound (DQSE, 2014)

Subject: Integrated Science Form 2

Unit code and title: **SCI 8.6 LIGHT AND SOUND**

Strand 1: Physical Properties

This chapter is almost completely descriptive in nature focusing on the physical properties of light and sound and how they are detected by the eye and the ear respectively. Consequently, the only areas that were considered to be suitable to tackle in relation to science awareness were ones only marginally tackled by the syllabus, namely the issues of blindness and deafness. It was decided to tackle the latter since it was considered to be more relevant to the students in this particular school as there were a number of students attending this school who had to deal with this problem.

**Objectives for syllabus topic Light and Sound**

The teacher will:

guide students to use ray diagrams to show how objects are seen.

show the structure of the eye and guide students to explain how our eyes enable us to see.

guide students describe sound and identify sound sources.

guide students to use the particle theory to explain how sound travels through materials but not through a vacuum.

show the structure of the ear and guide students to explain how our ears enable us to hear.

**Objectives (Science awareness)**

In the light of the concept of science awareness developed in this study, at the end of this activity the students were expected to recognise:

that deafness is an issue that has a science component.

the knowledge, skills and attitudes needed in order to engage with and take decisions related to deafness.

that through science education one can get the competencies needed to take decisions related to deafness to improve one's quality of life.

through science education one can get competencies needed to engage with and help persons who are deaf.

**Previous knowledge:**

At the beginning of this lesson, the students should have attained objectives 3-5 of the syllabus as indicated above.

**Introduction**

In this activity, the students were engaged in a discussion with a person who lost his hearing ability when he was 13 years old. He was also accompanied by a specialist in cochlear implant apparatus. The visitors were thoroughly informed about the objectives of the lesson. Through this interaction, the pupils were made more aware that most of the decisions that have to be taken to improve the quality of life of deaf people are in fact science-based. Since cochlear implants are quite new in scientific research and improvements are continuously being made, then students were prompted to reflect that these decisions are far from simple. What information do these people or parents of these people need, how do they weigh the benefits and risks, how do they face such situations, what attitudes do they espouse?

**Development**:

The speaker was contacted and a date was set (12th April 2016). The objectives of the lesson were passed on and explained to the speaker. The students were also prepared by asking them to do some background reading on the subject, revise their notes re ears and hearing, recollect their personal experiences if any and prepare a set of questions they may wish to ask the guest.

**Assessment**:

Following this activity, the students were asked to answer the following question in their journal:

*Do you think that choosing whether to have a cochlear implant is related to science?*
*What do you think Mr X did before deciding to have a cochlear implant?*
*Do you think that Mr X's science education was important in this respect?*

## Raising science awareness through the topic Forensic Science (DQSE, 2014)

Subject: Integrated Science Form 2

Unit code and title: **SCI 8.7 FORENSIC SCIENCE**

Strand 1: Physical Properties, Life processes and Living things, Materials and their properties

**The objectives of the syllabus for this topic are to:**

guide students to describe the importance of forensic science to solve crimes and relate

observation skills to forensic science

guide students to collect and process evidence from a crime scene

guide students to use separation techniques to provide evidence.

guide students to collect and process evidence from a fire

This is the area of the syllabus that specifically addresses the work of scientists. It shows who scientists really are and what science actually is. It shows that scientists are not loners who work isolated in labs but are expected to work also with other experts even out of the lab such as in courtrooms. Forensic science also shows very clearly the overlap that exists between the traditional sciences that are so strictly divided in science education. Therefore, it was decided to enhance students' image of scientists through the work of forensic scientists. Knowing what scientists really do is very important if students are to engage with issues of a scientific component. This activity was also merged with the organisation of the Teen Science Café, an initiative by DQSE (Directorate of Quality and Standards in Education) to promote STEM careers.

**Objectives**

In the light of the concept of science awareness developed in this study, at the end of this activity the students are expected to recognise that:

the work of scientists is very important

scientists work closely with other experts to solve problems.

the competencies of scientists go beyond the possession of scientific knowledge

scientists tend to have positive attitudes and enthusiasm to take action, but may also make mistakes.

**Previous knowledge:**

At the beginning of the lesson, the students should have at least some idea of what a scientist is.

**Introduction**

The students were asked to draw an image of a scientist in their journal. They were also asked to write a few words to describe a scientist. They were also briefed about the Teen Science

Café activity that was to be held at school and asked to keep reflecting on this image of a scientist during the activity itself.

**Development**:

The students were then informed about the respective STEM professionals that were to visit the school by their PSCD (Personal, Social and Career Development ) teachers. They were prompted to come up with a number of questions they wished to ask these visitors and to write them on question cards provided by DQSE.

The Teen Science Café was held on the 10th March during which the students had short informal discussions with six professionals, including a Forensic scientist in succession.

**Assessment**:

Following this activity, the students were asked to answer the following question in their journal:

*Refer to the image of a scientist you drew before the Teen Science Café. Do you still regard scientists and science in the same way following this activity?*

The students were also asked to discuss their thoughts.

## Raising science awareness through the topic Climate Change (DQSE, 2014)

Subject: Integrated Science Form 2

Unit code and title: **SCI 8.9 CLIMATE CHANGE II – ENVIRONMENTAL CHEMISTRY**

Strand 1: Materials and their Properties

The two chapters on climate change include quite a number of social and global scientific issues such as global warming, waste management, water pollution etc. Thus, in contrast to other areas of the syllabus, in this case it wasn't quite difficult to choose the area to tackle. It was decided to use analysis of newspaper articles for students to derive the sources, effects and remedies of pollution and climate change (as required by Climate Change II), while at the same time reflecting on how scientists can work with other important social bodies and even citizens to tackle these problems. The role of science education in this regard was also targeted.

**Objectives for syllabus topic Climate Change II**

The teacher will:
guide students to explore sources of air pollution and their effects.

guide students to explore sources of land pollution and their effects.

guide students to explore sources of water pollution and their effects

**Objectives (science awareness)**

In the light of the concept of science awareness developed in this study, at the end of this activity the students are expected to recognise:
the science is very important to tackle issues of pollution and climate change.
that such issues have social and global political and economic implications.
that the role of several key players is crucial to tackle and solve such issues.

**Introduction**
The *Times of Malta* (Allied Newspapers Ltd.), which is one of the most prominent newspapers on the island was screened for articles related to the pollution and climate change. Criteria for choice of articles included that they:
were as recent as possible (last two years)
referred to a Maltese scenario
were related to areas mentioned in the syllabus.

The list of articles tackled is given in the table below:

| Area | Date of article | Title of article |
|---|---|---|
| **Air pollution** | Thursday, July 3, 2014 | The air that we breathe. |
| | Saturday, May 9, 2015 | Clean air. |
| | Sunday, May 3, 2015 | Solution to air pollution: fewer cars or cleaner fuels |
| | Friday, April 15, 2016 | Improving the air we breathe. |
| **Water pollution** | Saturday, October 11, 2014 | Oil clean up at 'advanced' stage. |
| | Wednesday, July 15, 2015 | Bay watch after oil spill. |
| | Wednesday, July 22, 2015 | Swimming ban in Qajjenza because of oil spill. |
| | Wednesday, March 188, 2015 | Fresh reports of raw sewage near Xghajra. |
| | Thursday, September 4, 2014 | Probe into boats dumping sewage. |
| | Wednesday, September 3, 2014 | The effects of plastic marine pollution. |
| **Land pollution** | Thursday, April 17, 2014 | Duties when recycling waste |
| | Wednesday, January 14, 2015 | Food waste action plan launched. |
| | Saturday, May 9, 2015 | EU Commissioner visits biological waste treatment plant. |
| | Thursday, October, 9, 2014 | 'Consumers must change habits over waste. |
| **Climate change** | Friday, August 1, 2014 | Wasting food is wasting resources. |
| | Thursday, June 18, 2015 | Pope demands climate change action |
| | Thursday, June 19, 2014 | Climate change will 'hit' tourism. |
| | Wednesday, April , 2015 | The economic cost of climate change. |

The articles were downloaded and printed and then divided among four groups of students each of which tackled one of the areas shown in the table above.

**Development**:

Every student read one or two of the articles of the set assigned and attempted to identify the source, effect, remedies of the factors mentioned in the article.

Following this process, the students were asked to discuss their findings further in the group set up, to reflect upon how the issues tackled and the remedies listed were related to science. They were also asked to reflect on how the solutions to such problems go beyond science and require the input of significant others.

All the groups were then asked to reflect about these aspects with the rest of the class through a discussion scaffolded by prompts from the teacher. In particular, the teacher asked the students to think about how their science education was helping them become part of the solution to the problem of pollution.

**Assessment**:

Following this activity, the students were asked to write answers to the following questions in their journal:

*Do you think that pollution is a problem created by the rich?*

*Who are the key players involved in finding a solution to pollution and climate change? How do they work together to achieve this?*

*How do you think you can be part of this solution?*

## Raising science awareness through the topic Fieldwork (DQSE, 2014)

Subject: Integrated Science Form 2

Unit code and title: **SCI 8.10 FIELDWORK**

Strand 1: Life Processes and Living Things

**The objectives of the syllabus for Fieldwork is to:**

investigate a habitat and identify the human impact on this habitat through a fieldwork activity by:
identifying examples of human negative impact on the environment.
identifying examples of human positive impact on the environment.
identifying and explaining links between the human behaviour and the environment
explain conservation and the role of NGOs

Since the first three objectives are usually covered quite extensively through fieldwork, then it was decided that more emphasis should be given to the role of the NGO that was responsible for organising the fieldwork chosen to cover this topic at Buskett, namely Birdlife.

**Objectives (science awareness)**

In the light of the concept of science awareness developed in this study, at the end of this activity the students were expected to recognise that:
the issues tackled by birdlife e.g. laws to control hunting of birds are related to science.
activists such as members of birdlife have skills and attitudes that go beyond scientific knowledge.
science education may help in developing these values and attitudes.

**Previous knowledge:**

At the beginning of this lesson, the students should have had an introduction to the fieldwork and some common scientific terms that are usually mentioned.

**Introduction**

The students were divided into groups and were asked to go through website of Birdlife Malta (www.birdlifemalta.org), which is very detailed and updated.

**Development**:

In the process, they were asked to reflect on the issues tackled by Birdlife and the activities it organises. In particular, the students were asked to discuss whether the activities and issues tackled by Birdlife are related to science, the qualities needed by members of this environmental NGO and in what ways science education may have helped them in the acquisition of such competencies.

This was followed by fieldwork organised by Birdlife in the main woodland in Malta, namely Buskett.

Here, they reflected further on the importance of environmental NGO's by discussing the role of Birdlife with a veteran member of this NGO through the following questions:
*Do you think that the issues that are tackled by Birdlife are related to science? why?*
*What qualities does a person need to carry out these activities?*
*In what ways did your science education helping you to get these qualities?*

**Assessment**:
Back at school, the students were asked to reflect on the whole activity, by writing responses to the same questions that were asked to the member of the NGO during the fieldwork and which are listed above.

**APPENDIX J Permissions granted to carry out the learning activities during Phase 2 of this study.**

EDu/072/15
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# UNIVERSITY OF MALTA

## UNIVERSITY RESEARCH ETHICS COMMITTEE

***Check list to be included with UREC proposal form***

Please make sure to tick **ALL** the items. Incomplete forms will not be accepted.

| | | YES | NOT APP. |
|---|---|---|---|
| 1a. | Recruitment letter / Information sheet for subjects, in English | ✓ | |
| 1b. | Recruitment letter / Information sheet for subjects, in Maltese | ✓ | |
| 2a | Consent form, in English, signed by supervisor, and including your contact details | ✓ | |
| 2b | Consent form, in Maltese, signed by supervisor, and including your contact details | ✓ | |
| 3a | In the case of children or other vulnerable groups, consent forms for parents/ guardians, in English | ✓ | |
| 3b | In the case of children or other vulnerable groups, consent forms for parents/ guardians, in Maltese | ✓ | |
| 4a | Tests, questionnaires, interview or focus group questions, etc, in English | ✓ | |
| 4b | Tests, questionnaires, interview or focus group questions, etc, in Maltese | ✓ | |
| 5a | Other institutional approval *for access to subjects*: Health Division, Directorate for Quality and Standards in Education, Department of Public Health, Curia... | ✓ | |
| 5b | Other institutional approval *for access to data*: Registrar, Data Protection Officer Health Division/Hospital, Directorate for Quality and Standards in Education, Department of Public Health... | | ✓ |
| 5c | Approval from person *directly responsible for subjects*: Medical Consultants, Nursing Officers, Head of School... | ✓ | |

| | |
|---|---|
| **Received by Faculty office on** | 20/05/2015 |
| **Discussed by Faculty Research Ethics Committee on** | 26/05/2015 |
| **Discussed by university Research Ethics Committee on** | 17/7/2015 |

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## UNIVERSITY OF MALTA

**Request for Approval of Human Subjects Research**

Please type. Handwritten forms will not be accepted

You may follow this format on separate sheets or use additional pages if necessary.

| FROM: *(name, address for correspondence)* | PROJECT TITLE: |
|---|---|
| Claudette Azzopardi<br>44/2 Melwood Park<br>Triq Anglu Gatt<br>Mosta MST4025 | Raising the Level of Science Awareness amongst Early Secondary Students |
| TELEPHONE: 27420753/ 79283855 | |
| E-MAIL<br>claudette.azzopardi.01@um.edu.mt | |
| COURSE AND YEAR:<br>Ph.D. (2010-2017) | |
| DURATION OF ENTIRE PROJECT:<br>from September 2015 to June 2016 | FACULTY SUPERVISOR'S NAME:<br>Prof. Suzanne Gatt |

ANTICIPATED FUNDING SOURCE: n/a
*(include grant or contract number if known)*

1. Please give a brief summary of the purpose of the research, in non-technical language.

Several studies have shown that students, particularly those at the end of secondary schooling tend to be detached from their science education (Schreiner & Sjoberg, 2004; Azzopardi, 2008). The majority regard school science as important but not for them (Jenkins, 2005). The aim of this research is to develop learning strategies specifically targeted at raising science awareness amongst early secondary students at a stage when attitudes towards science are still in their formation (Bennett & Hogarth, 2009).

In this study, science awareness is being featured as a recognition: of the importance of science in personal and social lives; of the knowledge, skills and attitudes needed to engage with issues having a scientific/technological component; and that these competencies can be acquired through science education. It is an attempt at concretely addressing the issue of the relevance of science education rather than leaving it as a hidden part of the curriculum.

2. Give details of procedures that relate to subjects' participation

(a) How are subjects recruited? What inducement is offered? *(Append copy of letter or advertisement or poster, if any.)*

I have been teaching Integrated Science and Chemistry in the school where this research will be carried out since 2003. One group of Form 2 students, which usually includes around 13 students will be assigned to me by the Head of School where I teach after all the required permissions for research have been acquired. I will be their Integrated Science teacher for the rest of the year. The other groups of Form 2 students will be taught Integrated Science by other teachers. The lesson plans regarding science awareness will be shared with the other teachers so that they they can make use of them during their lessons at their discretion.

There will be no particular selection criteria. The only criterion that will determine which group I will teach is whether I will be available to teach the students in the slots allotted for Integrated Science in their time-table. Following a brief explanation of the project to the students, the attached information sheets and consent forms for parents and students will be distributed.



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(b) Salient characteristics of subjects—number who will participate, age range, sex, institutional affiliation, other special criteria:
The subjects will be around thirteen Form 2 girls all attending the Church school where I teach.

(c) Describe how permission has been obtained from cooperating institution(s)—school, hospital, organization, prison, or other relevant organization. *(Append letters.)* Is the approval of another Research Ethics Committee required?
Permission to carry out the final part of this study was obtained from the Head of School in question, and since this is a Church school from the Secretariat of Catholic Education. The approval of another Research Ethics Committe is not required.

(d) What do subjects do, or what is done to them, or what information is gathered? (Append copies of instructions or tests or questionnaires.) How many times will observations, tests, etc., be conducted? How long will their participation take?

At the beginning of the scholastic year, the students will be asked to answer the original questionnaire, already approved by UREC and which was used in the first part of this study. The data will be used to gauge the students' level of science awareness when compared to the general level of science awareness amongst Form 2 students in the Maltese Islands as found through the survey carried out in the first part of this research. A copy is being attached to this form.
Seven activities, with special emphasis on science awareness will then be carried out throughout the year, one each for seven main topics usually covered in the Form 2 Integrated Science syllabus. An exemplar is attached. One should note that raising science awareness in the way described in this study contributes to: "enabling students to become responsible citizens who can make decisions concerning science-related social issues"; and to "developing interest, skills and knowledge for future careers in view of enabling students to contribute in the current and future challenges in science and technology", both of which are aims of the Integrated Science Curriculum(DQSE, 2012, p8). In this sense, the intervention will be addressing the targets of the curriculum and is in no way extraneous to what students are expected to carry out during their science lessons.
Each of the learning activities will approximately take a double lesson. Data will be collected from the teacher/researcher's journal and the students' journal. The students are expected to write reflections on the seven activities related to science awareness that will be covered during the year. An interview will be carried out with three students towards the end of the scholastic year in order to discuss in more detail the reflections included in their journal. Selection of students at this stage will be based upon the range of science awareness mirrored through their journal reflections.
The questionnaire and the interviews will be carried out during free periods so as to avoid having students who opted not to participate in the data collection being idle during this process.
DQSE (Department of Quality and Standards in Education). (2012). Handbook for the Teaching of Integrated Science.

(e) Which of the following data categories are collected? Please indicate 'Yes' or 'No'.

| | | |
|---|---|---|
| Data that reveals – race or ethnic origin | | No |
| | political opinions | No |
| | religious or philosophical beliefs | Yes |
| | trade union memberships | No |
| | health | No |
| | sex life | No |
| | genetic information | No |

3. How do you explain the research to subjects and obtain their informed consent to participate? (If in writing, append a copy of consent form.) If subjects are minors, mentally infirm, or otherwise not legally competent to consent to participation, how is their assent obtained and from whom is proxy consent obtained? How is it made clear to subjects that they can quit the study at any time?

The research project and its aims will be explained to the group of students at the beginning of the scholastic year. An information sheet will also be given to the students and consent is sought both from the parents and the students (see attached forms). The subjects and the parents will be informed that should they refuse to participate in the study, the intervention will still be carried out but data will not be collected from the students in question.

4 .Do subjects risk *any* harm—physical, psychological, legal, social—by participating in the research? Are the risks necessary? What safeguards do you take to minimize the risks?

There is no known physical, psychological, legal or social harm associated with participation in this research. However, in order to avoid any undue pressure from my part on the students, a Head of Department, who is also employed at the school where the research is to be carried out has accepted to act as my critical friend. Amongst other things, she will see that I am ethically correct in the classroom.

5. Are subjects deliberately deceived in *any* way? If so, what is the nature of the deception? Is it likely to be significant to subjects? Is there any other way to conduct the research that would not involve deception, and, if so, why have you not chosen that alternative? What explanation for the deception do you give to subjects following their participation?

This research does not involve deliberate deception of the subjects.

6. How will participation in this research benefit subjects? If subjects will be "debriefed" or receive information about the research project following its conclusion, how do you ensure the educational value of the process? *(Include copies of any debriefing or educational materials)*

Since the learning strategies that will be used are being developed through rigorous triangulation of quantitative data, qualitative data and literature, the subjects will benefit to varying extents from an increased recognition of the importance of science and science education in their lives. They will also have a better understanding of the nature of science and thus will be in a better position to make an informed choice regarding the subjects they wish to study in the coming years.

TERMS AND CONDITIONS FOR APPROVAL IN TERMS OF THE DATA PROTECTION ACT

- Personal data shall only be collected and processed for the specific research purpose.
- The data shall be adequate, relevant and not excessive in relation to the processing purpose.
- All reasonable measures shall be taken to ensure the correctness of personal data.
- Personal data shall not be disclosed to third parties and may only be required by the University or the supervisor for verification purposes. All necessary measures shall be implemented to ensure confidentiality and where possible, data shall be anonymised.
- Unless otherwise authorised by the University Research Ethics Committee, the researcher shall obtain the consent from the data subject (respondent) and provide him with the following information: The researcher's identity and habitual residence, the purpose of processing and the recipients to whom personal data may be disclosed. The data subject shall also be informed about his rights to access, rectify, and where applicable erase the data concerning him.

I, the undersigned hereby undertake to abide by the terms and conditions for approval as attached to this application.

I, the undersigned, also give my consent to the University of Malta's Research Ethics Committee to process my personal data for the purpose of evaluating my request and other matters related to this application. I also understand that, I can request in writing a copy of my personal information. I shall also request rectification, blocking or erasure of such personal data that has not been processed in accordance with the Act.

Signature: C. A...

| APPLICANT'S SIGNATURE: | FACULTY SUPERVISOR'S SIGNATURE |
|---|---|
| *I hereby declare that I will not start my research on human subjects before UREC approval* | I have reviewed this completed application and I am satisfied with the adequacy of the proposed research design and the measures proposed for the protection of human subjects. |
| DATE 18/5/2015 | DATE |

UNIVERSITY OF MALTA Faculty of Education MSIDA MALTA

***Return the completed application to your faculty Research Ethics Committee***

EDU 72

*To be completed by Faculty Research Ethics Committee*

We have examined the above proposal and advise

**Acceptance** **Refusal** **Conditional acceptance**

For the following reason/s:

Signature [signature] Date 27th May 2015

*To be completed by University Research Ethics Committee*

We have examined the above proposal and grant

**Acceptance** **Refusal** **Conditional acceptance**

For the following reason/s:

Signature [signature] Date 23/7/15

## Information Letter – Head of school

I am currently working on a doctoral research project at the Faculty of Education, University of Malta, to enhance science awareness amongst early secondary students. Several studies have shown that students, particularly those at the end of secondary schooling tend to be detached from their science education. The majority of students regard school science as important but not for them. The aim of this research is to develop learning strategies specifically targeted at raising science awareness amongst early secondary students at a stage when attitudes towards science are still in their formation. The level of science awareness of early secondary students was gauged towards the end of the scholastic year 2011-2012. This was achieved through a questionnaire that was distributed to a representative sample of 400 Form 2 students attending Maltese schools. May I thank you again for your support in the first phase of my study. A preliminary report of the quantitative results has already been sent to the schools which participated in this stage of data collection. The second set of data was collected during the third term of the subsequent scholastic year through a number of focus groups with different student subtypes. A number of learning strategies are now being developed through triangulation of data derived from literature, the survey and the focus group discussions in order to raise science awareness as defined in this study.

Your consent to carry out the the third and final part of this project in your school is now being sought. Subject to your approval, an intervention programme to implement the learning strategies developed will be carried out by me with a Form 2 group while covering the school science curriculum over the course of the scholastic year 2015-2016. The main target of this intervention is to gain some preliminary insights into the schemes developed. Seven activities, specifically targeting science awareness will be carried out by the researcher throughout the scholastic year 2015-2016. The activities, lasting a double lesson each will all be embedded in the targets of the curriculum and are in no way extraneous to what students are expected to carry out during their science lessons. The students will also be asked to keep a journal in relation to the activities tackling science awareness. Thus, data will be collected from the students through:

- their responses to the original science awareness questionnaire
- their reflections on the activities included in their journal
- audio recordings of interviews regarding the reflections included in the journal.

During this intervention:

- data will only be collected once consent has been granted by the parents and the students.
- the students' responses will be kept strictly anonymous and none of the data released will identify the participants by name, or any other data, descriptions or characterizations.
- the students may discontinue their participation at any time
- all the data collected will be destroyed once the thesis is complete.
- a Head of Department who is also employed in your school has accepted to be my critical friend and to screen the process both at an ethical and academic level.

Claudette Azzopardi

Address: 44/2, Melwood Park, Triq Anglu Gatt, Mosta Mob:79283855 e-mail: claudette.azzopardi.01@um.edu.mt

**Information Letter – Secretariat of Catholic Education**

I am currently working on a doctoral research project at the Faculty of Education, University of Malta, to enhance science awareness amongst early secondary students. Several studies have shown that students, particularly those at the end of secondary schooling tend to be detached from their science education. The majority of students regard school science as important but not for them. The aim of this research is to develop learning strategies specifically targeted at raising science awareness amongst early secondary students at a stage when attitudes towards science are still in their formation. In this study, science awareness is being featured as a recognition of: the importance of science in personal and social lives; the knowledge, skills and attitudes needed to engage with issues having a sociological and technological component; and the importance of science education in the acquisition of these competencies. It is an attempt at concretely addressing the issue of the relevance of science education rather than leaving it as a hidden part of the curriculum.

The level of science awareness of early secondary students was gauged towards the end of the scholastic year 2011-2012. This was achieved through a questionnaire that was distributed to a representative sample of 400 Form 2 students attending Maltese schools. May I thank you again for your support in the first phase of my study. A preliminary report of the quantitative results has already been sent to the schools which participated in this stage of data collection. The second set of data was collected during the third term of the subsequent scholastic year through a number of focus groups with different student subtypes. A number of learning strategies are now being developed through triangulation of data derived from literature, the survey and the focus group discussions in order to raise science awareness as defined in this study.

Your consent to carry out the the third and final part of this project in a church school (name) is now being sought. Subject to your approval, an intervention programme to implement the learning strategies developed will be carried out by me with a Form 2 group while covering the school science curriculum over the course of the scholastic year 2015-2016. The main target of this intervention is to gain some preliminary insights into the schemes developed. Seven activities, specifically targeting science awareness will be carried out by the researcher throughout the scholastic year 2015-2016. The activities will all be embedded in the targets of the curriculum and are in no way extraneous to what students are expected to carry out during their science lessons. The students will also be asked to keep a journal in relation to the activities tackling science awareness. Thus, data will be collected from the students through:

- their responses to the original science awareness questionnaire
- their reflections on the activities included in their journal
- audio recordings of interviews regarding the reflections included in the journal.

During this intervention:

- data will only be collected once consent has been granted by the Head of School, the parents and the students.
- the students' responses will be kept strictly anonymous and none of the data released will identify the participants by name, or any other data, descriptions or characterizations.
- the students may discontinue their participation at any time
- all the data collected will be destroyed once the thesis is complete.
- a Head of Department who is employed in the same school has accepted to act as a critical friend in order to screen the process both at an ethical and academic level.

Claudette Azzopardi

Address: 44/2, Melwood Park, Triq Anglu Gatt, Mosta Mob:79283855 e-mail: claudette.azzopardi.01@um.edu.mt

# APPENDIX K: Interview questions used to investigate different levels of science awareness.

MELISSA – INTERVIEW – HIGH LEVEL OF SCIENCE AWARENESS

X'laqtek  l-iktar fil-lezzjonijiet tax-xjenza din is-sena?

*What struck you during this year's science lessons?*

Liema tip ta lezzjonijiet laqtuk l-iktar?

*What type of lessons did you like the most?*

Il-journal taħseb li għinek taħseb aktar fuq dak li kont qiegħda titgħallem?

*Did the journal help you to think more about what you were learning?*

X'diffikultajiet sibt meta kont qegħda tikteb il-journal?

*What difficulties did you encounter while you were writing the journal?*

A country becomes richer when diamonds are found. Comment.  "I think a country which found diamond gets richer in a way but it also has disadvantages from the other side". What disadvantages were you referring to?

Taf b'xi każijiet oħra fejn nies sinjuri jużaw il-benefiċċji tax-xjenza b'detriment għal ħaddiehor?

*Can you mention other cases where rich people use the applications of science at the detriment of others?*

"Fil-kaz ta smoking. I think I'm not able to set up stands because it needs to have a lot of neatness, organisation and planning and I think I wouldn't be able to do them. I dont' think I would be able to talk to higher people in the health promotion unit to help me raise awareness."

Liema tip ta' lezzjonijiet taħseb li jgħinuk tagħmel dan?

*What type of lessons do you think will help you achieve this?*

"Scientists and jobs that include science sometimes are a lot different than they seem on TV." X'giegħlek taħseb hekk?

*What made you think in this way?*

Taħseb li x-xjentisti dejjem jaqblu bejniethom?

*Do you think that scientists always agree?*

Taħseb li huma dejjem responsabbli?

*Do you think that scientists are always responsible?*

"He went to see the doctor and asked for advice and had some tests." Kieku int kont qegħda f'din is-sitwazzjoni u kellek tiddeċiedi jekk tagħmilx implant jew le, x'taħseb li kont tagħmel? (kompli elabora fuq knowledge, skills u attitudes).

*If you were in this situation and had to decide whether to have an implant or not what would you have done?*

"The key players involved in finding solution to pollution would be World Health Organisation."

Taħseb li hemm xi nies jew gruppi oħra involuti?

*Do you think that there are other people or groups involved?*

"The only thing that I can do is to try and use less energy."

Kieku kellek taħseb iktar fil-fond, taħseb li hemm affarijiet oħra li tista' tagħmel?

*If you had to think further, do you think that there are other things that you can do?*

Do you think that the issues tackled by Birdlife are related to science? Why? What qualities does a person need to carry out these activities? In what way is your science education helping you to get these qualities?

"In my opinion, it matters which subject is chosen but I don't think it helps a lot."

X'ridt tfisser eżatt?

*What did you mean?*

Għaliex m'għażiltx it-tlett xjenzi?

Why didn't you choose the three sciences?

CHARMAINE – INTERVIEW – MEDIUM LEVEL OF SCIENCE AWARENESS

A country becomes richer when diamonds are found. "They become richer because they can sell them and make money."

Taħseb li jista' jkun hemm xi żvantaġġi? Taf b'xi każijiet oħra fejn nies sinjuri jużaw il-benefiċċji tax-xjenza b'detriment għal ħaddieħor?

*Do you think there can be any disadvantages? Can you mention other cases where rich people use the applications of science to the detriment of others?*

"I learned how to research better on the web and to work better in groups." Liema kienu dawk l-affarijiet li għinuk biex taħdem aħjar fi grupp?

*What were the factors that helped you work better in a group?*

"I cannot set up stands and enter a competition because sometimes I get shy and I would be worried about something going wrong."

Taħseb li tista' tegħlibha  din il-ħaġa? Kif?

*Do you think you can overcome this problem? How?*

Taħseb li x-xjentisti dejjem jaqblu bejniethom?

*Do you think that scientists always agree?*

Taħseb li huma dejjem responsabbli?

*Do you think they are always responsible?*

Taħseb li ġieli jagħmlu żbalji?

*Do you think that sometimes they do make mistakes?*

"*Before the cochlear implant he had to wear lots of different types of hearing aids…he started with a small one and the problem got worse and so he went to the doctor and had surgery".

Kieku int kont qegħda f'din is-sitwazzjoni u kellek tiddeċiedi jekk tagħmilx implant jew le, x'taħseb li kont tagħmel? (kompli elabora fuq knowledge, skills u attitudes).

*If you were in this situation and had to decide whether to have an implant or not what would you have done?*

"A person needs to be someone who loves the environment and someone who is willing to go against the government's word and they have to be someone who don't give up."

Taħseb li int kapaċi tagħmel ix-xogħol ta' dawn in-nies? Xi tħoss li għandek nieqes? X'tip ta' lezzjonijiet jistgħu jsiru biex jgħinuk tagħmel dan?

*Do you think you are able to carry out the work of these people? What do you think you still lack? What type of lessons can help you out?*

Għaliex m'għażiltx it-tlett xjenzi?

*Why didn't you choose the three sciences?*

JAEL – INTERVIEW – LOW LEVEL OF SCIENCE AWARENESS

X'laqtek l-iktar fil-lezzjonijiet tax-xjenza din is-sena?

*What struck you during this year's science lessons?*

Liema tip ta lezzjonijiet laqtuk l-iktar?

*What type of lessons did you like the most?*

Il-journal taħseb li għinek taħseb aktar fuq dak li kont qiegħda titgħallem?

*Did the journal help you to think more about what you were learning?*

X'diffikultajiet sibt meta kont qegħda tikteb il-journal?

*What difficulties did you encounter while you were writing the journal?*

X'jista' jsir biex jgħinek tikteb aħjar?

*What can be done to help you in writing the journal?*

"When a country finds diamond, they become rich because they are rare to find and they are expensive."

Taħseb li jista' jkun hemm xi żvantaġġi relatati mas-sejba tad-diamonds?

*Do you think that there can be any disadvantages related to the extraction of diamond?*

Tkellimt ma xjentisti differenti. Taħseb li x-xjentisti ġieli jagħmlu żbalji?

*You spoke with different scientists. Do you think that sometimes scientists do make mistakes?*

Kif taħseb li x-xjentisti jiddeċiedu x'għandhom jistudjaw?

*What do you think determines what scientists choose to study?*

Inti għidt li m'għandekx tkun parti minn din is-solution fuq pollution u climate change. Għaliex le u allura min taħseb li għandu jkun responsabbli?

*You stated that should shouldn't be part of the solution to pollution and climate change. Why not?...and therefore who is responsible?*

X'taħseb li jridu jkunu kapaċi jagħmlu n-nies li jaħdmu mal-Birdlife?

What do you think members of Birdlife should be able to do?

"Negative effects and leaflets yes, design experiments, competitions no.

Naħseb li miniex kapaċi nagħmilhom waħdi." Għalfejn, xi tħoss li għandek nieqes?

*I don't think I am able to do them on my own. Why? What do you think you lack?*

Taħseb li l-lessons ta din is-sena għamlek iktar konxja tas-science fil-ħajja tiegħek kemm personali u anki soċjali?

*Do you think that this year's science lessons have made you more aware of the importance of science in your personal and social life?*