GAUGING THE LEVEL OF SCIENCE AWARENESS AMONG EARLY SECONDARY MALTESE STUDENTS.

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Abstract: Science education for the general student currently aims to enable all students to engage with and acting upon personal, social and global issues which have a scientific/technological aspect. It is generally agreed that this engagement involves the acquisition of certain subject, personal and social attributes. An effort is being made by science educators to promote positive attitudes to science, particularly towards school science as several studies have shown that attitudes to science tend to decline between the age of 11 and 14. In this paper, it is argued that the basis for improved engagement with science depends on a good level of science awareness by young people during the early secondary years of education. An attempt is made to fine tune the definition of science awareness and to distinguish it, yet simultaneously relate it with 'scientific literacy' and 'science for citizenship'. The meaning of science awareness that guided this study was derived from a psychological definition of awareness combined with a sociocultural relativistic view of science. A questionnaire was designed to gauge the level of science awareness amongst Maltese students in the second year of secondary schooling. Results have shown that some beliefs that the students have about the importance of science and science education do not reflect the role of science and technology in society. The factors that affect the development of science awareness in Malta have been found to be highly related to schooling, such as the type of school attended and the pedagogies adopted in science classrooms. Engagement with science can be improved through a conscious effort to adopt appropriate pedagogical strategies aimed at raising science awareness during school science.

Keywords: science awareness; engagement; early secondary; attitudes; scientific literacy; science for citizenship.

INTRODUCTION

Research in science education in Malta has been focused mainly on students who are preparing for their school leaving (Azzopardi, 2008; Galea, 2008; Degabriele, 2008). There was less interest in the early secondary years which may be crucial in shaping students' attitudes towards science and in determining subject choice. Malta has not performed well in the TIMSS study in 2007 (Gonzales *et al.,* 2008), with almost all other participating European Union countries obtaining a better placing than Malta. These results also caused the impetus to carry out this study.

In this study, an attempt is made to provide a measurement of science awareness among young Maltese students (average age of 12) in their second year of secondary schooling. In this study, the notion of science awareness as an understanding of common science concepts is challenged. The definition of science awareness in this research is derived from its psychological roots and is considered to involve the recognition of the importance of science and science education as a pre-requisite to the formation of attitudes and decision to be actively engaged in school science and or scientific social issues. Scientific awareness may thus be considered as the foundation of a willingness to engage in science. It provides a disposition/readiness to gain the knowledge, skills and attitudes that are the desired outcomes

of science education for the general student. It is believed that if young students are not aware of the roles of science in their personal life and in society, and how school science can equip them to deal with scientific issues in society, that they would not be willing to engage in school science.

The measure of science awareness was obtained through a questionnaire designed as part of a doctoral research entitled: *Raising the Level of Science Awareness Amongst Early Secondary Students*. This tool is built on the assumption that cognitive beliefs on which students base their attitudes about the usefulness of science and technology in their personal life, and the value that they give to school science education provide a measure of this science awareness. The measure also provides other important insights into aspects of science education in Malta prior to subject specialisation, such as: the students' achievement in science; factors determining subject choice; the type of pedagogies used in the classroom; participation in out-of-school science activities; students' home background; and their general attitudes to science.

THEORETICAL BACKGROUND

The cultural context characterising contemporary youth and the increasing impact of science and technology on their personal and social lives are the two main influences on the current design of school secondary science education are. Present-day youth form part of a *participatory culture* (Jenkins, 2006), where the widespread use of digital media has changed the position and role of science and scientific enterprise in society through new forms of social dialogic interactions. The constant bombardment of scientific results from the media has contributed to make individuals aware of the uncertainty characterising scientific knowledge. The responsibility for decision-making and action in the face of contradictions, risks and conflicts presented by scientific and technological matters has thus shifted from experts to individual citizens (Beck,1992). Scientific knowledge is no more that unquestionable body or knowledge but has become just another imprecise tool which provides insights rather than definite answers. Any decision reflecting scientific issues now acknowledges the potential marginal sources of error present within the scientific knowledge generated. This requires that citizens possess a wider range of skills and competences if they are to take decisions in the best interest of present and future society.

Handling decision-making and action in relation to scientific and technological issues is not an innate aptitude. An educational framework is required for this participatory role. Consequently, there is currently a more deliberate emphasis of curricula on the *functional* (Hurd, 1998), or *society usefulness* of science education (Holbrook & Rannikmae, 2009) rather than its theoretical aspects. There is a shift towards an *education through science* (Holbrook & Rannikmae, 2007), with science education being envisaged mainly as a vehicle to achieve the much wider educational outcomes of the curriculum for a particular age group. More focus is being placed on the acquisition of 21st century skills (NRC, 2010) or competencies (OECD, 2006) that require students to show what they know, value and are able to do within personal, social and global contexts in relation to scientific and technological issues. The acquisition of these aptitudes is not being left to chance but is featured as a more explicit outcome of the science curriculum, rendering its realisation more likely (UNESCO, 2009).

Science education targeted at the social usefulness challenges the positivistic outlook that science represents a unique and disconnected approach to knowledge. "Such a science is not a dogmatic body of unchanging truth but a science that offers us knowledge, understanding

and methods of working that offer powerful ways to look at the world. It connects with other curriculum subjects and with the lives of the students in and out of school and their communities." (UNESCO, 2009, p.15)

Science education is thus more based on Vygotskian sociocultural philosophical theories which acknowledge the social, technological, historical and economic contexts in which science concepts are embedded. Science is depicted as a social practice featuring an interplay between science, technology and society (Gremmen, 1993). Since citizenship manifests itself in social practices (Van Aalsvoort, 2004), then science education can serve to develop the qualities needed for this participation.

Despite many efforts, the engagement of students with science is still a challenge. Research in attitudes to science in Malta (Azzopardi, 2008; Gonzales *et al.,* 2008) and abroad (Osborne & Collins, 2001; Cerini, Murray & Reiss, 2004) has shown that secondary level science subjects tend to instil negative affective attitudes amongst students. This dislike to science seems to increase with age with a steep drop in attitudes being reported between ages of 11 and 14 (Bennett & Hogarth, 2009). Additionally, while general appreciation of science outside school, also termed *impersonal science* (*ibid*.) was identified, this was not reflected with respect to more *personal* aspects, with respect to science in school, or a desire to have jobs involving science. Science is perceived by students as *important but not for me* (Jenkins & Nelson, 2005), While there is appreciation of science in society, youth see it as useful only for the minority wanting to become scientists. Otherwise science is considered to be irrelevant to the actualisation of their life project.

A deliberate focus on an awareness of the personal and social importance of science and science education is necessary as awareness precedes and is a pre-requisite to engagement (Deci & Ryan, 1985). Awareness is considered as the minimal level of the process of internalization whereby science successively and pervasively becomes part of the individual (Klopfer,1976). The individual first needs to be aware of science or perceive it before s/he is willing to attend to it, develop positive feelings towards it and eventually responds to scientific issues. If the definition of science awareness is based on psychological roots, then it should include solely beliefs or perceptions and intentionally excludes general attitudes and behaviours or intended ones that emerge from it and have been directly used to signify science awareness in other studies (Stocklmayer & Gilbert, 2002; ASTA, 2004). The formation of perceptions also excludes deep understanding of scientific concepts, as although a mental component is acknowledged to awareness it is not considered to involve deep knowledge and processing of data (Gregory,1987). More specifically, science awareness for this specific study means the personal realisation that:

- science and technology have an increasing impact on individual lives and society, implying that;
    - 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; and that
- science education can contribute to the development of these competencies, values and attitudes and thus makes one more able to function in society.

This meaning assigned to science awareness makes it distinct from other overlapping educational objectives such as scientific literacy and science for citizenship. 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 (OECD, 2006: NRC, 1996; AAAS, 1993). Science awareness also excludes the higher capability of political action which is a much expected behavioural outcome of

teaching science for citizenship (Hodson, 2003; Barton & Tan, 2010) Science awareness is that which precedes the development of all these aspects and can be considered to describe individuals who hold a set of beliefs or perceptions about the value of science and science education to enable them to become scientifically literate and to engage in scientific issues as citizens. Scientific awareness highlights that the individual must first realize the relevance of science to his/her level of satisfaction before he or she can engage with it and to participate democratically in relation to personal and social issues with a scientific and technological component.

Secondary education in Malta consists of 5 years which follows primary education and includes students between the ages of 11-16 years. During their secondary education, students follow a general integrated science curriculum during the first two years, at the end of which, students need to decide whether they want to specialise in science and can choose any combination from the separate sciences: Physics; Chemistry; or Biology; or else opt for one science subject which to date includes one science subject of the Physics, Chemistry or Biology. Malta also reflects different forms of education provision with around 60% provided by the State; 30% by the Catholic Church; and the remaining 10% by Independent (Private) schools. The Pisa (2011) exercise showed that Malta lags behind major countries in science education, and that significant differences in achievement were identified between the State, Church and Independent providers. It is within this context that this study was carried out.

AIM OF STUDY

The aim of this study was thus to measure the level of science awareness among early secondary level students. The age cohort was considered of particular interest as it targeted students at the stage of secondary education where they decide their subject specialisation. It is believed that the higher is the students' level of science awareness, the more the students will be ready to engage in science and thus opt for science specialisation. The main research question thus was: What level of science awareness do Maltese students in their second year of secondary education have? The research reported here forms part of a doctoral research. Based on the students' measure of science awareness, a number of science education activities within the second year integrated science curriculum and which involve a social perspective of science aiming at raising students' scientific awareness is to be designed and trialled with students. At the time of writing of this article, focus group of interviews aimed at identifying students' interests related to the social aspect of science have been conducted and the science activities aimed at promoting science awareness are being drawn up.

METHODOLOGY

The main tool used to measure science awareness among 12-year old Maltese students was a questionnaire. Science awareness is based on a continuum of beliefs and thus the questionnaire was designed to measure specific indicators formulated from the definition of science awareness stated in the previous section. Raising science awareness implies steering students towards a heightened belief that:

1. Science has an increasing impact on individual lives and society. Thus, a student who is more scientifically aware is more likely to acknowledge that:

a. several issues the individual and society face today pertain a science component;.
b. recent scientific and technological advances are more uncertain and risky than ever before;
c. society influences the progress in science and technology; and
d. science and technology are related to social justice and sustainability of the planet.

2. A range of competencies, values, knowledge and attitudes are essential to be able to engage with and act upon issues having a science component. Thus, a student who is more scientifically aware is more likely to acknowledge that in order to attend to and act upon personal, social and global scientific issues, one needs to:
   a. have some knowledge of scientific concepts useful in everyday life;.
   b. have some knowledge about the process of science;
   c. be able to identify scientifically-oriented issues;
   d. be able to explain phenomena based on data;
   e. be able to use scientific evidence to reach a conclusion;
   f. be interested in science;
   g. be willing to support scientific enquiry;
   h. have a clear feeling of what is right or wrong;
   i. be able to listen to the views of others;
   j. be able to argument and weigh evidence;
   k. cooperate in decision-making and resolution of conflict; and
   l. be politically literate
3. Science education can contribute to the development of these competencies, values and attitudes and thus makes us more able to function in society. 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.

Most items in the questionnaire followed the same basic logic. A statement is 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 can lead to confusion and frustration amongst the respondents (Gable & Wolfe, 1993). The responses go in ascending order: Strongly Disagree – Strongly Agree, or Never – Very Often. Statements related to the different aspects of science awareness indicated above were included.

Once finalised, the questionnaire was reviewed by two science education experts and was then translated in Maltese by a qualified translator. The instrument was piloted with 21 Form 2 students who then did not take part in the actual data collection. Following minor changes to the instrument and the acquisition of the necessary permissions, the instrument was administered to a sample of 400 students attending 28 different secondary schools in Malta and Gozo in May 2012. The sample was representative of gender and type of school. At the time of data collection, there were four types of schools in Malta, namely Independent schools, Church schools, Junior Lyceums (grammar type schools) and Area Secondary

schools (for the rest). The latter two are both state schools with the Area Secondary Schools catering for those students who do not pass their 11+ exams. 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.

Data was coded and analysed by means of the statistical programme SPSS IBM20. *Descriptive statistics* was employed to get a general picture of the school context and home background of the student population. Means and percentage distributions of responses were calculated for Likert scale items. Since a four-point Likert scale was employed, then students were considered to have a neutral opinion about a particular item when the mean was very close to 2.5. In some cases, the Agreement Index, AI (Jenkins & Nelson, 2005) was calculated to show the level of agreement with a particular statement. The *Independent Samples t-test* was employed to identify significant gender differences in science awareness, while the *Chi-Square test* was applied to identify significant differences in distributions in factors other than gender.

RESULTS:

General trends in science awareness

This section will tackle the results obtained for the different aspects of science awareness demonstrated by children and what trends were obtained across gender and/or across schools when these were present.

a) The role of science in different situations

In the first section of the questionnaire, students were asked to show to what extent they agree that a number of personal, social and global issues or decisions were related to science. This measured one aspect of science awareness. It was found that early secondary students tended to recognise the connection mainly of science issues when statements included technical terms usually learnt in science lessons, e.g. *exploration of space* (Mean = 3.44), *whether pollution from a particular source is a risk to health* (Mean = 3.26), *cloning of human beings* (Mean = 3.13), etc. On the other hand, they did not recognise the role of science in issues which had strong political connotation, e.g. *population control* (Mean = 1.78), *laws related to control hunting of birds* (Mean = 1.89), *whether an area should be built or developed* (Mean = 2.04), or involve 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. Students seemed to compartementalise the issues into science and non-science and fail to recognise the interdisciplinarity that threads through some issues which included both scientific and social aspects.

Since students were verbally instructed not to respond to items that they did not understand or which they had never encountered before. Thus missing data may also give useful insights. The most items with high missing data related global issues such as cloning of human beings (Missing = 39.0%) or ecological balance (Missing = 31.3%) . This showed that somehow students were limited to situations within their close environment and did not have a view of global issues. It was also noted that most of the missing data was from students who attended Area Secondary schools while the percentage was negligible for the other schools while missing data from Independent Schools is almost negligible. Except for *abortion*, girls left more empty responses than boys.

b) Awareness of uncertainty in science

Respondents were also asked to indicate their percentage of levels of risk in examples of contemporary scientific applications; and the interplay that exists between science, technology and society. Students disagreed strongly (A.I. = -72.2%) with the statement *the effects of science application are always safe* indicating an awareness of the risk characterising science and its products. Students also seemed to be aware of the uncertainty that characterises the scientific method and scientific results as shown by the values of the Agreement Indices for the items *the scientific method always leads to the correct answer* (A.I. = -33.3%), *the effects of scientific applications are always known exactly* (A.I. = -31.8%) and *scientists often disagree with each other* (A.I. = +14.2%). However, despite these results students still agreed strongly with a statement that reflects a blind-folded positive image of scientists, namely that *all scientists are responsible people* (A.I. = +63.3%).

Students either do not acknowledge or have an almost neutral opinion about the impact that society or its entities may have on the progress of science. They disagreed quite strongly *that scientists research is determined by politicians and industrialists* (A.I. = -43.6%) and exhibit lack of established beliefs in relation to governance: *the Government can control any dangerous developments in science* (A.I. = -6.1%); *common citizens can control the progress of science* (A.I. = -6.4%); and *people like me and my family have little chance to influence scientists* (A.I. = -6.1%). 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* (A.I. = -43.6%) and agree that *scientists often need to work with other experts* (A.I. = +53.1%).

c) Awareness of skills needed to engage in science

Another indicator of science awareness was taken to be the extent to which students recognise the importance of the competencies that they need to engage with scientific issues. The example involved an individual who was physically impaired following an accident and had to decide whether to opt for stem cell treatment, the students were asked to indicate the extent to which they agree that this individual needed certain scientific attributes such as: *showing interest in scientific research* or *evaluating whether the risks of the treatment outweigh the benefits* to improve his quality of life. All agreement indices for the responses were above +28.1%. The lowest A.I. was obtained for the item *his school science education.* This implies that although the students acknowledged the significance of acquiring scientific competencies to deal with certain life situations, they did not regard science education as the best of means to achieve them.

In the second context-based question, students were asked about how citizens who do not agree with a change in fuel for the local power station should behave. The students indicated that one should not remain passive in relation to socio-scientific issues with which one disagrees, but should learn relevant knowledge regarding the issue in question in order to take action. When, negative Agreement Indices were obtained for the only two items featuring passiveness, namely, *accept such a decision as good and final as it was taken by experts* (A.I. = -44.5%) and *only speak up if the decision affects them personally* (A.I. = -22.4%). The Agreement Indices for all the other statements included in this section e.g. *take part in demonstrations to stop the project* and *take part in television debates regarding the issue* are all positive.

d) Competences acquired through Science Education

Students were found to recognise that school science equips them with an understanding of the world around them and some insights of how scientists go about their work. However, they do not feel that it provides them with the competences needed to participate in political action which should be the main aim of a general science education programme. In fact, negative Agreement Indices were obtained for statements such as *participating in political action* (A.I. = -53.8%), and *willingness to participate in political action as a reflective citizen* (A.I. = -23.1%). This finding reflects the type of science learning activities in schools that fail to provide the social perspective of science. As student responses indicated, learning science is mainly teacher-centred and content-based. Community-based and outdoor activities are still one-off sessions. Students thus overall do not link learning science with the skills they need for political action.

Gender and other differences

Boys registered greater awareness of the 'hidden science' that threads through personal and social issues, such as *what car to buy* (Mean difference, M.D. = 0.311, p = 0.001) or *whether an area should be built or developed* (M.D. = 0.361, p=0.000). From the list of issues found to be significantly different, the mean of girls was only higher than that of boys in relation to *abortion* (M.D. = -0.275, p= 0.016). Perhaps this is because this issue is more personally relevant to them and has a socio-emotional perspective.

The awareness of the interplay between science, technology and society was complex. Boys seemed to have a more authentic awareness of the uncertainty characterising modern scientific applications, scoring significantly higher with items such as *the latest scientific applications are more risky than ever before* (M.D. = 0.313, p = 0.001) and *scientists often disagree with each other* (M.D. = 0.235, p = 0.001). They were also more aware that most of the time, scientists research what is politically and financially worthwhile. On the other hand, girls were more aware of the need for greater collaborative effort between scientists and other experts to find solutions to problems and that this is not their sole responsibility. Very few significant gender differences exist for the responses to the two context-based questions that both girls and boys acknowledged similar attributes required to engage with issues of a scientific/technological component.

Boys were also found to judge the personal and societal usefulness of science more negatively than girls, and agreed more strongly that *science is not useful for my everyday life* (M.D. = 0.223, p= 0.008), scientific discoveries do more harm than good; and science has ruined the environment. This reflects the boys' stronger perception of the uncertainty and risk characterising scientific and technological applications. However, boys then preferred school science more than girls with the latter agreeing more that *school science is difficult* M.D. = -0.247, p= 0.01).

More than half the items were found to be significantly different for the type of school making it the strongest determinant of science awareness. Results show that students from Independent and Church schools were in general more similar than students from state schools. The former two also tended to be more scientifically aware in that they demonstrated greater awareness 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. In addition, there seems to be a relation between these perceptions and beliefs characterising science awareness and the judgements or attitudes towards science. Students from Church and Independent schools were more scientifically aware, were also the

ones who held the more positive attitudes towards science and school science. This implies that by ameliorating science awareness one can help students have more positive attitudes towards science and science education.

Although to a lesser degree, the number of science lessons in the last year of primary schooling, as well as the scientific orientation was also important variables. In general, the more the students were exposed to science, the better their science awareness and the more positive attitudes they held about science and science education. Students who opted to study more than one science subjects were also more scientifically aware and portrayed more positive judgements about science and science education.

DISCUSSION

This study has provided insights into Maltese early secondary students' level of science awareness of the roles of science in society and the impact of science on social issues. It has also provided some information about important trends about the state of science education provision in Malta as well as areas of awareness which can be tackled in promoting science specialisation among students.

It has been found that students could identify the role of science mainly in those aspects which are closely related to school science. Students were, however, less aware of the social perspective of science at both personal and social level. In addition, among those who held higher levels of science awareness, this awareness was higher with respect to situations limited to the students' close environment. Students were less aware of situation related to science and global issues. Politics and its influence on science enterprise is also uncommon. The conclusion is that any science awareness among early secondary students in Malta is limited to the students' exposure to science at school and that efforts need to be made to help students learn about the role of science in society. Science is presented as a methodology and body of knowledge forming part of schools but not really relevant to everyday life. If students are not aware of the role of science and global issues, it is difficult to expect them to identify with science and to want to engage in scientific activities. For some reason, potentially science curricular material, pedagogical approach and lack of participation in out-of-school science all contribute to this lack of awareness among students and calls for action to be taken at this level. This is particularly important since science awareness seems to be related to an extent to students' willingness to engage in science reflected in them opting for science specialisation as part of their secondary education.

This research has also shown significant differences between State Schools and Church and Independent schools. It is not easy to explain the main factors contributing to this difference across school type. Independent schools are mixed ability schools. However, since parents pay high schools fees, unlike State and Church schools which are free or involve small amounts as donation (only in the case of Church schools), this means that there is selection based on socio-economic status, Although this does not necessarily mean that children come from better home backgrounds, it is also to be noted that there was a higher percentage of professional parents among those responding to the questionnaire in this study in Independent schools compared to the other two types of schools. This trend was also obtained in the case of the PISA 2011 results (Ministry of Education and Employment, Government of Malta, 2013) in relation to achievement in science at primary level.

There may be a number of factors influencing the poorer levels of science awareness among students in State schools. As the questionnaire indicates, there were more respondents from State schools who came from lower socio-economic status backgrounds as well as had

parents with lower educational levels. It could thus be that students in State schools tended to have less educationally supportive environments at home. In addition, since science is assessed in English and there is a greater tendency for students in State schools to lag behind in English proficiency as shown in the PISA 2011 results, that a different in science awareness can also result from a language barrier which some students may experience.

While there is a strong argument in favour of including the nature of science in curricula to raise the levels of science awareness across all early secondary students, this is also a great challenge mainly to State schools. Recent initiatives have seen the introduction of new science curricula in the first two years of secondary education where science is done within thematic areas. This approach may provide part of that missing link. The argument in favour of teaching specifically about the role that science has in people's personal lives and in society, still remains very strong.

CONCLUSION

This study has thus shown how early secondary students overall do not see the relevance of science when issues do not feature technical terms which were not covered during school science. Students' awareness of the impact that society may have on the progress of science is also restricted. Although the students perceive clearly the attributes required to deal with issues of a scientific/technological component, they do not regard science education as the means to achieve them. On the contrary, they view science education solely as relevant in endowing them with knowledge of and about science. This trend is possibly an outcome of the pedagogies used in early secondary classrooms, which have been shown to be still highly based on a transmission mode of learning.

The factors that seem to affect science awareness are all to a degree inter-related to the nature of science and go beyond the effect of school science. None the less there is still a strong argument in favour of efforts to find appropriate learning strategies to explicitly raise science awareness in schools. Promoting science awareness as a result of sporadic, out-of-school activities, or merely as a hidden outcome of the curriculum has to change. Making students aware of the role of science should be one of the main aims of early secondary level science and curricular space to introduce the social perspective of science in society should be found. It is the only way through which we can ensure a constant supply of scientists, as well as citizens who understand and appreciate the impact that science has on our personal, social and economic lives.

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