The Effect of a Number of SEC Subjects on A level Physics

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ABSTRACT

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The Effect of a Number of SEC Subjects on A level Physics

This study investigates the progression from Secondary Education Certificate (henceforth SEC) Physics to Advanced (henceforth A) level Physics, and any possible inherent problems for students and teachers. Four research questions related to this issue were identified: (a) the changes made in the 2012 SEC Physics syllabus; (b) whether the SEC Physics syllabus was a good foundation for A level Physics; (c) whether the SEC Mathematics syllabus was sufficient to satisfy the mathematical skills and knowledge required for A level Physics; and (d) the correlation coefficients between each of SEC Physics, Mathematics and English Language on one hand, and A level Physics on the other. A mixed methods approach was used for the collection of data from 165 questionnaires distributed among second year A level Physics students across Malta and Gozo, sixteen questionnaires and five interviews with A level Physics teachers, four interviews with SEC Physics teachers and a focus group of second year A level Physics students. Teachers considered the changes made in the 2012 SEC Physics syllabus as not so helpful as they believed that these increased the gap between SEC and A level Physics. Students still considered SEC Physics as a good foundation for A level Physics. Teachers believed that the SEC Physics syllabus provided a 'not so good' foundation for A level Physics. Students regarded an Intermediate level in Mathematics as the least level to study A level Physics. A good grade and understanding in SEC Mathematics was considered a desirable support for the study of A level Physics by teachers. Respondents also acknowledged the important role of English language skills in understanding A level Physics questions. The correlation coefficients for SEC Physics, Mathematics and English Language with A level Physics were 0.544, 0.452 and 0.411 respectively. Suggestions to reduce student difficulties and enhance the progression rates in A level Physics and in science related careers were also presented.

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Keywords:

SEC PHYSICS **SEC MATHEMATICS** **SEC ENGLISH LANGUAGE**

A LEVEL PHYSICS **SYLLABI** **CORRELATION COEFFICIENTS**

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DEDICATION

Every challenging piece of writing needs self-determination as well as an abundance of emotional support from others, especially those close to our heart.

I dedicate all my humble effort to my superheroes,

Mum & Dad,
Marthese & Martin

whose love, sacrifice, time and continuous support cannot be measured and who always instilled in me the importance of education.

In memory of my lovely, late grandmother who sadly passed away during the course of this dissertation.

A smart and courageous woman, who always encouraged me to further my education and never give up. I still miss her long conversations and advice.

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
A level:	Advanced Level
AM:	Advanced Matriculation
AQA:	Assessment and Qualifications Alliance
B.Ed	Bachelor of Education
ECDL:	European Computer Driving License
FREC:	Faculty Research Ethics Committee
GCSE:	General Certificate of Secondary Education
H_o:	Null Hypothesis
IT:	Information Technology
LO:	Learning Outcomes
LOF:	Learning Outcome Framework
MATSEC:	Matriculation and Secondary Education Certificate
MCAST:	Malta College of Arts, Science and Technology
OECD:	Organisation for Economic Co-operation and Development
PISA:	Programme for International Student Assessment
PMP:	Pure Mathematics and Physics
QCA:	Qualifications and Curriculum Authority
SEC:	Secondary Education Certificate
SPSS:	Statistical Package for the Social Sciences
STEM:	Science, Technology, Engineering and Mathematics
STS:	Science, Technology and Society
UK:	United Kingdom
UREC:	University Research Ethics Committee

Chapter 1

Introduction

1.1 Introduction

> Scientific understanding is changing our lives and is vital to the world's future prosperity, and all students should be taught essential aspects of the knowledge, methods, processes and uses of science. They should be helped to appreciate how the complex and diverse phenomena of the natural world can be described in terms of a small number of key ideas relating to the sciences which are both inter-linked, and are of universal application (Department for Education, 2015, p. 4).

There is a global increase in Science, Technology, Engineering and Mathematics (henceforth STEM) careers such as the building industry, aviation, shipping, artificial intelligence (henceforth AI), medical physics, technology and communication, amongst others. In order to address these rising demands, science professionals, who work in these fields, are often required to challenge themselves to go the extra mile in order to pioneer these innovations.

> Statistics from the European Centre for the Development of Vocational Training show that by the year 2025 about 26% of employment opportunities will be in science related spheres as well as engineering, health, commerce and training. Following concerns expressed by the Chamber of Commerce, Enterprise and Industry and the Malta Business Bureau that not enough suitable candidates are being found to fill vacancies in these spheres, the Malta Council for Science and Technology, MCAST and the University of Malta embarked on a programme to attract students to these spheres as future careers (TVM News, 2019, para. 2).

Science teachers in secondary schools are often the gateway to science, providing students with the first formal encounters with the subject. Thus, teachers have the responsibility to motivate students, nourish their inquisitive minds and instil in them a thirst for excellence from a young age. In order to do this, teachers need to address appropriately specific student demands and difficulties which "could inadvertently exclude young minds who have the potential to be amazing scientists" (Day, 2018, p. 1).

> [T]he sciences should be studied in ways that help students to develop curiosity about the natural world, insight into how science works, and appreciation of its

relevance to their everyday lives. The scope and nature of such study should be broad, coherent, practical and satisfying, and thereby encourage students to be inspired, motivated and challenged by the subject and its achievements (Department for Education, 2015, p. 4).

1.2 The Researcher's Position in the Study

The researcher has been teaching Secondary Education Certificate (henceforth SEC) Physics in a boys' Church school for four years. She is very much aware of the necessity that students choose A level Physics at Sixth Form, choose a university course in Physics and later make a STEM career.

When assessing students, be it through formative or summative assessment, incorrect answers have at times made the researcher wonder and reflect: Does the student lack Physics knowledge? Is the student knowledgeable in Physics theories, concepts and laws, but lacks mathematical skills? Is the student actually understanding the question properly? Is the student able to express his Physics knowledge correctly in writing? Does the student encounter difficulties when expressing himself in writing? The desire to answer these questions prompted the researcher, as a professional in the field, to undertake this study in order to be able to reduce these difficulties which might enhance students' progression in science related careers.

1.3 Aims of the Study

On further reflection, the researcher came up with the following research questions:

1. What were the distinctive changes in the SEC Physics syllabus in 2012?
2. Is SEC level Physics a good foundation/background for Advanced (henceforth A) level Physics?
3. Is SEC level Mathematics an adequate preparation for A level Physics?

4. What are the correlation coefficients between the grades in SEC Physics, Mathematics and English Language and A level Physics?

Following initial research on these four research questions, the researcher decided that this study should follow from a Bachelor of Education (henceforth B.Ed) dissertation that was conducted by Caruana and Muscat in 2006: *Is SEC Level Physics an adequate preparation for studies at Advanced Level?* and in 2009 paper by Caruana, Farrugia and Muscat with the same name. One should point out that this B.Ed dissertation had been submitted before the changes in the SEC Physics syllabus in 2012. As a result, apart from attempting to answer the four research questions, the current study could give a whole new meaning and perspectives on the preparation that SEC Physics provides for a course in A level Physics.

Research on this subject revealed the following gaps in knowledge in this particular field:

1. Were the changes in the SEC Physics syllabus in 2012 helpful or unhelpful to A level teachers and their students?
2. Does the SEC Physics syllabus, following the changes of 2012, provide students with an adequate background for A level Physics?
3. Does SEC Mathematics cover enough mathematical content for students to study A level Physics?
4. The correlation coefficients of SEC Physics, Mathematics and English Language with A level Physics for the 2015 SEC and the 2017 A level cohorts of Maltese and Gozitan students.

1.4 Research Objectives

To answer the four research questions, and thus fill in the gaps in knowledge in the best way possible, this study adopted three strategies: (i) homogenous purposive sampling was used to conduct questionnaires to Sixth Form second year students who study A level Physics and to Sixth Form Physics teachers; (ii) reputational case sampling was used to conduct interviews with Sixth Form Physics teachers and SEC Physics teachers; and (iii) convenience sampling was used to conduct a focus group with Sixth Form second year students who study A level Physics. Such data collection methods enhanced the validity of the research through the triangulation of data.

The different data collection tools provided the researcher with five themes:

(i) The effect of the changes introduced in the 2012 SEC Physics syllabus on students who then study A level Physics;
(ii) The challenges and expectations of students;
(iii) The relationship between Mathematics and Physics;
(iv) Language skills and A level Physics; and
(v) What does the future hold?

It is important to note that the researcher opted to gather data from Sixth Form second year students rather than SEC level students because they could provide the necessary information since they could compare their SEC studies with their present A level Physics studies. Last but not least, the researcher considered second year students to have the most experience in the subject compared to first year students and SEC students thus providing richer input to the study.

Another critical aspect which is critical to note is that during this dissertation, the grades of SEC Physics, Mathematics and English Language and A level Physics examinations were compared. Since these tests are held on a national level, the grades obtained could give the optimum feedback on the fourth research question regarding the correlation coefficients between the subjects under test.

1.5 Brief Outline of the Study

This study will consist of four other chapters: Chapter 2 – Literature Review, will deal with the theoretical perspectives of this study; Chapter 3 – Methodology will explain the methods used for data collection purposes; Chapter 4 – Results, Data Analysis and Discussion will discuss and analyse the data gathered; while Chapter 5 - Conclusion will attempt to give an answer to the four research questions. This chapter also provides the strengths, weaknesses and challenges of this study, implications to further research and lastly the researcher's personal view as the final conclusion.

1.6 Conclusion

Apart from enhancing the researcher's knowledge about the subject, this study has brought about numerous benefits for the researcher. The discussions that took place during the focus group with the students and the interviews with the teachers were extremely informative and also allowed the participants to share their feelings with the researcher. At the same time, the way these discussions flowed with ease increased the likelihood of the authenticity of the views and arguments expressed.

Additionally, the experience of merging this study's quantitative data from the questionnaires with the qualitative data from the focus group and interviews not only provided insights into the field of investigation but enhanced the academic development of the researcher.

Chapter 2

Literature Review

2.1 The SEC Physics Syllabus

According to the United Kingdom (henceforth UK) Department for Education (2015, p. 33), the aim of any Physics syllabus is

> to understand how, through the ideas of physics, the complex and diverse phenomena of the natural world can be described in terms of a small number of key ideas which are of universal application and which can be illustrated in the separate topics.

This is done by working scientifically on and applying:

1. "Development of scientific thinking
2. Experimental skills and strategies
3. Analysis and evaluation
4. Scientific vocabulary, quantities, units, symbols and nomenclature"

(Department for Education, 2015, p. 7).

2.1.1 The Influence of the UK Education System on that of Malta

Malta has a very similar educational system to those in the UK, both with regards to the subject syllabi and the progression of the school years. "The Maltese education system (from Kindergarten to University) together with its examination system followed very closely (because of Malta's colonial past) the British Model (Sultana et al., 1997; Zammit Ciantar, 1993; Zammit Mangion, 1992)" (Cutajar, 2007, p. 4).

Although in the past, the four countries of the UK, that is, England, Wales, Scotland and Northern Ireland, used to follow very similar curricula and syllabi, this is no longer the case. Scotland now follows the Curriculum of Excellence, whose goal is to expose the students to a wide array of subjects and courses. This tends to restrict the depth in which the subjects may be studied (The Scottish Government, 2008).

As a standard and national examination at the end of their secondary course, students residing in England, Wales and Northern Ireland sit for the General

Certificate of Secondary Education examination (henceforth GCSE), while those living in Scotland sit for the Standard Grade examination (Métais, Andrews, Johnson and Spielhofer, 2001, Table 1). There are several examination boards which assess the GCSE examination. These include the Assessment and Qualifications Alliance (henceforth AQA); Council for the Curriculum, Examinations and Assessment (henceforth CCEA); Pearson Edexcel; Oxford, Cambridge and RSA Examinations (henceforth OCR); and the Welsh Joint Examinations Committee (henceforth WJEC).

2.1.2 Changes in the 2012 SEC Physics Syllabus Compared to Two UK Syllabi

During one of the meetings of the Matriculation and Secondary Education Certificate (henceforth MATSEC) Board (2006) regarding the proposed changes in the SEC Physics syllabus, board members concluded that,

> [a]mong the principal changes which are being advocated are: (a) that the syllabus content will be grouped into themes; (b) stronger linkage to be effected between theory and everyday life; (c) the inclusion of the historical aspects, such as the great physicists; (d) the syllabus to be re-structured in terms of behavioural outcomes; (e) linkages to be established between physics and ICT; (f) a radical revision of course-work tasks; and (g) a revision of the presentation of Paper 2A and Paper 2B (MATSEC Board, 2006, Mins. 6/2005-2006, no. 42.1).

Since these changes concern one of the research questions of this study, an overview of the changes in the syllabus will be outlined in Section 4.3.1. A detailed list of all the Learning Outcomes (henceforth LOs) that were included and removed from the SEC Physics syllabus can be found in Appendix 8.

In this section, the 2012 SEC Physics syllabus will be compared to the AQA Physics syllabus and the Pearson Edexcel Physics syllabus. Only these two syllabi were chosen for comparison because these examination boards also operate in Malta (Examinations Department, 2012).

The three syllabi under review cover to a large extent the same topics. Thus, this investigation will consider the LOs that were included in and removed from the 2012 SEC Physics syllabus with respect to the LOs in the other two syllabi.

It was found that the majority of the LOs added to the SEC Physics syllabus were also found in the AQA and Pearson Edexcel Physics syllabi. Table 2.1 shows the very few LOs which were added into the 2012 SEC Physics syllabus but did not feature in the UK syllabi, namely Pearson Edexcel and AQA, marked with an X. On the other hand, the LOs of the SEC Physics which were found in either of the syllabi were marked with a ✓.

	Learning Outcomes added in the 2012 SEC Physics syllabus which did not feature in the Pearson Edexcel/AQA syllabi	**Pearson Edexcel**	**AQA**
3.5	Include terms displacement, amplitude, crest and trough	X	X
3.18	Associate refraction of light with apparent depth of water	X	X
3.21	Use semi-circular glass block to demonstrate that the direction of the emergent ray depends upon the angle of incidence in the glass block	X	X
4.4	Appreciate that the hotter a substance is, the more energy its particles have, resulting in expansion	X	X
4.6	Relate a rise in the temperature of a body to an increase in internal energy	X	✓
4.7	Describe evaporation in terms of the escape of the more energetic molecules from the surface of a liquid.	X	X
4.8	Relate evaporation to cooling.	X	X
4.13	Know the meaning of the term conduction and insulation	X	✓
5.13	Be able to draw current diagrams showing how an ammeter and/or voltmeter can be converted appropriately to measure current and voltage respectively	✓	X
5.30	Use the equation for Energy, $E = Pt$ in Joules and Kilowatt hours	X	X

5.32	Calculate the cost of electrical energy given the power, time and the cost per unit	X	X
6.1	Explain that magnetic poles exist in pairs	X	X
6.6	Describe how demagnetisation can be achieved using…	X	X
6.12	Investigate how changing the current or number of turns may vary the strength of the field of the solenoid.	X	X
8.3	Seasons	X	X
8.7	Characteristics of a planet to include also: has a nearly round shape; has cleared the neighbourhood around its orbit	X	X
8.9	Recognise that Pluto is a dwarf planet because it has not cleared the neighbourhood around its orbit	X	X
8.11	State that distances in space are measured in light years and that one light year is…	X	X
8.13	Identify a few of the social and economic benefits of space explorations	X	X
8.14	Recognise that there are still many unanswered questions about our Universe.	X	X

Table 2.1: Learning outcomes added in the 2012 SEC Physics syllabus not found in the Pearson Edexcel and/or the AQA Physics syllabi
(Source: MATSEC Examinations Board (2006); Pearson Edexcel Physics Syllabus (2016); AQA (2016)

It was also found that the majority of the LOs that were deleted from the SEC Physics syllabus were also absent in the Pearson Edexcel and AQA Physics syllabi. Table 2.2 shows the very few LOs that were removed from the SEC Physics syllabus but are still present in the Pearson Edexcel and the AQA Physics syllabi, marked with a ✓. The symbol X denotes those LOs which were deleted from the SEC Physics syllabus in 2012 and are also absent in the corresponding UK syllabi.

Learning Outcomes deleted from the 2012 SEC Physics syllabus but still feature in the Pearson Edexcel/AQA syllabi	**Pearson Edexcel**	**AQA**
Length: Use and describe the use of rulers and measuring cylinders to determine a length or a volume	✓	✓
Units: All physical quantities should be accompanied by SI units	✓	✓
Rubber band under Hooke's Law	✓	X
Understand that for a body moving through a medium, resistive forces depend on body shape and speed. Understand that forces acting on a body which has reached terminal speed are balanced.	X	✓
Definition of specific heat capacity	✓	✓
Understand that insulation reduces energy transfer by conduction and convection	✓	✓
Identify wavelength and amplitude in transverse and longitudinal waves	✓	✓
Converging lenses: Describe the action and use of optical fibres	✓	X
Describe the production of sound by vibrating sources	✓	✓
State the approximate range of audible frequencies	✓	✓
Voltage: Show understanding that e.m.f. is defined as the energy supplied by a source in driving 1C round a complete circuit	✓	X
Alternating current: Describe how a diode may be used to rectify an alternating current and how an oscilloscope may be used to demonstrate this action of a diode	✓	X
Stability of nuclei: Appreciate that an element may change into another element when radioactivity occurs	✓	✓
Nuclear equations	✓	✓
Formation of stars	✓	✓
Origin of Universe	✓	✓

Table 2.2: Learning outcomes deleted from the 2012 SEC Physics syllabus but are present in the Pearson Edexcel and/or the AQA Physics syllabi.
(Source: MATSEC Examinations Board (2006); Pearson Edexcel Physics Syllabus (2016); AQA (2016))

It must also be stated that both UK syllabi include some LOs which are not found in the 2012 SEC Physics syllabus. These include the absolute zero; kelvin scale; relationship of pressure and volume for a fixed mass of gas at constant temperature; equation for linear elastic distortion; work done for stretching a spring; red shift; latent heat; and the force on a current carrying conductor at right angles to a magnetic field, among others.

2.2 Transition between Secondary and Post-Secondary Schooling

When students progress to post-secondary school, they "look forward to having more choices and making new and more friends; however, they also are concerned about being picked on and teased by older students, having harder work, making lower grades, and getting lost in a larger, unfamiliar school" (Mizelle, 1995; Phelan, Yu & Davidson, 1994 as quoted in Mizelle, 2003, par. 1). This statement shows that the transition from secondary to post-secondary school can be rather challenging. Challenges may include physical, emotional, and cognitive changes (Letrello & Miles, 2003).

Erickson, Peterson and Lembeck (2013) established that student drop-out is very high during their first year in Sixth Form. This could be due to several reasons mainly:

> "1. The social and developmental adjustment;
>
> 2. Structural and organizational change;
>
> 3. Increased academic rigor and failure"
>
> (Erickson et al., 2013, p. 2).

They assert that the fact that some post-secondary schools are much larger, and the relationship of the students with teachers is less personal than in secondary schools, students might feel more disconnected resulting in higher drop-out rates (Erickson et al., 2013). During this period of change, the students' social life and their relationship with their peers outweigh their scholastic responsibilities (Oakes & Waite, 2009). Furthermore, students may develop lower self-confidence and increased anxiety about their new lifestyle. This may result in uneasiness and misconduct (Cohen & Smerdon, 2009). Windeler (as quoted by MacDonald, 2017, para. 4) affirms that this transition is "one of the most exhilarating and also the most traumatic and dangerous experiences of your life. It's also the time that the onset of mental-health problems typically happens." This is because stress at this point in time may lead to bipolar disorder, anxiety, depression and even suicide (MacDonald, 2017).

Taking a look at the local scene, "[t]he percentage of 'early school leavers' in Malta has improved considerably in the past 11 years, from 32.2 per cent in 2006 to 18.6 per cent in 2017, but remains the worst rate in the European Union" (Times of Malta, 2018, para. 1). Early school leavers are persons aged between 18 and 24 who have not achieved at least five SEC passes and who for some reason or another are no longer in education and training (National Statistics Office, 2013). "The Europe 2020 target is to reduce the rates of early school leaving in the EU to below 10% by 2020" (European Commission, 2017, para. 1).

"Transitions are an unavoidable part of life, and youth will do best when they learn how to adjust productively" (Grossman & Cooney, 2009, p. 9). Reyes, Gillock, Kobus and Sanchez (2000) confirm that even though students know that they will come across more hard work during their post-secondary years, those who have the will to succeed do so with flying colours. Oakes and Waite (2009) found that a smooth transition to post-secondary is related to student accomplishment in secondary school and beyond. An effective transition could be guaranteed by collaboration and teamwork between the secondary and the post-secondary school, stronger parental involvement, the use of statistical data for early intervention such as national statistics of drop-out students, and introducing transition programmes such as orientation visits and seminars (Erickson et al., 2013, p. 2-3).

2.3 Are Students Being Sufficiently Prepared for A level Physics?

> The Physics syllabus at Secondary Education Certificate (SEC) level is seen to have a dual role. First it aims to introduce students to Physics as a preparation for life. However, it is also expected to be attractive such that it inspires some students to continue studying Physics at higher levels (Caruana, Farrugia & Muscat, 2009, p. 10).

2.3.1 A 'Definition' of Physics

Young and Freedman (2004) define physics as an experimental science since its specialists observe the phenomena of nature and try to find patterns and principles that relate to those phenomena in the form of theories, physical laws or principles.

According to the Norwegian University of Science and Technology, "Physics is a natural science based on experiments, measurements and mathematical analysis with the purpose of finding quantitative, physical laws for everything from the nanoworld of the microcosmos to the planets, solar systems and galaxies that occupy the macrocosmos."

According to the UK Department for Education (2015, p. 33), "Physics is the science of the fundamental concepts of field, force, radiation and particle structures, which are inter-linked to form unified models of the behaviour of the material universe."

2.3.2 SEC Physics as a Preparation for A level Physics

In this section, discussion revolves around whether the SEC Physics syllabus is an adequate preparation for the students' challenges at A level Physics. When Caruana and Muscat tackled this issue in 2006 and later, in 2009, together with Farrugia, they claimed that

> [t]he current syllabus is not an adequate preparation for students who want to choose it at higher levels… This suggests that the level of the SEC Physics

> syllabus should be enhanced, such that it is not too superficial and so straightforward (Caruana & Muscat, 2006, p. 74).

In fact, it was later claimed that "[t]eachers often described the SEC syllabus as superficial and which does not provide the students with the appropriate tools for the deeper Advanced level syllabus" (Caruana, Farrugia & Muscat, 2009, p. 18).

Hardy (2013, para. 11) states that "some subjects have a reputation for particularly sudden jumps in difficulty between GCSE and AS-level… Maths and Chemistry are viewed as especially hard, with difficult conceptual content that is a big leap up from GCSE." This was also found in the case of Physics in Malta. "Teachers and students felt that there is a considerable gap between SEC level and Advanced level in all the major areas of Physics, including practical work, mathematical skills, and the content itself" (Caruana, Farrugia & Muscat, 2009, p. 18). This gap was especially felt in Fields and Nuclear and Particle Physics and noted less in the topic of Mechanics (Caruana, Farrugia & Muscat, 2009).

One might logically think that SEC and A level Physics are strongly correlated because they are different levels of the same subject. Several researchers have attempted to bring out the correlation coefficient between the two levels. Ventura (2001) found a correlation coefficient of 0.572 between the cohort of students who attempted the 1998 SEC Physics and those who attempted the A level Physics examination in 2000. Pace and Bonello (2006) attempted the same calculation, this time between the students who sat for SEC Physics in 2000 and those who attempted A level Physics in 2002. This gave a correlation coefficient of 0.488. They obtained a correlation coefficient of 0.442 when they performed a similar test between the 2002 SEC Physics and the 2004 A level Physics examinations. Farrugia and Ventura (2007) found that the correlation coefficient between the 2004 SEC Physics and the 2006 A level Physics is 0.62. In the UK, Sutch (2013) calculated a correlation coefficient of 0.589 between the 2010 GCSE Physics and the 2012 A level Physics.

According to Coe (1999) from the Curriculum Evaluation and Management Centre at Durham University, students' performance at GCSE is the best evidence on which to predict the students' achievement in A level examinations. In 2004, Farrugia and Ventura came to the same conclusion when they stated that in general, "SEC examinations in all subjects provide a good foundation for study at Advanced and Intermediate level" (Farrugia and Ventura, 2007, p. 23). In the case of Physics, "[i]t seems that students' experience of the SEC level Physics syllabus may be giving the impression that Physics is an easy subject but when they come to Advanced-level studies they find that Physics is much more challenging than expected" (Caruana, Farrugia & Muscat, 2009, p. 18).

Indeed, following a UK study on a cohort of students in 2008, represented in Figure 2.1, it was concluded that "over 50% of pupils with a grade A in GCSE physics that go on to A level physics achieve a grade C or lower" (Education Standards Analysis and Research Division, 2012, p. 18). This is shown in the second column of Figure 2.1 below.

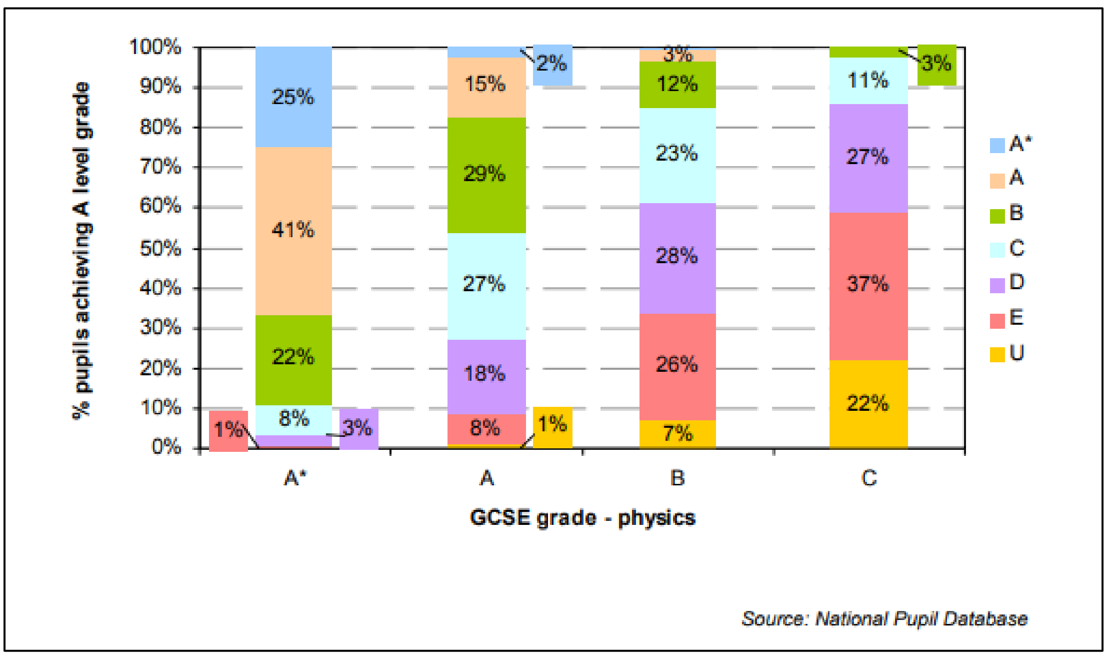

Figure 2.1: Performance at A level Physics of students who had obtained grade A in GCSE Physics (Source: UK National Pupil Database, 2012 as cited in Education Standards Analysis and Research Division, 2012, p. 20)

The first column in Figure 2.2 shows the second column in Figure 2.1. It displays the distribution of grades in A level Physics for the students who obtained a grade A in GCSE Physics. Figure 2.2 also compares the distribution of A level grades in other subjects for students who obtained a grade A in the respective GCSE subjects.

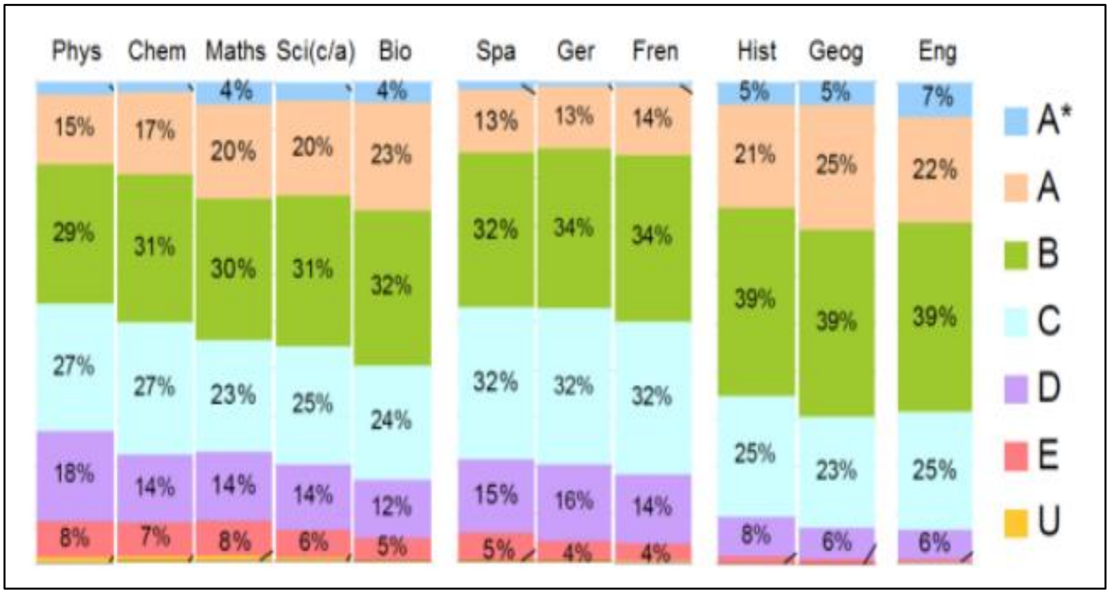

Figure 2.2: *Distribution of A level grades for students who obtained a grade A in GCSE (Source: Ofqual's Strategy, Risk and Research Directorate, 2017)*

An analysis of the chart and a calculation of the percentages of students who achieved grades C, D and E at A level for all the subjects indicates that A level Physics has the highest percentage (53%) among all the science subjects. "As such, physics could be seen as being more difficult at A level than the other sciences" (Education Standards Analysis and Research Division, 2012, p. 18).

Farrugia and Ventura (2007) investigated this assumption by analysing results obtained by Maltese students who sat for 2004 SEC and the 2006 A level examinations. In the case of Physics, only 30% of the students who achieved grade 1 in their SEC examination obtained grades C or lower in their A level examination. Although this seems to be a low percentage when compared to the UK figures, in Malta it was also the highest percentage when considering the three sciences. Only 26% of the students who achieved grade 1 in their SEC Chemistry examination obtained grades C or lower in their A level, while in the case of Biology, the figure was only 4%.

These figures are bound to have repercussions, because "progression from GCSE to A level depends on the grade at GCSE, with lower progression rates for lower GCSE grades" (Education Standards Analysis and Research Division, 2012, p. 12). A decrease has already been noted in the number of students choosing A level Physics both in the UK and in Malta. "Physics A level entries are the weakest of the three traditional sciences, starting from the lowest base and falling continuously between 1999 and 2006" (Education Standards Analysis and Research Division, 2011, p. 2). This trend is also evident in the 2008 cohort of students who sat for their GCSE examinations in the UK (Education Standards Analysis and Research Division, 2012). Table 2.3 shows the percentage of this cohort of students and their progression from GCSE to A level in every subject with respect to their GCSE grade. The highlighted figures show the highest progression rate for each grade. As can be noted, Physics has the lowest progression rate among the three science subjects being Biology, Chemistry and Physics.

	% of pupils progressing from GCSE to A level					% point difference between A* and C progression rates[5]
	GCSE grade					
Subject	**A***	**A**	**B**	**C**	**A*-C**	
Biology	47%	37%	19%	3%	29%	44
Chemistry	54%	30%	11%	1%	26%	52
Physics	38%	22%	8%	1%	19%	37
Core and additional science[1, 2]	62%	46%	21%	3%	18%	59
History	46%	37%	24%	10%	28%	36
Geography	35%	31%	21%	6%	21%	29
French	35%	14%	3%	0%	9%	34
German	33%	14%	4%	0%	8%	33
Spanish	37%	18%	6%	1%	14%	36
English[3]	44%	34%	20%	5%	18%	39
Maths[4]	73%	34%	6%	0%	14%	72

Table 2.3: Percentage of pupils progressing from GCSE to A level in various subjects (Source: UK National Pupil Database as cited in Education Standards Analysis and Research Division, 2012, p. 13)

Taking a look at the local scene,

> [a]s of 2005, biology became the most popular AM [henceforth Advanced Matriculation] science subject; AM biology registrations show a general increase. AM chemistry registrations show a general increase, but it was the least popular till 2009. In 2010, chemistry registrations surpassed physics. AM chemistry dipped again below physics in 2011 and 2012, but clearly surpassed physics from 2013 onwards. Physics registrations show a general decrease from 2012 (Musumeci, 2018, p. 475).

These figures are shown in Figure 2.3. "The popularity of chemistry and biology seems to be increasing although there have been small drops as from 2015. The opposite is true for physics and pure mathematics" (MATSEC Examinations Board, 2017, p. 48). According to Smithers (2013) from the Centre for Education and Employment Research at the University of Buckingham in the article published by Sellgren (2013, para. 14), "there is still a long way to go before uptake is at the same level as it was 20 years ago." He continued by stating that "it has always been difficult to attract the most able students into physics."

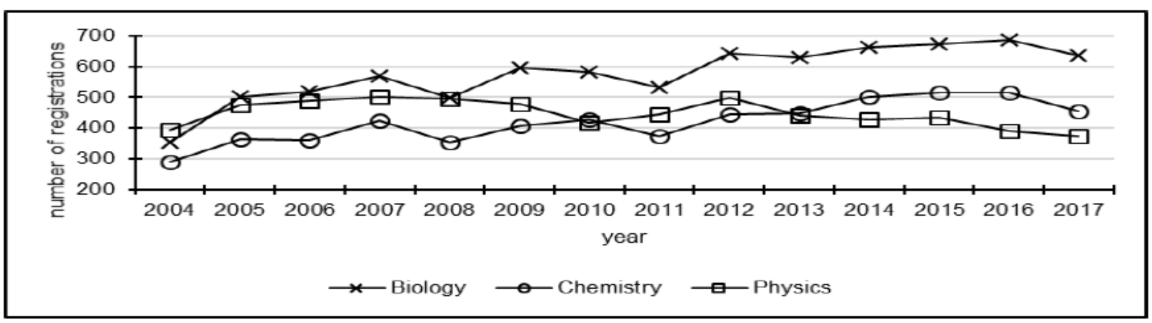

Figure 2.3: Number of AM registrations for the three science subjects per year (Source: Musumeci, 2018, p. 475)

The list presented below compiled by Bennett, Lubben and Hampden-Thompson (2013) was published in a report by the UK Institute of Physics in 2018. It presents a number of considerations students make when they come to choose their A level subjects:

- It is needed for their chosen career path
- It is a prerequisite for their chosen university course
- They enjoy the subject
- The subject fits their personality, or is an area of knowledge they enjoy

- They have confidence in their ability to study the subject
- They view the subject as a lower risk option
- They want to keep their options open
- The subject is part of a combination that go well together
- The person that taught them the subject
- Their perceived ability
- The availability of the subject on the school timetable
- Views of their teachers and/or their parents

(Bennett et al., 2013 in *Institute of Physics*, 2018, p. 20).

Magro and Musumeci (2019, p. 4) agreed with Bennet et al. by stating that, "the PMP [henceforth Pure Mathematics and Physics] cohort and the experts considered career aspirations as the prime factor" which influences subject choice. Gill and Bell, 2013, considered a strong relationship between the grades in science and mathematics at GCSE with the probability of choosing Physics as an A level subject (Gill & Bell, 2013).

2.3.2.1 Gender Differences

"The most striking difference between the students is and remains the heavy deficit of girls choosing to study Physics at Advanced level, where they are outnumbered by a ratio higher than 2:1" (Pace & Bonello, 2006, p. 42). Twelve years later, this statement still applies. In fact, the 2018 Matriculation Certificate Statistical Report showed that of the total 366 applicants for A level Physics, 239 (65.3%) were males while 127 (34.7%) were females. (MATSEC Statistical Report, 2018). This means that there were almost twice as many male applicants with respect to females.

This difference was also noted in the UK. "For girls, the differences in progression to A level between the two GCSE routes is larger in physics than in chemistry, biology and mathematics" (Institute of Physics, 2018, p.16). "In 2016, physics was the second most popular A level for boys and the 18th most popular for girls" (Institute of Physics, 2018, p. 11).

Moreover, Mujtaba and Reiss (2016) found that when girls come to choose their A level subjects, their self-confidence is lower than that of boys and throughout their mathematics and physics education, girls experience more inequalities than boys. Gill and Bell (2013, p. 770) conclude that "[t]he reasons for this difference in uptake are still uncertain. It may be partly due to the fact that females find physics a more difficult subject while studying it at GCSE." Also, "[i]t seems most likely that there still exists a perception that it is more of a boys' subject" (Gill & Bell, 2013, p. 770).

However, local research found very little to no gender differences in achievement in A level Physics. Pace and Bonello (2006) recorded "very little differences between male and female students throughout the two years of study" (Pace & Bonello, 2006, p. 42). "They noted no gender differences in the students' performance in the SEC and A level results" (Caruana, Farrugia & Muscat, 2009, p. 11). The most recent statistical data with regards to A level Physics grades published in the 2018 Matriculation Certificate Statistical Report shows very similar percentages between males and females for all the grades.

The next section presents an analysis of the current SEC and A level Physics syllabi set by MATSEC.

2.3.2.2 A Comparison of the Themes in the SEC Physics and Topics in A level Physics Syllabi

The table below shows the themes covered at SEC level and the 'corresponding' topics covered in A level Physics.

SEC level	**A level**
On The Move Linear Motion, Newton's Laws of Motion, Momentum, Energy, Power, Different forms of Energy	**Physical Quantities** SI unit, Scalar & Vector Quantities

Balancing Forces Types of Forces, Scalars and Vectors, Hooke's Law, Moments, Equilibrium, Centre of Gravity, Pressure	**Mechanics** Linear Motion, Newton's Laws of Motion, Energy, Circular Motion, Equilibrium, Rotational Dynamics
The Nature of Waves Types of Waves, Reflection/Refraction/ Diffraction of Water Waves, Light: Reflection/ Refraction/ Total Internal Reflection, Dispersion, Optics, EM Spectrum	**Vibrations and Waves** Simple Harmonic Motion, Superposition of Waves, Optics, The Expanding Universe
The Earth & The Universe The Earth's orbits, Gravity, Solar System, Galaxies, Space Exploration	**Materials** Solids
Staying Cool Properties of solids, liquids & gases, Density, Heat	**Thermal Physics** Heat, Energy Transfer, Heating Matter, Gases, Transfer of Heat
Electricity in the House Charges, Current, Voltage, Resistance, Circuit Symbols, V-I graph, Plugs, Power, Kilowatt-hour	**Electrical Currents** Charge and Current, Resistance
Magnets and Motors Magnetic Poles, Magnetising and Demagnetising, Magnetic Fields, Solenoid, Fleming's Left Hand Rule, Lenz's Law, Transformer	**Fields** Gravitational Fields, Electrostatic Fields, Capacitors, Magnetic Fields, Electromagnetic Induction, Alternating Currents
Radiation and its Uses Atoms, Isotopes, Properties of α/ β/ γ, Uses of Radioactivity, Background Radiation, Half Life, Precautions of Radioactive Materials	**Atomic, Nuclear and Particle Physics** Quantum Theory, Evidence for a Nuclear Atom

	Experimental Physics Lab Practice and Data Analysis

Table 2.4: Showing the different sections and themes in the Physics SEC and A level syllabi (Source: SEC Physics Syllabus MATSEC Exam Board (2012) and AM Physics Syllabus MATSEC Exam Board (2019))

As can be observed in Table 2.4, some of the topics in the A level syllabus are introduced in the SEC syllabus and are highlighted in the same background colour for ease of reference. Table 2.4 also shows that some sub-topics in the SEC syllabus do not featrure in the A level syllabus. Likewise, some sub-topics in the A level syllabus are not covered in the SEC syllabus. The topics that do not appear in both syllabi are underlined in the same table.

The UK Qualifications and Curriculum Authority's [henceforth QCA] (2005) *Review of standards in physics* report highlights the relationship between GCSE Physics and A level Physics in 1997 and 2002. These are still relevant today.

> At GCSE, students studied aspects of electricity, such as simple electrostatics, circuits, current and voltage relationships and electrical power. These were useful preparation for A level where the progression to the study of electric fields, Kirchoff's laws and resistivity was apparent (QCA, 2005, p. 14).

Other topics in the GCSE which were considered as good preparation for A level Physics were mechanics, density and pressure. "The study of refraction also showed clear progression, with descriptive work at GCSE forming the basis for Snell's law at A level. Similarly, the topics on atomic physics and electromagnetism were important and suitable preparation for A level" (QCA, 2005, p. 14).

The QCA also declares that the calculations involved in the topics of motion (equations of motion) and heat (specific heat capacity) were "giving students more opportunity to work quantitatively" (QCA, 2005, p. 14). The topic 'Earth and the Universe' was seen as a motivator at GCSE level. Furthermore, "the practical skills developed at GCSE were an excellent preparation for A level work, but there was no clear progression between the assessment of practical skills at the two levels" (QCA, 2005, p. 14).

2.4 Is SEC level Mathematics Relevant to A level Physics?

“Although students’ initial level of physics concept knowledge may have no impact on their learning gains, the same cannot be said for their initial level of mathematics skill” (Meltzer, 2002, p. 1266). According to Redfors, Hansson, Hansson and Juter (2014, p. 377), this is because “mathematics is an inherent part of theories and makes powerful predictions of natural phenomena possible.”

2.4.1 Does Physics Depend on Mathematics?

Einstein (1934, p. 117) concluded that “the actual creative principle in physics lies in mathematics”. The relationship is further explained by Jiar and Long (2014, p. 234), “Mathematics is used to evaluate nature phenomena in more precise way while physics is applied to discover and develop a new theory to explain nature phenomena.”

Basson (2002, p. 682) states that Physics is the most quantitative among all the science subjects. Therefore, it is heavily dependent on “many mathematical skills to prove and quantify the different physical laws and principles.” Hudson and Rottmann (1981) conclude that previous mathematical skills significantly affect student accomplishment in Physics courses. Baylon (2014, p. 199) reports that “[m]athematics is now considered the tool and language of physics.” Thus, he concludes that “there was a significant positive relationship between Mathematics and Physics Achievement.” This is corroborated by Sidhu (2006, p. 7), who states that “mathematics gives a final shape to the rules of physics.” Furthermore, Pask (2003) states that mathematics is able to make powerful analogies doable.

Gill and Bell (2013, p. 757) agree with Baylon (2014) when they state that “a good grade in GCSE mathematics is often required if students wish to take A level Physics.” They continue to state that an accomplishment in Mathematics and Physics qualifications at age 16 is one of the factors which determine the uptake of

A level Physics. This was also confirmed by Caruana and Muscat (2006, p. 75). Furthermore, Swinback (1997, p. 113) states, “those students who do not also study A level Maths are at a particular disadvantage … they often find themselves struggling with mathematical aspects of Physics.”

In their study, Delialioğlu and Aşkar (1999, p. 38) showed “that there is a significant correlation between mathematical skills and physics achievement.” In fact, Sutch (2013) found a correlation coefficient of 0.557 among the cohort of students who sat for the GCSE Mathematics in 2010 and those who sat for their A level Physics examination in 2012. Delialioğlu and Aşkar (1999) reported that students who do not succeed in mathematical skills do not tend to obtain high marks in Physics tests which include mathematical applications. Nevertheless, they stated that this should not be taken as a general rule because if the students are able to reason on an abstract and theoretical level, they could excel in Mathematics and attain a low achievement in Physics and vice versa.

Despite this, it seems that in the UK, students encounter some difficulties in mathematics at university.

> A report published by the Institute of Physics in 2011 warned that A levels were failing to teach pupils enough maths to study physics and engineering at university. It suggested that many students are left struggling with degree courses because they lack a good understanding of maths, with sixth-formers simply taught to pass exams at A level (Sellgren, 2013, para. 6).

2.4.2 Mathematical Factors Affecting Student Achievement in Physics

Researchers have tried to determine the mathematical factors which affect achievement in Physics.

> Four general intellectual factors or abilities are seen to be most important:
> 1. The ability to reason in terms of visual images (visualization or spatial ability).
> 2. Mathematical insight (mathematics).
> 3. The ability to evaluate the logic of arguments (logical thinking ability).

4. The ability to attack problems in a potentially productive way (problem solving). (Deliaglioglu & Askar, 1999, p. 34).

2.4.3 The Language of Mathematics in Physics

"Probably, mathematics is considered to be the sole language of science because of which real understanding of science is considered to be impossible without adequate knowledge of mathematics" (Mallick, 2012, para. 10). "Mathematics is more than just a tool for working with physics problems; the discourse of physics is mathematical in nature" (Uhden, Karam, Pietrocola & Pospiech, 2012, in Nilsen, Angell & Grønmo, 2013, p. 1).

Nonetheless, Redish and Kuo (2015) state that

> [i]n science, we don't use math, we make a meaning with it in a different way than mathematicians do … There are many important differences in what seems to be the physicist's 'dialect' of speaking math, so, while related, the languages of 'math in math' and 'math in physics' may need to be considered as separate languages (Redish & Kuo, 2015, p. 2).

They also state that physicists give physical meaning to symbols resulting in a different interpretation from that of mathematicians.

According to Sherin (2001), this is seen through symbolic forms. Redish and Kuo (2015, p. 8) state that "[a] symbolic form blends a grammatic signifier – a mathematical symbol template – with an abstraction of an understanding of relationships obtained from embodied experience – a conceptual schema." Furthermore, "symbolic expression allows learners to have a better understanding of Physics contents and improve their procedural knowledge to interrelate various symbols during solving physics problem" (Jiar & Long, 2014, p. 232). Sherin (2001, p. 525) adds that "some symbolic forms are likely acquired during physics instruction and some much earlier, in the context of mathematics instruction."

2.4.4 Models of Conversion between Physics and Mathematics

Stating that "mathematics is the 'language of physics' implies that both areas are deeply inter-connected such that often no separation between 'pure' mathematics and 'pure' physics is possible" (Pospiech, Eylon, Bagno, Lehavi & Geyer, 2015, p. 1). In the literature that was discussed earlier, it is clearly evident that Mathematics is a tool for A level Physics. In fact, Nilsen, et al. (2013) state that for a student to be proficient in physics, s/he needs to shift between the different modes of physics and mathematics. Researchers have come up with different models of conversion between physics and mathematics.

2.4.4.1 Dolin, Niss as cited in Nilson et al.'s models

Dolin (2002) came up with five different physics competencies. These are:

" 1. Perform physics thinking and reasoning;
2. Plan, perform and describe experiments;
3. Build and analyse models;
4. Work with different representations of the same phenomena;
5. Communicate in, with, and about physics."

(Dolin, 2002, as cited in Nilsen et al., 2013, p. 5).

Niss (2003) worked on these physics competencies and came up with relevant mathematical competencies that the students use when performing such tasks. Subsequently, Nilsen et al. (2013) worked on Niss's (2003) mathematical competencies and highlighted the most prominent three which are important in physics education. These are: "handling symbols, mathematical modelling, and handling mathematical representations" (Nilsen et al., 2013, p. 6).

Handling symbols itself involves three competences:

1. clarifying the mathematical language and relating it to ordinary language;
2. converting the common language to mathematical language and

3. managing and knowing how to work with equations and formulae

(Nilsen et al., 2013).

Mathematical modelling is achieved when the student links together the different variables present in the problem by creating a mathematical description of the real world. Handling mathematical representations is the skill to use, grasp and alternate between different mathematical representations such as graphs, symbols and diagrams (Nilsen et al., 2013).

2.4.4.2 Bing and Redish's Model

Bing and Redish (2009) worked on and enhanced Disessa's (1993) three-stage model showing the conversion of knowledge between physics and mathematics:

Stage 1: Physics mode – Students use physics to describe the problem;

Stage 2: Mathematical mode – Students use mathematical operations to solve the problem; and

Stage 3: Physics mode – Students use physics to describe and interpret the mathematical result through the physical world.

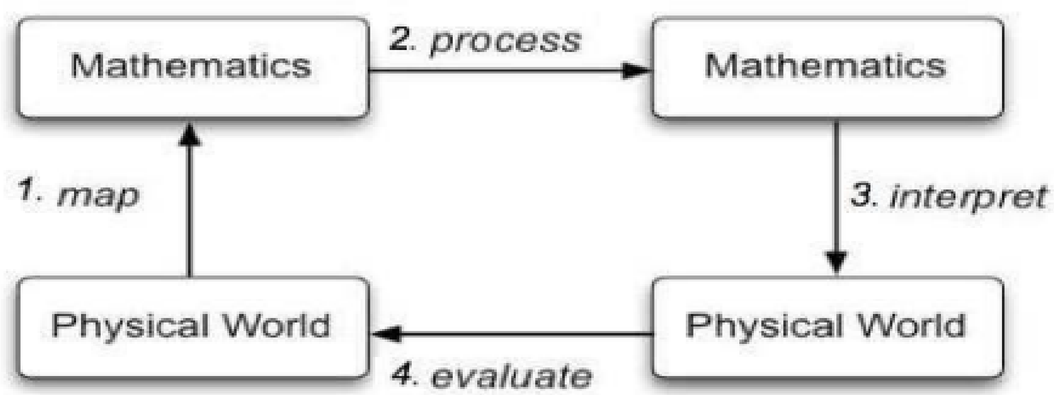

Figure 2.4: "A model describing the transfer of knowledge between physics and mathematics" (Source: Nilsen et al., 2013, p. 7)

2.4.4.3 Merging of the Different Models

Later, Nilsen et al., (2013) merged the recommended mathematical competencies for Physics with Bing and Redish's (2009) model.

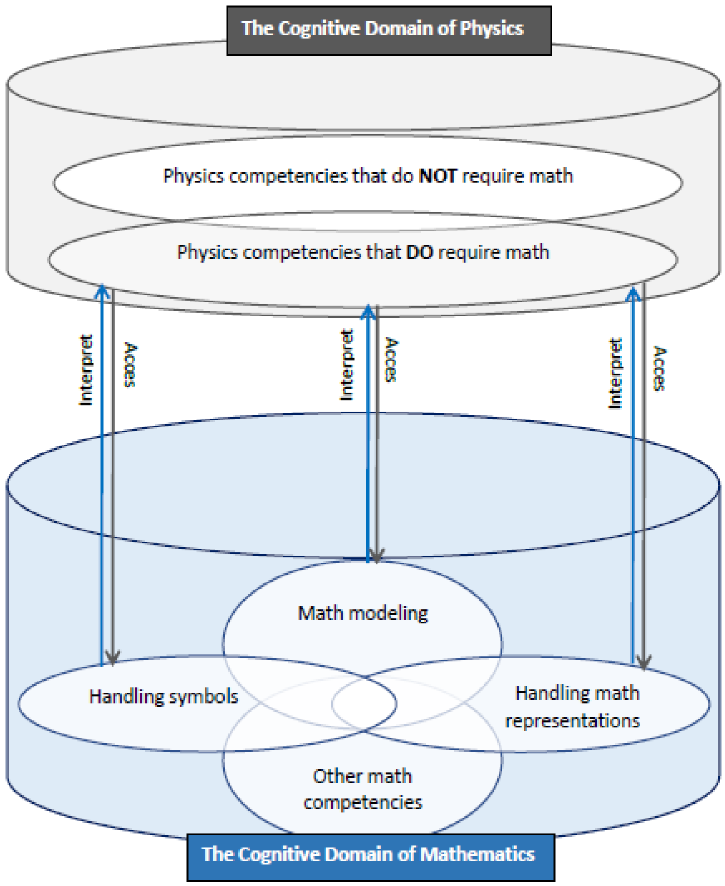

Figure 2.5: Nilsen et al.'s (2013) mathematical model

Nilsen et al., (2013) explained that the cognitive domain of Physics, which appears in the top part of Figure 2.5, includes two different areas: the 'Physics competencies that do NOT require math' and the 'Physics competencies that DO require math'. According to the literature, both competences have other influential factors which are beyond the scope of this study such as motivation, self-efficacy and attitude. The competencies which require mathematics, are directly connected with the cognitive domain of Mathematics.

The bottom part of Figure 2.5 represents 'The Cognitive Domain of Mathematics'. This cylinder includes the three most prominent mathematical competencies discussed earlier by the same researchers. They consist of handling symbols, mathematical modelling and handling mathematical representations. There may also be other mathematical competencies present.

In order to complete a Physics assignment successfully, a student needs to switch between the modes of Mathematics and Physics (Nilsen et al., 2013). Students need to switch from Physics to Mathematics to "access" symbols and mathematical representations. However, they would then need to switch back from Mathematics to Physics to "interpret" their results. Through this model, Nilsen et al., (2013) indicated that student mathematical abilities significantly influence their achievement in Physics, the most important ability being that which requires them to handle symbols.

Concurring with Nilsen et al., (2013), Karam, Pospiech and Pietrocola (2010, in Kaminski & Michelini, 2010, p. 131) express their belief that "one of the most important abilities to deal with phenomena in the Physics domain is to be able to use Mathematics as a reasoning instrument."

2.4.4.4 Redish and Kuo's Model

This mathematical model was later improved by Redish and Kuo (2015) by expanding it into the following four steps:
<u>Step 1</u>: Modelling - The model starts by identifying the variables, mapping them into mathematical symbols and agreeing upon an appropriate mathematical operation.

<u>Step 2</u>: Processing – The mathematical operation that was chosen in step 1 needs to be worked out correctly in order to solve the equation, thus solving the problem which leads to answers which cannot be deduced through physical ways.

<u>Step 3</u>: Interpreting - The mathematical result which was derived during step 2 needs to be interpreted back to explain physical phenomena.

Step 4: Evaluating – Eventually, the result has to be evaluated in physical terms to prove or disprove the physical phenomena observed.

According to Redish and Kuo (2015, p. 7), "each of these four steps – modelling, processing, interpreting, and evaluating – are critical skills in the toolbox of a scientist who uses math to describe the behaviour of the physical world." Pospiech et al. (2015, p. 4) affirmed that "the path from a phenomenological level up to a more abstract level where mathematical reasoning concerning physical laws and processes can take place has to be shaped carefully treating both the technical and the structural aspect."

"The results of physical experiments and observations are ordered with the help of an abstract symbolic system, and the communicative aspect, using and setting into relation to each other different representations" (Krey, 2012, in Pospiech et al., 2015, p. 2).

2.4.5 Analysis of the Topics in SEC level Mathematics and A level Physics

Table 2.5 below presents the Mathematics topics covered at SEC level and the mathematical requirements needed for A level Physics.

SEC level Maths	Mathematical requirements for A level Physics
Number	**Arithmetic and Computation**
Integers,	
Sequences,	
Fractions,	
Decimal Number,	Use of Decimal,
Numerical Operations,	
Indices,	Reciprocal, Squares, Inverses,
Standard Form,	Standard Form,
Percentages,	
Ratio,	Angles: Degrees and Radians,
Proportion,	Handling of Data,
Rates of Change,	
Measures,	
Scales,	
Money,	
Estimation and Approximation,	Approximate Estimations
The Calculator	Use of Calculator
Algebra	**Algebra**
Algebraic Representation,	Algebraic Equations,
Equations and Inequalities,	Simultaneous Quadratic Equations,
Formulae,	Changing the Subject of the Formula,

Graphs, Information Graphs, Indices, Sequences	Logarithms, Understand and Use the Symbols: =, >, <, >>, <<, ≈, α, ~, Σ×, Δ×
Shape, Space and Measures Geometry (Angles, Lines and Line Segments, Triangles and Pythagoras' Theorem, Quadrilaterals, Polygons, Circles), Trigonometry Construction Mensuration Symmetry and Congruency, Bearings, Transformation Geometry, Loci	**Geometry and Trigonometry** Areas of triangles, Circumference and Areas of Circles, Surface Areas and Volumes of Rectangular Blocks, Cylinders and Spheres, Pythagoras' Theorem, Similarity of Triangles and the Angle Sum of a Triangle and Quadrilateral, sine, cosine, tangent, Relationship between Angular Measure in Degrees and Radians: for small angles sin θ ≈ tan θ ≈ θ (in radians), and that cos θ ≈ tan θ ≈ θ
Data Handling Statistics,	**Graphs** Translate information between numerical, algebraic, written and

Probability	graphical form, plotting of two variables, choosing suitable scales for graph plotting, rearranging an equation to linear form, determine the gradient and the y-intercept, logarithmic plots and ln, rate of change, dx/dt area under the graph

Table: 2.5: The topics in SEC level Mathematics and the Mathematical requirements in A level Physics (Source: 2019 SEC Mathematics syllabus and 2019 AM Physics syllabus)

Similar mathematical topics in the two syllabi are highlighted in the same colour. As can be observed, most mathematical requirements needed for A level Physics are covered during the secondary school years. However, A level Physics requires other mathematical skills and knowledge of a level higher than SEC. These include: angles in radians, logarithms and a number of 'areas' in differentiation.

2.4.6 Student Difficulties

In previous sections it was clearly demonstrated that there is a consensus among researchers that attainment in Physics depends, to a certain extent, on competence in Mathematics. This may ultimately lead to complications and difficulties when working out problems in Physics. This is because "non-physics related deficiencies play a big part in how students solve problems" (Soong, Mercer & Er, 2009, p. 364). This section will deal with such difficulties encountered by students.

Sometimes, teachers assume that students who are able to work out Physics problems would have put in a great deal of effort and have grasped the physics theories and models. However, this is not always true. Students who succeed in working out Physics problems, especially beginners, are likely to find an equation from the equation sheet provided which best fits the unknown variables present in the problem. It is reported that

> [o]ne of the most mentioned strategies was the *Rolodex equation matching* (i.e., finding equations that contain the same variables as the list of knowns and unknowns). According to our teaching experiences, this process often runs without thinking about physics concepts involved in the problems and therefore solving the task often turns into simple mathematical manipulation with formulas (Snetinova & Koupilova, 2012, p. 96).

This can create misconceptions among teachers with regards to the learning process. "Furthermore, teachers often complain that students do not have sufficient mathematical abilities in order to handle the physical equations" (Pospiech in Kaminski & Michelini, 2010, p. 101).

Finding the equation which fits could also prove to be a problem. Torigoe (2008, p. ii) found that students encounter difficulties while working with symbolic equations.

> We find that the main cause of students' poor performance on symbolic questions is due to confusion about the meaning of symbols and symbolic equations. Symbolic solutions require a greater attention to meaning than do numeric solutions. When solving a symbolic question students must actively identify known quantities while reading the question, keep track of symbol states, and keep track of relationships between symbols (Torigoe, 2008, p. ii).

In fact, in her study, Kieran (1981, p. 5) asked students, in a Mathematics class, to interpret the equal sign. She found that the majority of the students considered the equal sign as a "do something signal" rather than a symbol of equality. SEC examiners note that "[m]ajor difficulties were faced by candidates to write the equations in terms of symbols" (MATSEC Examinations Board, May 2017, Q. 1).

Another difficulty that students come across when working Physics problems concerns explanations and problem-solving tasks, when they need to correlate real-world phenomena with theoretical models, especially when merging mathematical applications with abstract reasoning on physical phenomena (Kuo et al., 2012; Michelsen, 2006; Tuminaro & Redish, 2007; Uhden et al., 2012 as cited in Redfors et al., 2014).

> It's often the case that students perform poorly on mathematical problem-solving tasks in the context of Physics. There are at least two possible, distinct reasons for this poor performance: (1) students simply lack the mathematical knowledge and skills needed to solve problems in Physics, or (2) students do not know how to apply the mathematical skills they have to particular problem situations in Physics (Tuminaro, 2004, p. 106).

Additionally, Rushton and Wilson (2014, p. 10) found that in higher education, "students' algebraic skills were considered weak by the majority of teachers, and students were considered to be underprepared in this area." Nilsen et al., (2013, p. 2) agreed with Tuminaro (2004) as they both confirmed that "difficulties with mathematics in Physics could be related to 1) the prerequisite mathematical competencies required in Physics and/or 2) struggles with transfer between mathematics and physics."

According to SEC examiners, "[i]t can be noted that many candidates continue to experience difficulty with numerical calculations. In many cases, candidates were able to identify the correct equation and substitute properly, but were then unable to determine the final answer" (MATSEC Examinations Board, 2016, p. 2). Similarly, Rebello, Cui, Bennett, Zollman and Ozimek (2007, p. 30) claim that "... the main difficulty that students appear to have does not lie in their lack of understanding mathematics *per se*, rather it lies in their inability to see how mathematics is appropriately applied to physics problems". "In a study by Angell et al. (2008), the physics students reported that the algebra required in physics in fact was simple, yet they could not perform simple manipulations of equations" (Nilsen et al., 2013, p. 17). Jeremy Lewis, Head of a UK private school answered that "our exam systems are just not preparing students to make that leap from secondary to higher education." He notes that they just focus on the subject content (Ali, 2016). "After all, students who understand the physics concepts taught might not do well in an examination if they are unable to identify the correct concepts that the questions are evaluating, or are unable to understand the questions posed" (Soong, Mercer & Er, 2009, p. 364).

2.4.7 MATSEC Examiners' Comments

The following are a number of comments by the A level Physics MATSEC Examiners which highlight the importance of mathematical competence for A level Physics.

"The majority of candidates expressed good understanding of algebraic manipulation of units. However, logical presentation of facts is still lacking. It is still common that mathematical steps contain a mixture of units and symbols for quantities" (MATSEC Examinations Board, 2017, Q1).

"[C]andidates showed good mathematical ability in deriving and solving equations" (MATSEC Examinations Board, 2017, Q12).

"[T]he majority of candidates showed good understanding of the topic and were able to provide correct answers through good mathematical manipulation of the relevant equations" (MATSEC Examinations Board, 2016, Q10).

> It is amazing how candidates at this level do wrong mathematical calculations when requested to determine the increase in KE of a mass of blood. Quite a surprising number of candidates found incorrectly the change in KE by first finding the difference in velocity, squaring this value and multiplying by half the mass. Candidates also found it difficult to calculate the power (MATSEC Examinations Board, 2014, Q4).

"In part (b), the first two segments were answered correctly however when a little working was introduced, for the second two segments, the calculations started to contain basic math mistakes" (MATSEC Examinations Board, 2013, Q10).

2.5 The Role of English in Physics Examinations

> The language of science is a unique hybrid: natural language as linguists define it, extended by the repertoire of meaning of mathematics, contextualised by visual representations of many sorts, and embedded in a language (or more properly a

> ‘semiotic’) of meaningful specialized actions afforded by the technological environments in which science is done (Lemke, 2004, p. 34).

The following section attempts to carry out an in-depth investigation on the language challenges in a Physics classroom, thus, addressing the demands of making Physics more accessible to students whatever their language background (Day, 2018).

2.5.1 Is Achievement in English and Physics Correlated?

Brookes (2006) shows that students’ language is crucial in their learning, particularly when it comes to the concepts of Physics. Similarly, Farrell (2010) believes that students’ proficiency in both English and Maltese influences their abilities and performance in science examinations. Ojo (2008) maintains that reading ability is of utmost importance in student achievement in Physics. Baylon (2014, p. 199) concludes that “there was a significant positive relationship between English and Physics achievement.”

In the Program for International Student Assessment’s (henceforth PISA) publication, it is reported that there is a positive correlation coefficient of 0.83 between success at science and reading (Organisation for Economic Co-operation and Development [henceforth OECD], 2009). Aina, Ogundele and Olanipekun (2013, p. 357) found that “there is a strong correlation between English language proficiency and students’ academic performance in science courses with a correlation coefficient of 0.553. This means good English language proficiency determines good academic performance of students in science courses.” The researchers also conclude that “those who passed English language performed better in science than those who failed English language since mean score of those who passed is higher than those who failed” (Aina, Ogundele, Olanipekun, 2013, p. 357).

2.5.2 Language versus Performance in Physics/ Science Education

In his research study, Farrell (2010, p. 342), found that

> [t]he vast majority of students who were *High* in both Physics and Mathematics were found to be *High* in both languages as well. One can notice how the figures for *High* Physics and *High* Mathematics drop for students who were Intermediate in the two languages or who were *High* in just one language.

Ventura (2016, p. 249) tested this theory and concluded that "[t]he performance of the more able students in science is independent of the language of the test, but the less able obtain far better results if they take the test in Maltese, although their performance is still very weak."

Ventura (2016) also believes that the relationship of language proficiency and student achievement in science decreases with age as the students develop adequate skills to surmount the language factor. Nevertheless, the language barrier at examinations lingers even up to Sixth Form level with a small fraction of A level Physics students (Farrell, 1996).

2.5.2.1 Challenges of Learning Physics in Malta's Bilingual Society

Bilingualism is defined as "the regular use of two (or more) languages" (Grosjean, 1985, p. 468). "All students using more than one language in their everyday life, regardless of language proficiency, are viewed as bilinguals" (ünsal, 2017, p. 37). Research shows that there is a negative correlation between science achievement and speaking a home language which is not the same as the language of instruction (Janssen & Crauwels, 2011, Martin et al., 2012; OECD, 2009, 2010). It was concluded that performance in science subjects is affected by the level of proficiency in the language of instruction (Taboada, 2012; Aina, Ogundele & Olanipekun, 2013).

Lemke (1990, p. 1) stated that for students to learn the language of science, they should be "speak[ing] it with those who have already mastered it and employ[ing] it for the many purposes for which it is used." As a result, "[i]t is very important for its learners to be able to express their views and ideas in clear and attractive form" (Mallick, 2012, para. 5). Moreover, Taboada (2012) points out that both in the cases of language minority students (those who have a different home language than the language of instruction) and language majority students (those whose home language is also the language of instruction), the proficiency of vocabulary strengthens the apprehension of science texts.

In Malta, during their lessons "[s]cience teachers may use the English language or the Maltese language or code-switching with a variable mix of both languages for oral communication with students" (Ventura, 2016, p. 242). Due to the bilingual nature of Maltese society, some teachers, reduce the use of English and instead employ code-switching to ensure understanding during lessons (Camilleri, 1995). This can be considered as a support system (Cummins, 2001) in order to reduce weak understanding on account of the language of instruction being different from the home language, thus making the syllabus content more accessible (Clark et al., 2012; Kenner et al., 2008; Riches & Genesee, 2006). Apart from enhancing their understanding of science, this will improve and develop the students' scientific language and inquiry skills (Reyes, 2009).

"[A] teacher's language is vital in teaching science and creating the condition for meaningful learning" (Oyoo, 2015, para. 2). Thus, the science teacher needs to appear as a "mediator between everyday language and descriptions and the formal language of science with its ways of conceptualising the world" (Wellington & Osborne, 2001, p. 119). Students might encounter difficulties due to the misunderstanding of specialized scientific vocabulary which might give new meanings to everyday terms (Brookes, 2006).

> Some of these non-technical words give identity to certain science subjects where they are used to embody a particular concept important to a process of learning in the specific science subjects: 'reaction' in chemistry, 'diversity' in biology and 'disintegrate' and 'resistance' in physics" (Oyoo, 2015, para. 7).

"In practice, however, the lack of a standard scientific language in Maltese may cause problems to markers who may misinterpret some of the answers written in a non-standard language and consequently lower the reliability of the results" (Ventura, 2016, p. 251). Ventura (2016) reports that all the science books, lesson notes, lab reports and assessment records in Malta are written in English. In such circumstances, students need to interpret and comprehend the questions being asked and write down answers of various lengths in the same language, which is different from the home language (Ventura, 2016). O'Reilly and McNamara (2007) concluded that the individual's achievement in science can be anticipated by their reading skills. Moreover, language minority students are generally weak in comprehension skills, including vocabulary knowledge and reading comprehension (Cremer & Schoonen, 2013). "It is presumed that any weaknesses the students may have in these skills will prevent them from demonstrating their true understanding of science and consequently underachieve" (Ventura, 2016, p. 243).

Therefore, students in such a situation face a greater challenge in accomplishing the same grades in science education as language majority students (Martin, Mullis, Foy & Stanco, 2012; Van Laere, Aesaert, van Braak, 2014; OECD, 2009, 2010). Consequently, "[s]tudents learning in their mother tongue are generally thought to have an advantage over their counterparts who are being taught in a second or third language" (Oyoo, 2015, para. 4).

2.5.2.2 MATSEC Examiners' Comments

The following are comments by the SEC and A level Physics examiners' reports, which support the arguments with regards to the importance of the English language in Physics, presented in the previous sections.

> Written explanations must address the question. At times candidates gave generic answers which were not much related to the question being asked. Candidates tend to write everything they could think of, related to the topic, instead of answering the question asked (MATSEC Examinations Board, 2017, General Comments).

“Written explanations continue to be lacking in detail or are not sufficiently specific to the question asked” (MATSEC Examinations Board, 2016, General Comments).

“For a qualitative question like this, the student is required to have good command of the English language. Indeed, many candidates find it difficult to express their reasoning. Language difficulty is also pronounced while recalling standard rules like Kirchoff’s laws” (MATSEC Examinations Board, 2016, Q6).

“In part (d), only a small number of candidates managed to correctly explain in full and in good English why the motion of the skater along the half-pipe is not SHM [henceforth Simple Harmonic Motion]” (MATSEC Examinations Board, 2016, Q10).

“In questions that required explanations, candidates performed quite poorly. It is recommended that they should carefully consider what the question is asking and answer accordingly” (MATSEC Examinations Board, 2015, General Comments).

“There also appeared to be a difficulty in expressing oneself correctly” (MATSEC Examinations Board, 2015, Paper I, Q3).

“[T]he absolute majority of candidates did not manage to explain their answer for (b)(vi) either due to lack of understanding or due to poor usage of the English language” (MATSEC Examinations Board, 2015, Paper I, Q10).

“In general, candidates were also able to answer part (d) quite well, even though there were cases where the use of the English language was poor, to say the least” (MATSEC Examinations Board, 2015, Paper II, Q1).

2.6 Cross-Correlation and Correlation Coefficients between the Different Subjects under Test

The term ‘correlation’ can be defined as “mutual relation of two or more items/things” (Essays, 2013, para. 2). The theory of correlation between subjects is expressed through “connection and merging of the content” (Šimunovi & Bleki, 2012). Accordingly, correlation between subjects can bring about several advantages: students learn faster, show more interest and so participate more during the lesson. Also, "[s]tudents will find the opportunity to relate the knowledge which they have already gained, with the knowledge which they are gaining. This kind of relation activity leads to development of interest among the students" (Mallick, 2012, para. 3). Moreover, "[d]eliberate effort should be done by the science teacher to bring about co-relation in between the science and other subjects of the curriculum, which are being imparted to the students" (Mallick, 2012, para. 2).

In the document *Guidelines for the prospective student*, the University of Malta Junior College Physics Department advocates that, "[a] grade 3 or better in SEC Physics and/or a grade 3 or better in both Mathematics and English suggests that you have the potential to do well at Advanced level" Physics (University Of Malta Junior College Physics Department, n.d., p. 2). In fact, in the A level Physics Examiners' Report (MATSEC Examinations Board, 2016, Q7), it was stated that "[a]s a semi-qualitative question, Question 7 required candidates to have a good command of the English language while having mathematical ability to answer part (b)."

The UK's Education Standards Analysis and Research Division (2012) reports that in 2007/08, 95% of the students taking Physics at GCSE achieved at least a grade C. Only 65% of the students who took up English at GCSE attained at least a grade C, while 59% of the students who attempted Mathematics at GCSE obtained at least a grade C.

In its SEC 2017 statistical report, the MATSEC Examinations Board reported that 70% of the candidates who sat for SEC Physics achieved between grades 1 and 5; 74.9% of candidates who sat for the SEC English Language exam obtained grades in that range, while in the case of Mathematics, only 61.9% of the candidates obtained grades in the same range (MATSEC Examinations Board, 2017).

Table 2.3 shows that in the UK, of the three subjects being investigated, Physics shows the highest progression rate (19%) of students taking up A level from GCSE. This figure is followed by English (18%) and Mathematics (14%). These progression rates are not corroborated by those published in Malta in the 2018 MATSEC Examinations Statistical Report. This states that English has the highest progression rate (14%). "The popularity of the two national languages was generally increasing at AM Level" (MATSEC Examinations Board, 2018, p. 48). This progression rate is then followed by Mathematics (9%) and Physics (7%).

Since the "connection and merging of the content" (Šimunovi & Bleki, 2012) is considered advantageous for students, several studies, both locally and internationally, have tried to bring out the correlation coefficients between subjects. For the purposes of this study, only correlation coefficients between A level Physics and SEC Physics, Mathematics and English Language will be presented in Table 2.6.

Researcher/s	**Year of Research**	**Correlation between subjects**	**Correlation coefficient (r-value)**
Ventura	2001	SEC Physics 1998 A level Physics 2000	0.572
Pace & Bonello	2006	SEC Physics 2000 A level Physics 2002	0.488
Pace & Bonello	2006	SEC Physics 2002 A level Physics 2004	0.442
Farrugia & Ventura	2007	SEC Physics 2004 A level Physics 2006	0.62
Sutch	2013	GCSE Physics 2010 A level Physics 2012	0.589
Sutch	2013	GCSE Maths 2010 A level Physics 2012	0.557

Sutch	2013	GCSE English Language & Literature 2010 A level Physics 2012	0.468
Aina, Ogundele and Olanipekun	2013	English Language & students' academic performance in science courses	0.553

Table 2.6: Correlation coefficients of the subjects under test by different researchers

2.7 Conclusion

This chapter presented multiple arguments and findings put forward by various researchers in their studies. These will be used as the theoretical framework for the data analysis. The next chapter describes the methods used to address the research questions of this study.

Chapter 3

Methodology

3.1 Introduction

This chapter will describe the methodology and the research tools used in this study in order to address the research questions. Since the data collection included a great deal of human element (students and teachers), this brought about several challenges which had to be overcome in order to obtain the most valid results.

3.2 Aims and Objectives of the Study

One of the aims of this study was to identify some of the effects of the changes implemented in the 2012 SEC Physics syllabus. It also aimed to investigate whether the 2012 SEC Physics syllabus provides students with a good preparation for the A level Physics course leading to the local Advanced Matriculation Certificate in the subject. Another aim was to discover whether the SEC Mathematics syllabus provides sufficient mathematical groundwork for the A level Physics course and examination. The research study also investigated the cross-correlation relationships between SEC grades in Physics, Mathematics and English Language and the grade obtained in A level Physics.

The researcher will attempt to answer the above research questions supported by results from the data collected.

3.3 Research Approach

Since this research study examines questions which have already been investigated before and questions which will fill in a gap in the already existing knowledge, the researcher decided to follow both a deductive and an inductive reasoning approach.

A deductive approach was used to compare and contrast existing theories and knowledge. A "[d]eductive research approach explores a known theory or phenomenon and tests if that theory is valid in given circumstances" (Dudovskiy, 2011, para. 6). Such a research approach presents the following advantages:

"1. Possibility to explain casual relationships between concepts and variables;

2. Possibility to measure concepts quantitatively;

3. Possibility to generalize research findings to a certain extent"

(Dudovskiy, 2011, para. 5).

On the other hand, when the present researcher did not find any available theories and existing knowledge to address any of the research questions, she had to resort to an inductive approach. This was done by designing the appropriate tools to collect suitable data to answer and fill in the gap in knowledge. An "[i]nductive approach is concerned with the generation of new theory emerging from the data" (Gabriel, 2013, para. 1). This type of research approach generates more inquiry. "It fuels more exploration to test if the judgement or probable inference is right or wrong" (Ayres, 2016, para. 4).

3.4 Research Design

Particular methods of data collection were chosen in order to gather a very wide range of opinions from sources that have a great deal of experience in this field. Taking into consideration the aims and objectives of this study, the researcher opted for a mixed research method approach, which would best address the research questions. According to Johnson, Onwuegbuzie, and Turner (2007, p. 123), "mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches for the purposes of breadth and depth of understanding and collaboration."

In terms of quantitative data, numerical data were collected through questionnaires distributed among Sixth Form second year students (Appendix 3) in all the Sixth Form schools and colleges in Malta and Gozo. A total of 165 duly filled questionnaires were returned by the students. Questionnaires were also distributed among all the 23 Physics Sixth Form second year teachers (Appendix 4) where 16 filled-in questionnaires were returned. The grades obtained by students in the 2015 SEC Physics, Mathematics and English Language examinations, as well as in the (corresponding) 2017 A level Physics examination, were obtained from the MATSEC Support Unit office at the University of Malta in order to support and corroborate the arguments brought forward in this study.

Regarding the qualitative data, five face-to-face interviews were carried out with Physics Sixth Form second year teachers (Appendix 6). Another four face-to-face interviews were conducted with SEC Physics teachers (Appendix 7). Moreover, a focus group involving seven Sixth Form second year students (Appendix 5) was also held. The interviews and the focus group were based on "understanding and interpreting social interactions" (Cohen, et al., 2005, p. 302) in order to understand and decipher better the different elements that are involved in the attainment of good performance in A level Physics.

The use of these various types of data collection methods were also aimed at creating the desirable goal of triangulation.

> By analogy, triangular techniques in the social sciences attempt to map out, or explain more fully, the richness and complexity of human behaviour by studying it from more than one standpoint and, in so doing, by making use of both quantitative and qualitative data (Cohen, et al., 2005, p. 112).

The researcher ensured that the four research questions were perused and answered by respondents of different age groups and experiential knowledge, thus enabling the researcher to obtain different perspectives.

3.5 Sampling Technique

According to Punch (2003, p. 36), sampling is very important since, "we usually wish to generalise our survey findings from the sample back to the population."

3.5.1 Type of Sampling

Since it is not practical to include a whole population in a study, careful planning should precede the actual choice of the type of sampling which could be used in collecting the necessary data. It was ensured that the recruited participants in this study came from different educational sectors, namely, state schools, Church schools and private schools. This enhanced the validity of the study since it minimalized the amount of bias in the respondents (Cohen, et al., 2005).

3.5.1.1 Questionnaires

The first step taken by the researcher was to ask the relevant authorities responsible for both the Church schools and the state schools for the necessary permissions to carry out the research in their schools.

Once all permissions were obtained, the researcher handed out a questionnaire and a consent form to all the Sixth Form second year students studying A level Physics in Malta and Gozo and also to all Sixth Form Physics teachers. A note was included which explained that they were free to choose whether they wanted to participate in the study or not and that they were free to terminate their participation in the research at any time.

The sampling technique that was employed was homogenous purposive sampling which is a non-probability mode of sampling. In purposive sampling, "the researcher has deliberately – purposively – selected a particular section of the wider population to include in or exclude from the sample" (Cohen, et al., 2005, p.

99). “When researchers use the homogeneous purposive sampling technique to collect information, then they are selecting individuals who have a shared set of characteristics” (Ayres, 2019, para. 10).

According to Ayres (2019), even though the information obtained cannot be extrapolated to the whole population, through purposive sampling the researcher can still generalize the results for a similar group of people.

3.5.1.2 Interviews

As another data collection method, interviews with Sixth Form second year teachers and with SEC Physics teachers were carried out during this study. The chosen purposive sampling mode for the interviews consisted mainly of reputational-case sampling. This type of sampling is used in order to recruit people who are knowledgeable in the topic of the research (Ball, 1990). The researcher used this type of sampling to gain the experience and outlook of teachers who come face to face with the themes included in the research questions every day.

3.5.1.3 Focus Group

This study also included a focus group with Sixth Form second year students in order to receive in-depth views about their experience in the subject. The chosen purposive sampling for the focus group was convenience sampling. “Convenience sampling is a non-probability sampling strategy where participants are selected based on their accessibility and/or proximity to the research” (Bornstein, Jager & Putnick, 2013, p. 361). According to Patton (1980), convenience sampling saves time and money.

The researcher ascertained that all the samples of questionnaires, interviews and focus group represented well both genders and different educational sectors hailing from both Malta and Gozo. This enhanced validity and reduced bias. Although the participants recruited for this research study came from different backgrounds, they were asked more or less the same questions to allow the researcher to compare and contrast their responses.

3.6 Methods of Data Collection

The appropriate type and use of data collection methods greatly influences the success of the research.

3.6.1 Questionnaire

The purpose of the questionnaires was to obtain brief information on the research topic from Sixth Form second year students studying A level Physics and Sixth Form second year Physics teachers in Malta and Gozo. "Large amounts of information can be collected from a large number of people in a short period of time" (University of Surrey, 2010). The aim of the questionnaires was to investigate the research questions mentioned in Section 3.2 above. This type of sampling was chosen since "there is a very large pool of potentially information-rich cases and no obvious reason to choose one case over another" (Sandelowski. 2000, p. 249).

3.6.1.1 Piloting the Questionnaires

Piloting a questionnaire is very important in order

> to gain feedback on the validity of the questionnaire items, to eliminate ambiguities or difficulties in wording; to gain feedback on the type of question and its format, to check the time taken to complete the questionnaire; to check whether the questionnaire is too long or too short, too easy or too difficult, too unengaging, too threatening, too intrusive, too offensive (Cohen, et al., 2005, p. 260).

A pilot questionnaire was distributed among three male and three female Sixth Form second year students and one teacher, purposefully selected in order to test its questions. The researcher was present when these questionnaires were filled, in order to address and/or clarify any queries. During the pilot study, some questions were found to be too open-ended and thus ambiguous. To address this issue, these questions were then re-formatted into closed-ended multiple choice questions.

3.6.1.2 Administering the Questionnaires

During this study, the information obtained indicated that about 315 students would be sitting for the A level Physics examination in 2019. The sample-size calculator indicated that 173 questionnaires (Figure 3.1) were needed to represent well this population. Such a sample provided the researcher with a confidence level of 95% and a confidence interval of 5. According to Mouly (1978, p. 189), the larger a sample, the greater the validity.

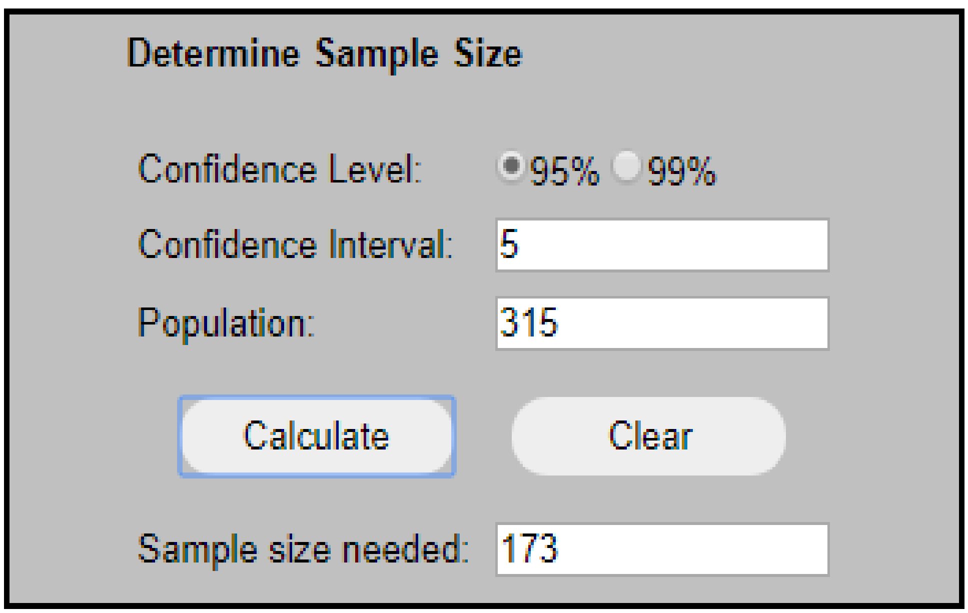

Figure 3.1: The calculated ideal sample size of student questionnaires in this study

Stapled copies of information sheets (Appendix 1), consent forms (Appendix 2) and questionnaires were left with the respective school secretary and collected a week later. A copy of each was passed on by the school secretary to Sixth Form second year students studying A level Physics. The students who accepted to fill in the questionnaire were expected to hand in a signed copy of the consent form along with the questionnaire. This was done to avoid wasting the students' time as all valid questionnaires had to be accompanied by a consent form.

Although all Sixth Form second year students in Malta and Gozo were given a questionnaire, 'only' 165 duly filled questionnaires were handed back from all Sixth Form schools and colleges - three state schools, two Church schools, and one private school. The number of collected student questionnaires gave a confidence interval of 5.27. If more questionnaires than the required number were to be handed in, the researcher would have accepted only the first 173 questionnaires (for a confidence interval of 5).

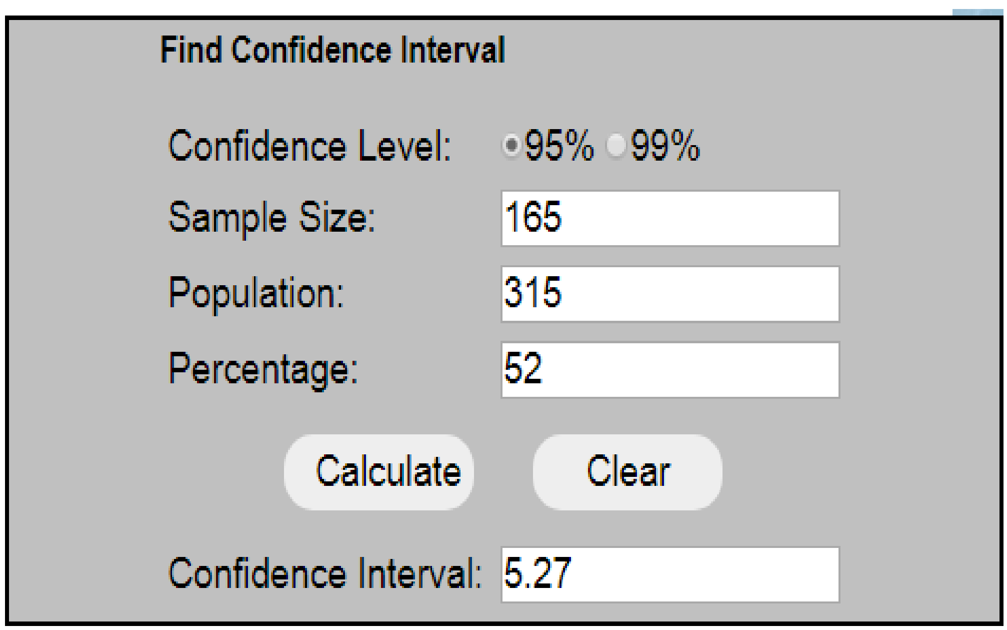

Figure 3.2: The calculated confidence level provided by the collected student questionnaires

The following tables show the number of questionnaires distributed and collected in each school.

Schools	Number of Questionnaires Distributed	Number of Questionnaires Collected	Percentage
A	101	57	56.4%
B	80	16	20.0%
C	35	23	65.7%
D	59	37	62.7%
E	29	20	68.9%
F	13	12	92.3%
Total	317 (100%)	165 (52.1%)	

Table 3. 1: A breakdown of the initial sample of student questionnaires distributed and collected partitioned by school

Schools	Number of Questionnaires Distributed	Number of Questionnaire s Collected	Percentage
A	8	6	75%
B	8	5	62.5%
C	2	1	50%
D	2	2	100%
E	2	1	50%
F	1	1	100%
Total	23 (100%)	16 (69.5%)	

Table 3. 2: A breakdown of the initial sample of teacher questionnaires distributed and collected categorized by school

3.6.2 Interview

The researcher opted for a qualitative approach by obtaining detailed opinions from a small number of participants on the statistical data that was gathered through the questionnaires. It was decided that interviews would best fit the researcher's intentions. This is because "[i]nterviews enable participants – be they interviewers or interviewees – to discuss their interpretations of the world in which they live, and to express how they regard situations from their own point of view" (Cohen, et al., 2005, p. 267).

Four face-to-face interviews with SEC Physics teachers and five face-to-face interviews with A level Physics teachers were held.

3.6.2.1 Piloting the Interviews

A pilot interview was conducted with a colleague of the researcher. This was done so that the researcher could gain confidence in asking questions and to receive her feedback on the questions asked. Some of the questions, which were closed-ended, were modified to become open-ended in order to facilitate further discussion. Some introductory questions were also added to the interview guide sheet to act as an ice-breaker. This allowed the interview to run more smoothly and confidently.

3.6.2.2 Conducting the Interviews

The interview questions were very similar to those in the questionnaire. This allowed the researcher to compare, contrast and support statistical results from the questionnaires. The researcher made sure that the majority of the questions were open-ended. These provided the interviewees with flexibility in terms of the length and depth of their answers. Moreover, the interviews were semi-structured to allow the interviewees to discuss related issues which the researcher was not aware of (Gill, Steward, Treasure & Chadwick, 2008).

Each interview took an average of thirty minutes and these were held in settings that were convenient to the interviewees. The interview questions were posed in English; however, to reduce inhibitions, the interviewees were free to put forward and discuss their answers in either English or Maltese. These decisions were taken to allow the participants to feel comfortable and thus the researcher could have better access to the real feelings of the respondents. All the interviews were recorded, later transcribed and where necessary translated into English by the researcher.

3.6.3 Focus Group

The focus group questions were very similar to those of the interview and the questionnaire. However, guided questions were added whenever necessary to make the students feel comfortable and to guide them through the discussion. As in the case of the interviews, this research tool provided the researcher with qualitative data.

The purpose of this particular research tool was to obtain in-depth opinions from participants who were currently experiencing the issue in focus in this study at first hand. Initially, the researcher was not sure whether to use face-to-face interviews or a focus group with the students. The researcher opted for a focus group for two reasons. The first reason was that since the students were not yet familiar with face-to-face interviews, they might have provided only cursory replies. Such short answers would not have been desirable for the researcher. So, a focus group was selected during which students could feel more free to discuss and elaborate their opinions at length. Furthermore, listening to fellow students give their opinions could motivate others to enter the discussion and give their own views. Focus groups "[p]rovide insight on multiple and different views and on the dynamics of interaction within a group context (Litosseliti, 2007, p.16).

The second reason was that since the participants were Sixth Form second year students, they were committed to their studies and could not easily find a suitable time for a face-to-face interview. It was much more convenient, both for the researcher and the students, to meet once with the whole group. The focus group was held on a Saturday evening and lasted approximately one hour. The students were left free to discuss their arguments either in Maltese or in English to reduce language inhibitions. The focus group was recorded, later transcribed and translated into English where necessary.

3.6.4 Examination Grades

The correlation coefficient between the different subjects could be worked out on the basis of the grades obtained in the MATSEC examinations. This quantitative data would help to prove or disprove the arguments put forward by the teachers and the students. For this reason, the A level Physics grades of students who sat for the examination in 2017 and the grades in SEC Physics, Mathematics and English Language of the same cohort (in 2015) were obtained from the MATSEC Support Unit.

It is important to point out that the students who took part in the questionnaires and focus group had not yet finished their Sixth Form course and therefore had not yet sat for their A level Physics examination. The A level Physics grades for the 2017 candidates were obtained; therefore the students participating in this study were not the same as the students whose grades were obtained, but one can easily assume that two groups are similar and so comparable. “For research to be reliable it must demonstrate that if it were to be carried out on a similar group of respondents in a similar context, then similar results would be found” (Cohen, et al., 2005, p. 117).

3.7 Data Analysis

"Data analysis is a body of methods that help to describe facts, detect patterns, develop explanations, and test hypotheses" (Levine, 1996, p. 1).

3.7.1 The Use of Microsoft Excel 2010

To interpret the quantitative data generated through the questionnaires, the responses were first inputted into a Microsoft Excel Office 2010 spreadsheet. With the help of this program, the researcher managed to transform all the data and generate relevant and appropriate plots.

3.7.2 The Use of IBM SPSS Statistics 23

IBM SPSS Statistics 23 was used to calculate descriptive statistics such as frequencies, percentages and correlation coefficients between the different SEC subjects, as well as to run statistical tests on the data.

The chi-square test was widely used in this dissertation. This test was used to assess the association between two categorical variables. One of these variables described the gender or school type attended by each student while the other variable described the question under test, particularly the effect of SEC subjects on A level Physics. It is important to note that the majority of the tests were run with respect to school type, however, data with respect to gender was also presented when this result was statistically significant. "The chi-square test measures the difference between a statistically generated expected result and an actual result to see if there is a statistically significant difference between them, i.e. to see if the frequencies observed are significant" (Cohen, Manion & Morrison, 2007, p. 525).

"The null hypothesis (henceforth H_o) attempts to show that no variation exists between variables or that a single variable is no different than its mean. It is presumed to be true until statistical evidence nullifies it for an alternative hypothesis" (Kenton, 2018, para. 1). "A p-value that is less than or equal to 0.05 is usually used to indicate whether there is strong evidence against the null hypothesis" (Kenton, 2018, para. 12).

In certain cases, some data sets were grouped together as the number of participants in those categories was extremely small. These data sets included grades 6, 7 and U when the researcher compared SEC grades with A Level grades. Also, the private school teachers had to be grouped with the Church school teachers because there was only one private school teacher. Since these data sets were very small, the categories were decreased to two by two matrices to facilitate the statistical analysis. Also, whenever one of the options in the questionnaire was not chosen by any participant, it was completely removed from the table. Moreover, even though the Junior College is within the structures of the University of Malta, it was considered as a state school in order to decrease the categories further.

The A level Matriculation results are given in a letter (A to F) format whilst the SEC results are in numeric (1 to 7 and U) format. In order to work out the correlation coefficient between the different subjects, the A Level grades had to be converted to numeric values to be compared to the SEC grades. With regards to SEC grades, grades 1 to 7 appear in that format while the SEC grade U was converted into number 8. As regards to A level grades, grades A to F were converted to numbers from grade 1 to grade 6.

In order to bring out the correlation coefficient between SEC Physics, SEC Mathematics and SEC English Language grades with A level Physics grades shown in Tables 4.9, 4.17 and 4.25 respectively, any students recorded as absent in any of these three subjects were completely eliminated from this study.

To calculate a value for the correlation coefficients, the Spearman rank-order correlation coefficient was used. This test was preferred over the Pearson correlation coefficient because when the variables were tested for normality with the Shapiro-Wilk test, they were all found to be not normally distributed (Lund

Research Ltd., 2018). “For nonnormally distributed continuous data, for ordinal data, or for data with relevant outliers, a Spearman rank correlation can be used as a measure of a monotonic association” (Schober, 2018, para. 1). Another reason for choosing the Spearman rank-order correlation coefficient is because there is a monotonic relationship between the two variables. This is because, generally, as one variable increased, the other variable increased as well.

The interpretation of the resulting correlation coefficients were based on those published by Gilchrist and Samuels of Birmingham City University (n.d.). A correlation coefficient between:

i. -0.3 and 0.3 is considered as weak;
ii. 0.3 to 0.5 and -0.5 to -0.3 are considered as moderate;
iii. 0.5 to 0.9 and -0.9 and -0.5 are considered as strong while
iv. 0.9 to 1 and -1 to -0.9 are considered as very strong.

3.7.3 The Use of Microsoft Word 2010

In order to interpret the qualitative data generated by the interviews and the focus group, a thematic analysis approach was used. The themes that emerged represented the patterns of experience within the data (Ayres, 2008).

This was carried out by first, transcribing the interviews and the focus group discussions word for word and later, translating them to English, wherever necessary. These documents were then read through and the important points were highlighted. During the first phase of the coding process, different codes were generated. These codes were then grouped and merged together to bring out the final five main themes, which were the following:

(i) The effect of the changes introduced in the 2012 SEC Physics syllabus on students who then studied A level Physics;
(ii) The challenges and expectations of students;
(iii) The relationship between Mathematics and Physics;

(iv) Language skills and A level Physics and

(v) What does the future hold?

In the data analysis, the male gender was taken to represent both the male and the female gender.

3.8 Enhancing the Validity and Reliability of the Study

In research, validity is extremely crucial because invalid research can be regarded as having little or no value at all. In light of this risk, triangulation was employed in order to enhance its validity. This specifically means that the data collection was based on two or more methods which study human behaviour.

> Triangular techniques in the social sciences attempt to map out, or explain more fully, the richness and complexity of human behaviour by studying it from more than one standpoint and, in so doing, by making use of both quantitative and qualitative data. Triangulation is a powerful way of demonstrating concurrent validity, particularly in qualitative research (Campbell & Fiske, 1959, as cited in Cohen, et al., 2005, p. 112).

Additionally, the purpose underpinning triangulation as an integral part of the research methodology is to strengthen the reliability of the data, the validity of the findings and recommendations, and to broaden the interpretations and explanations of outcomes measured by the study (Bryman, 2012).

Another advantage of the triangulation of data collection is that the more the research methods vary, the more confident should a researcher be of the results that emerge. Moreover, having different data collection methods also reduces bias, thus enhancing reliability. Another factor that strengthened reliability was that the teachers who were interviewed and the students who participated in the focus group were not given the questions beforehand. Thus, the participants had to discuss their viewpoints and opinions on the given topics spontaneously, reducing the risk of outside influences prior to the interview. Furthermore, before distributing the questionnaires, the researcher made it clear that students should be honest about the topic and should not copy answers from their friends, thus increasing the likelihood of accuracy and reliability.

3.9 Ethical Issues and Considerations

In this study, human behaviour and ideas were considered as fundamental and were fully taken into account. Thus, certain ethical issues had to be addressed. Hence, to carry out this research, permissions from the University Research Ethics Committee (henceforth UREC), Faculty Research Ethics Committee (henceforth FREC) and departments responsible for state, Church and private schools had to be requested beforehand.

3.9.1 Informed Consent

Subsequently, as a high number of potential participants were still minors, consent forms were distributed to their parents/guardians in order to acquire their permission for the students to participate in the research study.

For all permissions to be granted, certain terms and conditions had to be effected. In all consent forms, it was made clear that the data collection process would be anonymous and that no personal information such as names would be collected. Any audio-recordings would be stored, securely and safely in a laptop with a password, and deleted immediately from the laptop's system as soon as the dissertation was printed and submitted. Participants were also told that they were free to withdraw from the study at any time and without presenting any valid reason whatsoever.

3.9.2 Maintaining Confidentiality

One of the most important aspects of confidentiality is anonymity. The names of the participants in this dissertation were never mentioned. In fact, those students who filled in the questionnaires were never asked to write their names. In addition, when analysing the interviews and the focus group, the participants were assigned a letter of the alphabet or a number, for example 'teacher A / student 1'. This was done to shield their identity. Transcriptions and other important documents stored in the laptop were secured with a password and the data collected from the participants would be destroyed upon submission of the dissertation. The researcher believes that it would be a breach of trust and ethics if the data collected publicly revealed a participant's identity.

3.10 Conclusion

This chapter described the data collection methods and gave an overview of the data analysis in order to explain how and in what ways the research study was carried out. The process of triangulation of data collection, whilst showing the mindset of different persons, carved a factual and legitimate dissertation rather than an ideal and theoretical one. In the following chapter, a detailed analysis of the data collected, will be presented.

Chapter 4

Findings, Data Analysis & Discussion

4.1 Introduction

The aim of this chapter is to present the analysis of the data obtained from a number of sources for the purposes of this study. These sources included 165 questionnaires distributed among Sixth Form second year students studying A level Physics across Malta and Gozo. Data was also collected from sixteen questionnaires distributed among teachers of A level Physics across Malta and Gozo, five interviews with A level Physics teachers, four interviews with teachers who taught SEC Physics, and one focus group consisting of Sixth Form second year A level Physics students. The findings portray interesting perspectives of both the students and the teachers towards the theme of this study.

The findings should be put within the context of the research questions of this study, which were the following:

1. What were the distinctive changes introduced in the 2012 SEC Physics syllabus?
2. Is SEC level Physics a good foundation for A level Physics?
3. Is SEC level Mathematics an adequate preparation for A level Physics?
4. What are the correlation coefficients between the grades in SEC Physics, Mathematics and English Language, and A level Physics?

Furthermore, the thematic analysis of the focus group and interview sessions yielded five distinct themes:

1. How are the changes introduced in the 2012 SEC Physics syllabus affecting students who then study A level Physics?
2. The challenges and expectations of students;
3. The relationship between Mathematics and Physics;
4. Language skills and A level Physics and
5. What does the future hold?

4.2 The Participants

In this sub-section, a descriptive overview of the participants involved in this research study is presented.

4.2.1 The Students

A total of 165 Sixth Form second year students who studied A level Physics participated in this study. These were recruited from Malta and Gozo and were presented with the questionnaire found in Appendix 3.

The graph below gives the number of students who took part in this study, showing their gender and school type.

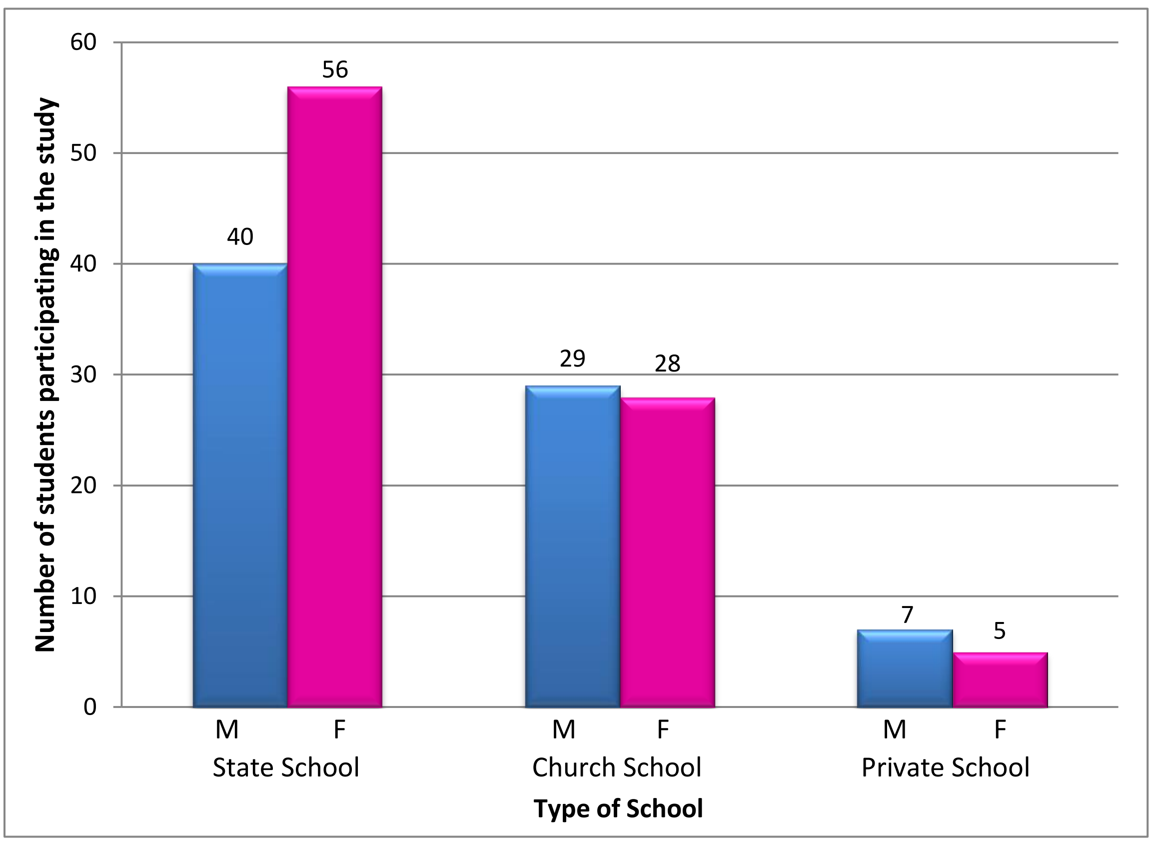

Figure 4.1: Student participants in the study

In their research, Pace and Bonello (2006, p. 42) stated that there was a discrepancy of 2:1 favouring male students who chose to study A level Physics. Since the students in this study were recruited by homogenous purposive sampling, this discrepancy was not noted as only the students who opted to participate in this study did so. This made it difficult for the researcher to identify the gender of the other students who did not participate in this study.

Seven of these participant students were also recruited for a focus group in order to collect more in-depth data which could be integrated with the data from the questionnaires.

As can be observed in the following sections, in the majority of the investigations, the p-value was larger than the 0.05 level of significance. Thus, it can be concluded that, in the majority of the cases, there were no significant differences among students coming from different school types. The researcher believes that since all the students at post-secondary level had achieved a number of passes in their SEC examinations, differences among them decreased and levelled off.

4.2.2 The Teachers

A total of sixteen teachers, who taught A level Physics, also participated in this study. As with the students, they were recruited from both Malta and Gozo. The teachers answered the questionnaire found in Appendix 4.

The graph below shows the number of participating teachers according to gender and school type.

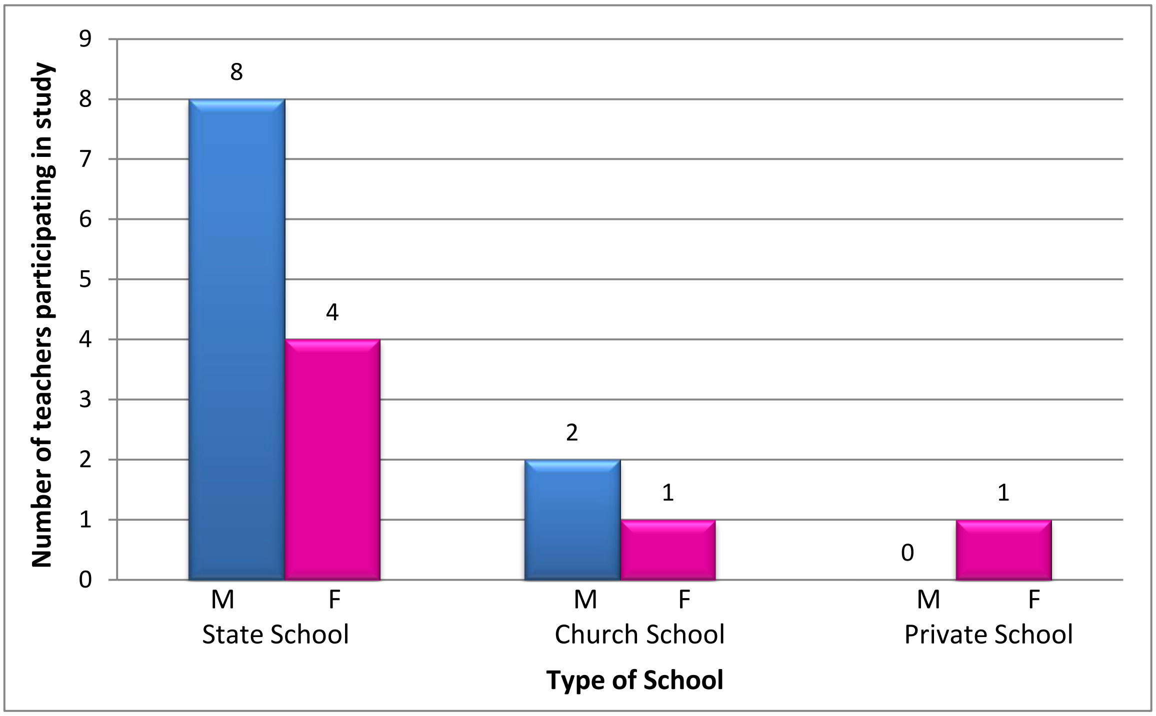

Figure 4.2: A level Physics teachers participating in the study

Five of these teachers together with four SEC Physics teachers were also recruited for an individual interview so that in-depth understanding and knowledge could be collected and integrated with the data from the questionnaires. The four SEC teachers will henceforth be called Teacher A, Teacher B, Teacher C and Teacher D while the five participating A level teachers will be called Teacher E, Teacher F, Teacher G, Teacher H and Teacher I. For the interviews, the teachers were recruited by reputational case sampling therefore it is important to note that teachers A and B were Heads of Department for Physics. They were recruited on the grounds that their comments should be more valuable and informed due to their position. Teacher H in particular had carried out research and published several articles on the research topic, and so the opinions of these teachers were bound to contribute significantly to this study.

4.3 The Effect of the Changes Introduced in the 2012 SEC Physics Syllabus on Students who Study A level Physics?

This section will present views and opinions with regards to the changes in the SEC Physics syllabus and the effects, if any, on A level Physics.

4.3.1 The Changes in the SEC Physics Syllabus

The Physics SEC syllabus underwent several changes between the years 2008 and 2011. "The panel suggested that the current syllabus should remain unchanged for 2011. The new syllabus is to come into effect in 2012" (MATSEC Board, 2008, Section 44.1, para. 4).

First of all, the topics were grouped into themes. These themes enabled students to link similarities between different chapters in a better way. Apart from differences in the format and layout of the syllabus, a new section named 'Historical and Science, Technology, Society (henceforth STS) connections' was introduced alongside the LOs. This was done to give students the opportunity to link and relate physics concepts with everyday situations. In that way, science did not remain an abstract concept but was rightly perceived as the basis of technology in the fields of electricity, Information Technology (henceforth IT), transport, robots, medicine and the building industry, among the many things we take for granted every day.

It also provided a historical background to the research carried out in the field of science to instil in students a better appreciation of the hard work involved in the creation of science for the benefit and convenience of contemporary society.

As can be seen in Appendix 8, several LOs were introduced while others were removed. Some changes can also be observed in the experimental section. The marking weight of the section 'Design and Planning of Experiments' in the written part of the examination, was increased from 15% to 20% (10% in Paper 1 and 10% in Paper 2). Moreover, for the school-based assessment part, students could now opt to present either fifteen experiments, or thirteen experiments and one long investigation. Furthermore, candidates were now expected to present at least two experiments from each theme instead of merely the best fifteen experiments.

During the interviews, both SEC and A level teachers were asked about the changes that were implemented in the 2012 SEC Physics syllabus. In general, this question prompted, more negative than positive responses from the teachers. On the favourable side, Teacher A declared that "the syllabus, as it is now, is more related to real life." This concurs with Caruana, Farrugia and Muscat who stated that the SEC Physics syllabus "aims to introduce students to Physics as a preparation for life" (2009, p. 10).

Teacher C and Teacher D had similar opinions when they stated that with the reduction in the SEC Physics syllabus, teachers had less time constraints and therefore could cover topics in a deeper way.

Teacher F had mixed opinions about this change in the syllabus:

> The change in the SEC Physics syllabus could have helped the students as they are now finding it to be easier. The teacher can now relate the topics more with everyday situations so the students can relate more. However, my concern is that they, for example, associate terminal velocity with a parachute or a fired bullet … and they remain at the association stage … they remain on a superficial level … – Teacher F.

This participant commented further that the current syllabus lacked detail.

> SEC students understand the physics concepts during the lessons. However, when they try to attempt to answer questions, they blank. If we want to teach physics concepts for everyday life, that's fine, let's keep on teaching it this way ... but, if we want the students to know how to answer a question scientifically, including higher order thinking, we need to start teaching the subject in more detail. – Teacher F.

Teacher I similarly stated that,

a great amount of the basic concepts in optics, resonance and waves were removed from the syllabus. Every reduction in the SEC Physics syllabus creates a heavier burden on us because in the very short time we have with the Sixth Form students, we have to teach the concepts that were not learnt at SEC level, correct any misconceptions, and concurrently teach the students the A level syllabus. Every reduction in the SEC Physics syllabus leaves a bigger gap and brings more pressure on the Sixth Form students as the A level Physics syllabus has not been changed or reduced. – Teacher I.

Teacher F agreed with Teacher I by stating that,

Sixth Form students find that there is a very big gap between SEC and A level Physics. SEC Physics is so simple compared to the subject at A level that they get the wrong idea that it is like that and then they may start to drop out ... if they haven't made up their mind that they want to succeed in it. – Teacher I.

Teacher C stated:

Personally, I think that something else could have been done instead of the reduction of some LOs in the SEC Physics syllabus. This could have been tackled by introducing training for SEC Physics teachers in how to deliver the topics in a much more feasible and hands-on way so that it can be easily understood by the students. – Teacher C.

In the focus group, the A level Physics students commented in various ways. Student 2 stated "If I had to change something, I would have gone into more detail in the SEC Physics topics so that those students who opt to study A level Physics would feel better prepared." Student 6 agreed with Student 2 as he would have preferred the 2012 SEC amendments to include much more detail in order for the student to feel more confident when he opts to study A level Physics.

Student 1 suggested that

more hands-on practical tasks and more equations should be added in the SEC Physics syllabus. For example, in the topic of Magnetism, to show the magnetic fields, only the experiment using iron filings was done. This contrasts with the A level as it introduced us to many more equations, some of which, in my opinion, could have been done in the SEC.

In fact, student 5 emphasised that the changes in the 2012 SEC Physics syllabus were so unhelpful that he proposed that those students who choose A level Physics should study it for three years instead of two as the syllabus is extremely vast.

This goes hand in hand with what the A level Physics teachers reported in the questionnaires. The null hypothesis (henceforth H_0) that was tested was whether the A level teachers' views on the helpfulness or otherwise of the changes in the SEC Physics syllabus were independent of their school type. From the results shown in Table 4.1 below, it can be concluded that 62.5% of the A level Physics teachers stated that the changes were not so helpful to the students, while the remaining 37.5% found them to be helpful to the students. The p-value corresponding to the chi-square statistic (henceforth X^2) clearly showed that the teachers' opinions were independent of their school type as the probability value (henceforth p-value), 0.074, exceeded the 0.05 level of significance. This implied that the null hypothesis could not be rejected, and thus there was no significant difference in the opinions of teachers coming from different educational sectors.

			School Type		
			State	Church/ Private	Total
How much do you consider the changes in the SEC Physics syllabus to be helpful for the students?	**Helpful**	Count	6	0	6
		Percentage	50.0%	0.0%	37.5%
	Not so helpful	Count	6	4	10
		Percentage	50.0%	100.0%	62.5%
Total		Count	12	4	16
		Percentage	100.0%	100.0%	100.0%

X^2 (1) = 3.200, p = 0.074

Table 4.1: Teachers' responses with regards to how much they considered the changes in the SEC Physics syllabus to be helpful to the students with respect to school type

Another null hypothesis tested the opinion of the A level Physics teachers on whether the changes in the SEC Physics syllabus were helpful to them during their lessons. This also resulted to be independent of the school type. As shown in Table 4.2, it can be safely deduced that 68.8% of the A level Physics teachers thought that the changes were not so helpful to them while the remaining 31.3% of the teachers found them to be helpful. The p-value corresponding to the chi-square statistic clearly showed that the teachers' opinions were independent of their school type as the p-value, 0.119, exceeded the 0.05 level of significance. This implied that the null hypothesis could not be rejected, and thus there was no discrepancy among the teachers coming from different educational sectors.

			School Type		
			State	Church/ Private	Total
On a personal level as a Physics teacher, how much do you consider the changes in the SEC Physics syllabus to be helpful to you?	**Helpful**	Count	5	0	5
		Percentage	41.7%	0.0%	31.3%
	Not so helpful	Count	7	4	11
		Percentage	58.3%	100.0%	68.8%
Total		Count	12	4	16
		Perentage	100%	100%	100%

X^2 (1) = 2.424, p = 0.119

Table 4.2: Teachers' responses with regards to how much they considered the changes in the SEC Physics syllabus as helpful to them with respect to school type

4.3.1.1 Reasons Behind the Changes in the SEC Physics Syllabus

During the interviews with the SEC Physics teachers, several reasons and opinions were put forward regarding the changes in the SEC Physics syllabus. Teacher A commented:

> I believe that the changes in the SEC Physics syllabus were made so that more students pass the SEC Physics examination. In my opinion, Physics should incorporate mathematical calculations. These were drastically reduced from the SEC Physics syllabus and they are now replaced with questions such as 'explain' or 'list'. I think that this is being done so that more students pass the SEC Physics examination. – Teacher A.

On considering the SEC examinations Statistical Reports from 2010 till 2018, it was evident that approximately the same percentage of students achieved a pass (grade 1 to 7) in the SEC Physics examination from year to year. This is portrayed in the Table 4.3 below:

Year	**Number of students with grades 1–7 in SEC Physics**	**Number of registered students in that particular year**	**Percentage**
2010	2853	3316	86%
2011	2765	3250	85%
2012	2763	3220	86%
2013	2603	3089	84%
2014	2588	3111	83%
2015	2496	3000	83%
2016	2646	3067	86%
2017	2265	2785	81%
2018	2749	2323	84.5%

Table 4.3: Percentage of students who achieved grades 1 to 7 in SEC Physics between 2010 and 2018

Other inputs included:

> Since there are many more subjects being studied by students during the secondary school years, like for instance European Computer Driving Licence (henceforth ECDL) and similar, then there needed to be a balance in the possible content to be taught in our current syllabus. Another reason might have been to ensure there are different aspects of physics that are relevant to our present day life. – Teacher B.

An increased relevance of the SEC Physics syllabus to everyday life was in fact one of the aims of the changes in the 2012 SEC Physics syllabus. This was reported in the minutes of one of the MATSEC board meetings (2006) and also by Caruana, Farrugia & Muscat (2009).

> I believe that such topics were removed from the SEC Physics syllabus after reviewing the lack of students' performance in them along the years. Having said that, to conclude if I agree with the changes, I need to know how the decision was taken ... Was the decision made after a great deal of trials to improve the situation? Or was it made on the students' lack of performance in the subject? Or maybe a fine line between the two? We need to consider other countries, especially the UK, as well. Have these topics been removed from the Physics syllabi of these countries? – Teacher C.

What Teacher C stated has been discussed in the Literature Review of this study. Table 2.1 shows the LOs added to the 2012 SEC Physics syllabus which were not found in two foreign GCSE Physics syllabi, namely, the AQA and Pearson Edexcel. On the other hand, Table 2.2 shows the LOs which were deleted from the 2012 SEC Physics syllabus and are still present in one or both of the two British syllabi.

"There were still some topics that were considered hard by the students, and were not practical for their future life." – Teacher D.

4.3.2 The Relationship between SEC Physics and A level Physics

Both the students and the teachers were asked whether the SEC Physics syllabus provided students with a good foundation for A level Physics. Table 4.4 shows the students' responses while Table 4.5 shows the teachers' responses. The null hypothesis was tested via a chi-square test to investigate whether the opinions of students/teachers were independent of their school type. Since the p-value corresponding to the chi-square statistic for both crosstabs exceeded the 0.05 level of significance, it was concluded that the opinions given by both students and teachers were independent of the school type. This indicated that the null hypothesis could not be rejected, and thus there was no significant discrepancy among the opinions of students and teachers coming from different educational sectors.

When comparing Table 4.4 with Table 4.5, one notes that 15.8% of the Sixth Form second year Physics students considered SEC Physics as being a very good foundation for the subject at A level while only 12.5% of the teachers shared that view. A staggering 55.8% of the student population believed that SEC Physics provided a good basis for A level Physics while only 37.5% of the teacher population concurred with this. As many as 26.1% of the students and 50.0% of the teachers considered SEC Physics as not being such a good foundation for the subject at A level. It can be noted that this is the second highest percentage in the students' crosstab and the highest percentage in the teachers' crosstab. Only 2.4% of the students thought that the groundwork provided by SEC Physics was not good at all. The category 'not good at all' in the teachers' crosstab is not shown as this was not chosen by any teacher.

			School Type			
			State	Church	Private	Total
Do you consider that SEC level Physics is a good foundation for A level Physics?	**Very good**	Count	21	3	2	26
		Percentage	21.9%	5.3%	16.7%	15.8%
	Good	Count	54	33	5	92
		Percentage	56.3%	57.9%	41.7%	55.8%
	Not so good	Count	18	20	5	43
		Percentage	18.8%	35.1%	41.7%	26.1%
	Not good at all	Count	3	1	0	4
		Percentage	3.1%	1.8%	0.0%	2.4%
Total		Count	96	57	12	165
		Percentage	100%	100%	100%	100%

$X^2(6) = 12.212$, $p = 0.057$

Table 4.4: Students' responses on whether they considered the SEC Physics syllabus as a good foundation for A level Physics

			School Type		
			State	Church/ Private	Total
Do you think that SEC Physics gives students a good foundation for A level Physics?	**Very good**	Count	2	0	2
		Percentage	16.7%	0.0%	12.5%
	Good	Count	5	1	6
		Percentage	41.7%	25.0%	37.5%
	Not so good	Count	5	3	8
		Percentage	41.7%	75.0%	50.0%
Total		Count	12	4	16
		Percentage	100%	100%	100%

$X^2(2) = 2.286$, $p = 0.319$

Table 4.5: Teachers' responses on whether they considered the SEC Physics syllabus a good foundation for A level Physics

Teachers A and B gave a score identical to the highest percentage given by the students, but this was not the same as the highest percentage given by the A level teachers.

> To prepare the students better for the A level Physics syllabus, there are certain topics that could be explained better in the SEC syllabus such as radioactivity and electrostatics. However, yes, overall, I believe that the SEC syllabus gives the students a good basic preparation for the A level Physics syllabus. – Teacher A

> If the student takes the subject seriously and prepares well for SEC, then there is a good foundation for A level. The pedagogy used in class would be important in that the skills passed on to the student need to form a critical mind able to analyse physical concepts adequately. The syllabus emphasises the basic physical concepts and principles. – Teacher B

The majority of the A level teachers' responses contrast with the report published by the UK Qualifications and Curriculum Authority which states that the GCSE syllabus gives a good preparation for A level Physics. However, they go hand in hand with the local research carried out by Caruana and Muscat who, in 2006, reported that the SEC Physics syllabus did not prepare the students thoroughly to further their knowledge in the subject.

Moreover, considering the present researcher's seven-year interval between SEC Physics examination (2008) and her first year of teaching (2015), she feels that the SEC Physics syllabus has been reduced drastically in recent years (since 2012). As can be shown in Appendix 8, this observation applies with regards to physics concepts, theories and laws and especially mathematical problems. These reductions do not reflect the views of Caruana and Muscat (2006), who suggested that "the level of the SEC Physics syllabus should be enhanced, such that it is not too superficial and so straightforward" (p. 74).

One can note that during this seven-year period, only very slight changes were made to the A level Physics syllabus. The researcher believes that drastically reducing one syllabus and leaving the other almost intact ultimately imposes a burden which, needless to say, needs to be carried by A level students and their teachers.

This opinion, however, was contradicted by the responses in the student questionnaire as 55.8% of the sample stated that SEC Physics gave them a good foundation for A level. However, the in-depth responses given during the focus group, as reported in Section 4.3.3.1, show that the students had a very hard time studying the subject, especially during the first Sixth Form year. Since the question requested a Likert Scale response, the term 'good' may have been interpreted by the students as meaning that the foundation given by SEC Physics was better than average. One possible explanation for this relatively high percentage, 55.8%, could be that the respondents may not have been familiar with the pre- 2012 SEC Physics syllabus. Therefore, they could not make comparisons.

Another question dealt with whether students and teachers thought that there was a continuation between the topics covered in SEC Physics and those in A level

Physics. Table 4.6 shows the students' responses. The majority of the students, 63.6%, stated that A level Physics was a continuation of what they had studied at SEC level Physics, but harder. The p-value of the chi-square statistic resulted to be 0.740, thus showing that the students' opinions were independent of the school type.

			School Type			
			State	Church	Private	Total
When studying A level Physics, do you consider it to be:	**A continuation of what you studied in SEC Level Physics, but harder**	Count	63	34	8	105
		Percentage	65.6%	59.6%	66.7%	63.6%
	Completely different from the SEC Level	Count	33	23	4	60
		Percentage	34.4%	40.4%	33.3%	36.4%
Total		Count	96	57	12	165
		Percentage	100.0%	100.0%	100.0%	100.0%

$X^2(2) = 0.603$, $p = 0.740$

Table 4.6: Students' responses with regards to continuity between the SEC and A level Physics syllabi

The majority of the students' responses corresponded with the majority of the teachers' responses in the following crosstab, since 81.3% of teachers considered that there was continuity between SEC and A level Physics. The p-value of this chi-square test, 0.712, also showed that the teachers' responses were independent of their school type.

			School Type		
			State	Church/ Private	Total
Do you consider A level Physics to be:	**A continuation of Physics at SEC Level, but harder**	Count	10	3	13
		Percentage	83.3%	75.0%	81.3%
	Completely different from the SEC Level	Count	2	1	3
		Percentage	16.7%	25.0%	18.8%
Total		Count	12	4	16
		Percentage	100%	100%	100%

$X^2(1) = 0.137$, $p = 0.712$

Table 4.7: Teachers' responses with regards to continuity between the SEC and A level Physics syllabi

During the focus group, student 1 concurred with these results and stated:

> There is continuity for sure. In A level, we are covering the same topics we covered during SEC. Obviously, the only difference is the amount of detail in the topic. Let's take Magnetism as an example. In SEC, we learnt about the basic concepts of magnets such as domains and magnetic fields. In A level, we are introduced to more types of magnetic fields and even equations. – Student 1.

Student 6 further agreed by stating that their A level teacher starts every topic with a lesson or two briefly revising the SEC content to brush up the concepts learnt in SEC thus enhancing the continuation between SEC and A level Physics.

Teacher F offered this view:

> There is continuity. Students studying A level know the basic information of every topic. However, in my opinion, there is a great deal of information and knowledge that the students need to know from SEC to A level. The topics in A level are much more challenging! – Teacher F.

Teacher G expressed mixed feelings with regards to this question:

> SEC Physics is an introduction to the topics at A level. The students know the SEC topics - however, when, we go in depth at A level, they start to consider it as a totally different subject. Those students who covered the SEC topics really well

are able to get good grades in A level. However, those students who covered the SEC topics superficially find the A level topics as ambiguous. – Teacher G.

In this study another question was put forward whereby the students were asked if they considered A level Physics syllabus 'completely different', 'slightly different' or 'not so different' from that of SEC level Physics. Table 4.8 shows that most students, 55.2%, considered the A level Physics syllabus to be 'slightly different' from SEC level Physics. It is imperative to observe that the percentage of students coming from Church schools, 61.4%, in the 'slightly different' category surpassed the percentages of students coming from state and private schools (51.0% and 58.3% respectively). Having said that, the p-value of this chi-square test (p = 0.340) showed that the students' responses were independent of their particular school type.

The result of Table 4.8 further confirms that the majority of teachers and students observed continuity between SEC level Physics and A level Physics syllabi as shown in Tables 4.6 and 4.7.

			School Type			
			State	Church	Private	Total
How different do you consider A level Physics from SEC Level Physics?	**Completely different**	County	43	22	4	69
		Percentage	44.8%	38.6%	33.3%	41.8%
	Slightly different	Count	49	35	7	91
		Percentage	51.0%	61.4%	58.3%	55.2%
	Not so different	Count	4	0	1	5
		Percentage	4.2%	0.0%	8.3%	3.0%
Total		Count	96	57	12	165
		Percentage	100%	100%	100%	100%

$X^2(4) = 4.521$, $p = 0.340$

Table 4.8: Students' responses when comparing the SEC and A level Physics syllabi

In order to compare these responses with the actual achievement of the respondents, the researcher considered the 2015 SEC Physics and the 2017 A level Physics grades obtained by the same cohort of students. According to Coe (1999), the way students perform in their GCSE examinations is the best predictor of their achievement in their A level examination. The results of this comparison are presented and analysed in Table 4.9 below. According to the Matriculation Certificate Examinations 2017 Statistical Report published by the MATSEC office, the total number of students who sat for the three SEC subjects that feature in this study, namely, Physics, Mathematics and English Language, and who again sat for A level Physics in 2017, was 252. To bring out the relationship between the SEC Physics grades and the A level Physics grades shown in Table 4.9, students recorded as absent in any of these three subjects were eliminated from this study.

			Physics A level grade						
			A	B	C	D	E	F	Total
Physics SEC level grade	**1**	Count	13	14	18	1	1	0	47
		Percentage	5.2%	5.6%	7.1%	0.4%	0.4%	0.0%	18.7%
	2	Count	6	25	41	18	2	1	93
		Percentage	2.4%	9.9%	16.3%	7.1%	0.8%	0.4%	36.9%
	3	Count	2	12	25	24	13	6	82
		Percentage	0.8%	4.8%	9.9%	9.5%	5.2%	2.4%	32.5%
	4	Count	0	0	5	10	5	4	24
		Percentage	0.0%	0.0%	2.0%	4.0%	2.0%	1.6%	9.5%
	5	Count	0	0	0	0	2	3	5
		Percentage	0.0%	0.0%	0.0%	0.0%	0.8%	1.2%	2.0%
	6, 7 or U	Count	0	0	0	0	0	1	1
		Percentage	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.4%
Total		Count	21	51	89	53	23	15	252
		Percentage	8.3%	20.2%	35.3%	21.0%	9.1%	6.0%	100.0%

$X^2(25) = 133.235, p < 0.001$

Table 4.9: 2015 SEC Physics grades and 2017 A level Physics grades obtained by the same cohort of students

The results of this test showed that there is a statistically significant relationship between the grade obtained for SEC Physics and the eventual A level Physics grade since the p-value was less than the 0.05 level of significance. There is very strong evidence to reject the null hypothesis, thus assuming a relationship between the variables. This indicates that the students who did well in the SEC examinations tend to perform well in the A level Physics examination. This result can be generalised because it is not attributed to chance. It should also be noted that the chi-square test statistic of 133.235 is very large, which indicates a strong relationship between SEC Physics and A level Physics grades. Pertinently, the University of Malta Junior College Physics Department's guidelines for prospective students advise that to succeed in A level Physics, a student should have achieved a grade 3 or better.

It must also be noted that the Spearman Rank Correlation Coefficient (henceforth r), between the 2015 SEC Physics grades and the 2017 A level Physics grades is 0.544. According to Gilchrist and Samuels (Birmingham City University, n.d.), this is considered as a strong correlation. This correlation coefficient can be compared to the correlation coefficient reported in the research studies by Ventura (2001), Pace and Bonello (2006), Farrugia and Ventura (2007) and Sutch (2013), as shown in Table 2.5.

In Table 4.9, one can also infer that a relatively low 42% of the students who achieved a grade 1 in their SEC Physics examination achieved a grade C or lower in their A level Physics examination. It must be noted that this percentage of students was only 30% when Ventura and Farrugia (2007) tested the cohort of students who took the 2004 SEC examination and the 2006 A level examination. This does not concur with the UK research published by Ofqual's Strategy, Risk and Research Directorate (2017), whichs reported that over 50% of the students who achieved a grade A in GCSE Physics, achieved a grade C or lower in their A level Physics.

Another observation that can be made is that the most common grade in SEC Physics is 2 while that in A level Physics is C. In addition, one should also note the almost perfect symmetrical distribution of the A level Physics grades, shown in Figure 4.3 below. The standard deviation of this distribution is 11.13 while the skewness is 0.956, showing that the distribution is slightly skewed to the right but very close to having zero skewness like the normal distribution.

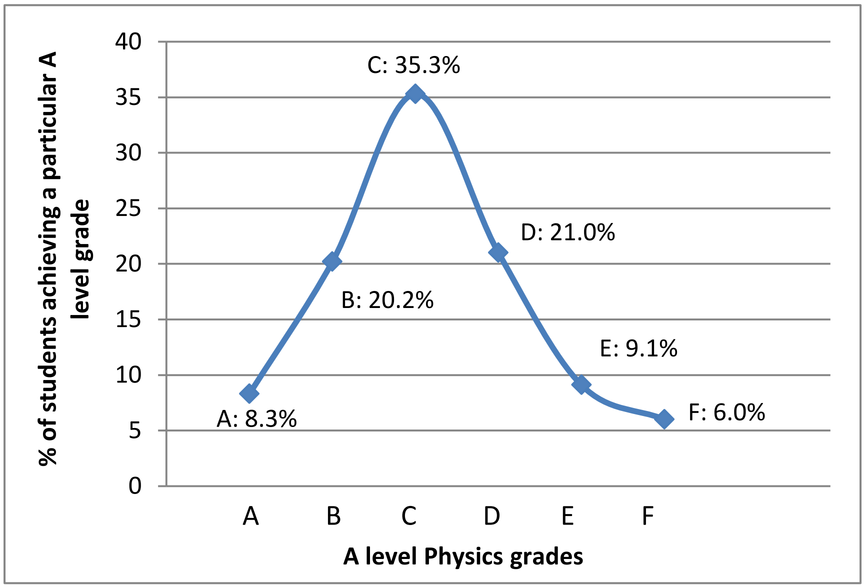

Figure 4.3: Distribution of the 2017 A level Physics grades

On the other hand, the curve in Figure 4.4 shows the distribution of the 2015 SEC Physics grades. It does not reflect a normal distribution, since it shows that there were significantly more students who achieved grades 1, 2 and 3 than grades 4, 5, 6, 7 and U (fail). It is also important to keep in mind that the SEC cohort includes a wide distribution of students in terms of ability, as Physics is still compulsory (although not formally so) in many schools, while the A level distribution of grades concerns students who voluntarily chose Physics as an A level subject and thus they probably considered themselves to be good at the subject.

When comparing Figure 4.3 with Figure 4.4, one can observe that there is a rapid decrease between the percentages of students achieving SEC Physics grades 1, 2 and 3 (a total of 88.1%) and A level Physics grades A, B and C (a total of 63.8%). Therefore, the question of whether the 2012 SEC syllabus is actually preparing the students well for A level Physics arises again. It could be the case that A level Physics students are not prepared as much as they think they are. In fact, during the focus group, student 6 stated that

> Physics topics in the SEC syllabus were covered superficially, that is, not in a lot of detail. Personally, as a student, I was not even 100% sure of certain concepts. So, I think that A level students will greatly benefit if these topics are taught and presented in more detail. – Student 6.

Student 2 believed that “the preparation between SEC Physics and A level Physics is very basic. Thus, if SEC Physics teachers go into some more detail, we would be better prepared for A level Physics.”

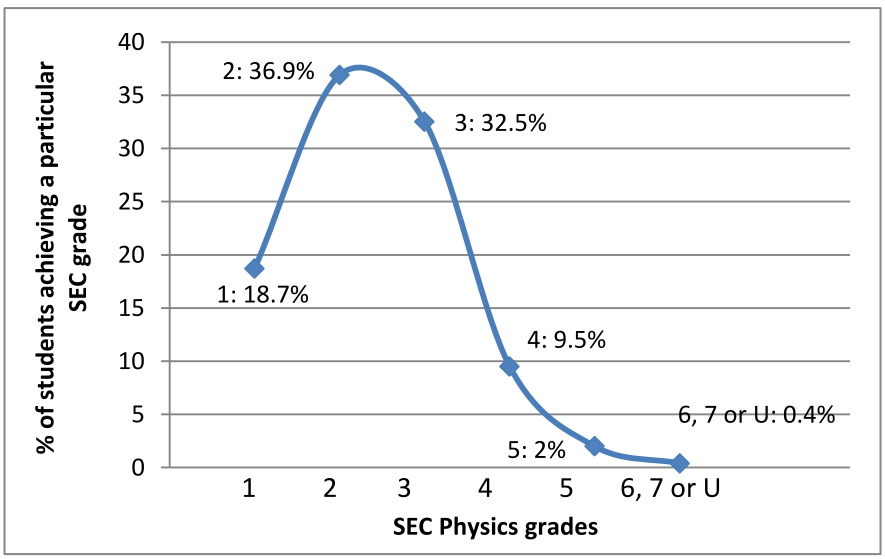

Figure 4.4: Distribution of the 2015 SEC Physics grades

The final conclusion that can be drawn from this relationship is that 95.7% of the students who obtained grade 1 in their SEC Physics examination obtained grades A to C in their A level Physics examination. This percentage is followed by that of 77.4%, representing the students who obtained a grade 2, and 47.5%, which stands for those who obtained a grade 3 who managed to achieve grades A to C in their A level Physics examination. It may also be noted that the majority of students who obtained grades A to C in their A level Physics examination had obtained grades 1 and 2 in their SEC Physics examination.

This could be compared with the data for the cohort of students studied by Farrugia and Ventura (2007). The students who obtained a grade 3 in their cohort differ from the students who obtained a grade 3 in this study; in contrast with their study's 68.0%, in this study only 47.6% of the students who obtained a grade 3 in SEC Physics obtained grades A to C in their A level Physics. A significant decrease in performance at A level was observed in the case of students who achieved a grade 4 or lower in their SEC Physics examination: only 16.7% of these students achieved grades A to C in A level Physics. This confirmed Farrugia and Ventura 's (2007, p. 23) conclusion: "candidates with a Grade 4 at SEC level are unlikely to achieve high grades at Advanced level… Furthermore, a Grade 5 obtained at SEC level seems to provide insufficient foundation for successful study at the higher level." In fact, Table 4.9 shows that 40% of the students who achieved Grade 5 in their SEC Physics examination, only managed to obtain Grade E in their A level Physics as their best mark.

In order to analyse further the transition between SEC and A level Physics, the students were asked to list at least three topics in A level Physics which, in their opinion, do not have a good preparation at SEC Level. The results were plotted in Figure 4.5. The researcher noticed that several students, 28.8%, did not answer this question – in fact, the total number of topics listed by the students was 352 instead of the 495 expected. The percentages were worked out of the total number of responses.

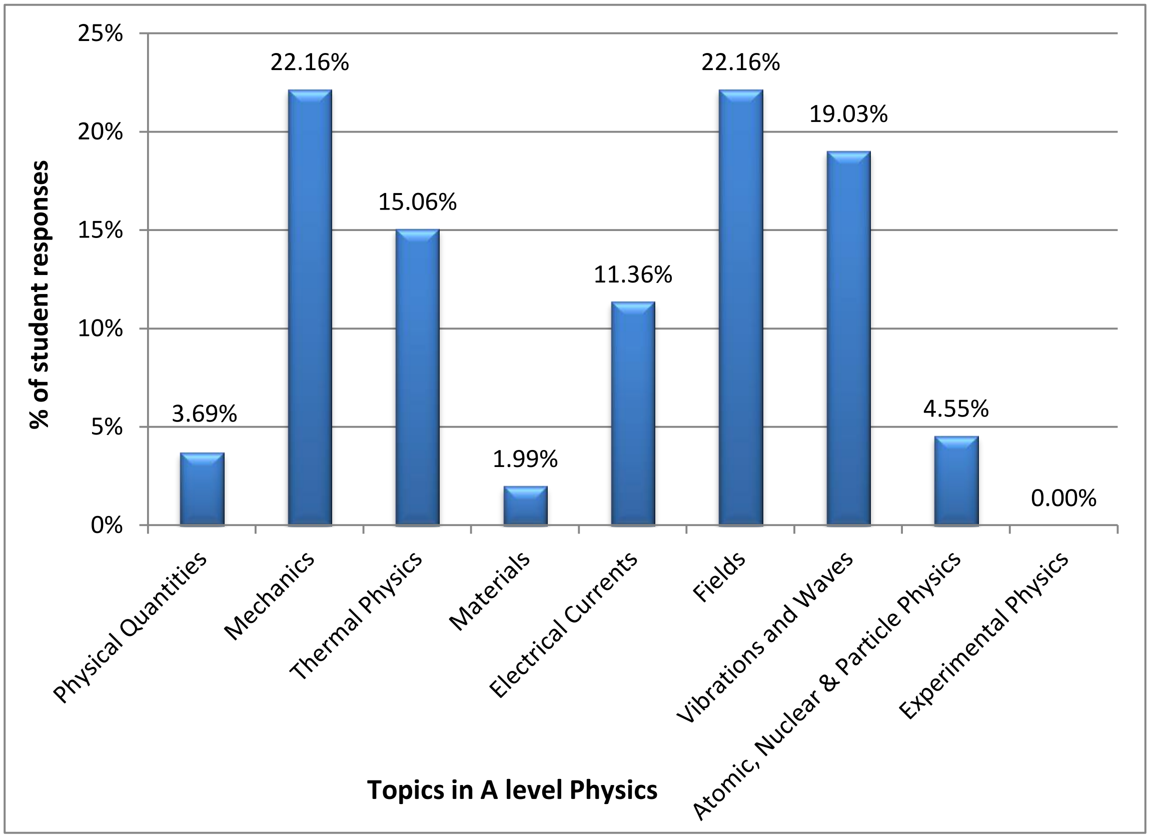

Figure 4.5: Student responses with regards to the topics which did not have a good preparation at SEC level

As can be shown in the graph above (Figure 4.5), the top topics which the students felt were insufficiently prepared at SEC level were: Mechanics (22.16%), Fields (22.16%) and Vibrations and Waves (19.03%). The students explained that their main difficulties were encountered in the sub-topics of: (i) Mechanics: Circular Motion and Rotational Dynamics, (ii) Fields: Electrical and Gravitational Fields; and (iii) Vibrations and Waves: Waves.

It is critical to note that these topics, perceived by students as insufficiently covered at SEC level, are first taught at A level. This contradicts Farrugia, Caruana and Muscat's (2009) claim that "Students felt best prepared in Mechanics and least prepared in Fields and Nuclear and Particle Physics." At first, the researcher thought that these contradictory opinions occurred because of the reduction of some LOs in the SEC Physics syllabus in 2012. However, a close look at the changes in the LOs in Appendix 8, would reveal that this could not be the case. This is because there were no significant changes in the SEC Physics syllabus with regards to the LOs dealing with the sub-topics of the topic of Mechanics in the A level Physics syllabus.

Combining the data represented in Figure 4.5 with what was discussed with regards to the continuity between SEC and A level Physics, during the interview Teacher I stated:

> Yes, there is continuity between the topics of SEC and A level. You are elaborating on what you started at SEC level; however, in my opinion, there are huge gaps. For example, Mechanics, Gravitational Fields, Interference and Projectile Motion, among others, are not mentioned at SEC and thus have no background whatsoever. – Teacher I.

4.3.3 A level Physics

Unlike in the case of SEC Physics, all the teachers agreed that A level Physics offers students a good preparation if they wish to pursue a physics course at university level. One opinion came from Teacher I: "the A level Physics syllabus has enough detail and is complex enough for those students who wish to continue their studies in physics at university level." According to the teachers views, this transition would not create as much turbulence as in the case of that between SEC and A level.

4.3.3.1 Students' Reaction to the Transition from SEC to A level Physics

The following were the Sixth Form students' reactions to their transition from SEC Physics course to that of A level. These clearly corroborate Cohen and Smerdon's (2009) findings that show that the transition from secondary to post-secondary could bring about lower self-confidence and increased anxiety.

"I chose A level Physics because I used to like it at SEC Level and achieved a good grade. So, I thought that the experience would be quite plain sailing… however, these two years have been a roller-coaster ride." – Student 5.

"Too much work … a great deal of confusion during the first year!" – Student 4

> If it was up to me, I would have changed the subject after the first six months of the first year. However, my parents convinced me to study hard, give it my best shot and decide later. Now, I am glad that I took their advice. – Student 2.

Obviously unaware of the students' input during their focus group, Teacher F stated:

> We might be giving the impression that SEC Physics is easy. In the SEC examinations … higher-order questions are very scarce. Because of this fact, students are achieving a good grade in SEC Physics and believe that they are capable to study it at A level. However, during the lesson, I notice several weaknesses and gaps in their scientific concepts which make it quite difficult for them to keep up with the A level syllabus. At A level, we need a certain level of English, a certain level of Mathematics, a certain level of higher-order thinking which, unfortunately, are not being taught at SEC neither with the old nor with the new syllabus. – Teacher F.

According to Teacher D, the problem was that "most of the students take physics as a science subject. The Intermediate level is also very simple, in my opinion ... there is also a huge gap between Intermediate and A level."

4.3.3.2 Examinations

During the focus group with the Sixth Form students, the majority of the participants commented about the A level Physics examination:

"The examination questions are too awkward. Sometimes, to understand the question, I had to read it more than three times." – Student 2.

"The wording of the question is not straight to the point." – Student 6.

> The language used in the questions is very difficult. Since the questions are very lengthy, I find it best to note down the important points next to the question to summarise it. This wastes a lot of my time during the examination! – Student 5

"I truly believe that these questions are written in such a manner to hinder the students in their examination." – Student 3.

> Apart from the difficult language used in the writing of the question, we, as students, need to assume certain things, for example: that the situation is being considered at room temperature and pressure. Sometimes, even our teacher has doubts! These should be made clear in the question as such uncertainties increase our stress, anxiety and pressure during the examination! – Student 6.

During the interviews, the A level Physics teachers commented as follows:

> The way some questions are written makes you wonder what is behind the examiners' thoughts. Sometimes, even I encounter some difficulties. Besides, some A level questions have mathematical mistakes. For example: May 2018 was full of mistakes! The majority of the students do not notice, but bright students notice immediately and this definitely hinders the students' progression in the examination. It is not fair on the students who have worked hard to achieve a good grade in the subject! - Teacher G.

> The A level Physics examination is extremely tough! Students are given three hours to work it out under examination conditions. I have been teaching A level Physics for a number of years now, and I still take three whole hours to work it on my own, not under examination conditions … Sometimes, I have to read the questions four times because the questions are very confusing. – Teacher H.

> There are a number of assumptions that are based on questions done previously. So, when the question is slightly modified, the assumption needs to be modified as well. It is then that the students are confused. This is a problem for us … let alone for the students! Students find the first few past papers we work out very difficult… until we set the ball rolling – Teacher E.

> The students find the way the questions are written in the A level Physics examination as very difficult. Sometimes, examiners try to test the students in what they do not know instead of in what they know. I certainly do not agree with this. I think that the boundaries of the syllabus need to be respected more. – Teacher I.

4.4 The Challenges and Expectations of Students

Times change and so do students. This section presents the opinions, ideas and expectations of the students and the teachers, the difficulties and challenges that students encounter and the subject choice for their future career.

4.4.1 Opinions, Ideas and Expectations

In order to break the ice with the students during the focus group, the researcher asked them about their transition from secondary to post-secondary. Their comments are presented below.

"It was quite a rocky transition. The first month was shocking … everything was different. It took me one whole year to settle down completely. There is a huge difference between the secondary and the post-secondary years." – Student 5.

"I was not prepared for this transition." – Student 2.

"It was challenging … even the way the teachers teach … in our secondary years, we were more spoon-fed." – Student 1.

"The progression of the lesson … and even of the syllabus, is very fast! If you understood, well and good … if you did not, it's up to you …" – Student 7.

To compare their answers, students and teachers were asked about the transition from secondary to post-secondary. It is interesting to note the students' perceptions are presented both with regards to gender (Table 4.10) and the type of school (Table 4.11). Both crosstabs show that the majority of the students found the transition from secondary to post-secondary a challenging one.

			Gender		
			Male	Female	Total
Looking back at your transition from secondary to post-secondary, do you consider it to be:	**Smooth**	Count	28	33	61
		Percentage	36.8%	37.1%	37.0%
	Challenging	Count	48	56	104
		Percentage	63.2%	62.9%	63.0%
Total		Count	76	89	165
		Percentage	100.0%	100.0%	100.0%

$X^2(1) = 0.001, p = 0.975$

Table 4.10: Student responses on their transition from secondary to post-secondary with respect to their gender

In Table 4.10, it was interesting to note that there was minimal difference between males and females on their perception of the transition from secondary to post-secondary as the percentages were very close to each other. Moreover, the p-value of the chi-square test (p = 0.975) showed that the students' responses were independent of their gender.

			School Type			
			State	Church	Private	Total
Looking back at your transition from secondary to post-secondary, do you consider it to be:	**Smooth**	Count	40	19	2	61
		Percentage	41.7%	33.3%	16.7%	37.0%
	Challenging	Count	56	38	10	104
		Percentage	58.3%	66.7%	83.3%	63.0%
Total		Count	96	57	12	165
		Percentage	100.0%	100.0%	100.0%	100.0%

$X^2(2) = 3.355, p = 0.187$

Table 4.11: Student responses on their transition from secondary to post-secondary with respect to school type

Table 4.11 shows that the majority of the students, 63.0%, found that the transition from secondary to post-secondary was challenging. The highest percentage, 83.3%, of such students attended private schools. These were followed by Church school students, 66.7%, while the lowest percentage, 58.3%, was scored by state school students. These responses resulted to be independent of the particular type of school as the p-value of this chi-square test was 0.187, which exceeded the 0.05 level of significance.

Table 4.12 shows the teachers' perceptions of the transition from secondary to post-secondary. Most teachers, 81.3%, stated that the transition was challenging. It is interesting to compare the percentage of the responses by the teachers with those of the students. The highest percentage of teachers, 100%, who believed that the transition was challenging came from Church and private schools. However, the p-value of the chi-square test, p = 0.267, again showed that the teachers' responses were independent of their particular school type.

			School Type		
			State	Church/ Private	Total
Do you think that the transition from secondary to post-secondary of the majority of the students you teach is:	**Smooth**	Count	3	0	3
		Percentage	25.0%	0.0%	18.8%
	Challenging	Count	9	4	13
		Percentage	75.0%	100.0%	81.3%
Total		Count	12	4	16
		Percentage	100.0%	100.0%	100.0%

$X^2(1) = 1.231, p = 0.267$

Table 4.12: Teachers' responses on the students' transition from secondary to post-secondary with respect to school type

Tables 4.10, 4.11 and 4.12 affirm what Mizelle (2003), Letrello & Miles (2003), Erickson et al. (2013), Oakes and Waite (2009) and Cohen and Smerdon (2009) found in their research, namely, that the transition between secondary to post-secondary school could be rather challenging due to the changes involved, both cognitive and social.

To further investigate this transition, another question was put forward. The teachers were asked about changes in the extent and mode of preparation of students for the A level Physics syllabus before and after the changes were introduced in the 2012 SEC Physics syllabus. Table 4.13 shows that 56.3% of the teachers believed that students were being prepared on the same level while 43.8% of the teachers stated that students were being less prepared. There is no decisive result in these responses since the percentages are relatively close. It is important to note that in the questionnaire, teachers had the option to choose 'more prepared'. However, since none of the teachers chose this option, this category was eliminated so as not to have a row full of zero counts in the contingency table. This yielded a two by two contingency table. The p-value of the chi-square test below, $p = 0.771$, showed that the teachers' responses were independent of their particular school type.

			School Type		
			State	Church/ Private	Total
By comparing the students with the ones you used to teach before the 2012 changes (in the SEC Physics syllabus), how are your present students being prepared to study A level Physics?	**The same**	Count	7	2	9
		Percentage	58.3%	50.0%	56.3%
	Less prepared	Count	5	2	7
		Percentage	41.7%	50.0%	43.8%
Total		Count	12	4	16
		Percentage	100.0%	100.0%	100.0%

$X^2(1) = 0.085$, $p = 0.771$

Table 4.13: Teachers' responses on present students' preparation when compared to those before the 2012 changes in the SEC Physics syllabus

The following are the teachers' responses to the same question during the interviews:

> The difference in the preparation is not because the students were better prepared or were more intelligent but because their thinking was more mature. They did not have the same distractions they have today. They did not have the same access to information as they have today. Also, the SEC examinations were more difficult than they are today. In my opinion, today's generation is more pampered, more fragile and more spoon-fed. – Teacher I.

> The students are more relaxed than in the past. In their secondary years, they are assessed in a way that if the students study the day before the examination, they get good grades. They try to adopt the same attitude in the A level subjects. When they do so, students achieve low grades or even do not pass. Sometimes, students do not pass and they are still relaxed! – Teacher F.

"I don't think it comes from the type of preparation during the SEC lessons. In my opinion, the students have changed for the worse. There are so many distractions which are far more interesting than Physics." – Teacher E.

> When one decides to study A level Physics, it is expected that the student sets out as an independent learner up to a certain extent and raise his/her understanding of the subject accordingly. This implies that any upskilling on new material needs coverage by the student him/herself as part of the coursework. – Teacher B.

The A level teachers reported that they felt frustrated when these expectations were not met by the students.

> They think that they know Physics because they know the topics of the SEC syllabus. Some students even resist new information. So they are weak in their scientific writing and mathematical thinking. For example, in resolution of vectors, there are still students who use the method of the triangle even after I teach them how to solve vectors using r cos theta and r sin theta. Once problems with five different forces start to crop up, it is impossible to use the method of the triangle for all the different forces. So, those students fall behind. – Teacher F.

> I always insist on drawing a diagram for every question so that the students are able to visualise and thus understand the problem better … this always falls on deaf ears. If the problem requires only one equation, the students will manage without a diagram. But if the problem requires the use of two or more equations, it becomes complicated and difficult to understand without the use of a diagram. - Teacher E.

"Attention span is very low … sometimes they do not read the question properly." – Teacher H.

4.4.2 Student Difficulties

During their focus group, the students put forward their concerns with regards to their difficulties while studying A level Physics.

> I find that the majority of the topics are not linked together. There is no link, not only between different topics but also between sub-topics. I find it extremely stressful and tiring that we do something new every lesson. Even when I study, I do not know how I should link things together. – Student 1

"I find the ways of applying the laws to a particular situation rather challenging. To do this, I need to know the laws extremely well." – Student 6.

Other frustrations put forward by the students concerned: (i) the time allotted for the A level Physics examination; (ii) the way questions are presented in the examination; and (iii) the lack of resources in their preparation for the examination.

> My biggest fear is the time allotted for the examination. Many students do not manage to answer all the questions in the given amount of time. Students need to be extremely quick to apply their knowledge to a very complicated question. – Student 2

"The questions are too complicated and not written straight to the point. Sometimes, we even have to assume certain things. I don't think this is fair on us, given that we are already stressed and under examination conditions." – Student 5.

"The fact that MATSEC never publishes the marking scheme of previous examinations leaves us in the dark as to how and in what depth we should answer the questions." – Student 4.

The responses given by the students during the focus group go hand in hand with what teachers G, H, E and I stated during the interviews, as presented in section 4.3.3.2.

A similar question was posed to Sixth Form students (Table 4.14) and teachers (Table 4.15) in the questionnaires, and they were given the option to mark more than one response. Table 4.14 shows the students' difficulties according to the particular school type. There were 314 responses in total. The percentages of the different school types were worked out of the total number of students while the total percentages (in the last column) in Table 4.14 were worked out of the total number of responses i.e. 314.

			School Type			
			State	Church	Private	Total
Are your difficulties in A level Physics characterised by:	**Discontinuity between what you learnt in SEC and A level Physics**	Count	38	21	4	63
		Percentage	41.3%	37.5%	33.3%	20.1%
	Understanding physics concepts, theories and laws	Count	49	39	6	94
		Percentage	53.3%	69.6%	50.0%	29.9%
	Confusion about the meaning of symbols and symbolic equations	Count	27	15	7	49
		Percentage	29.3%	26.8%	58.3%	15.6%
	Applying mathematical skills to solve physics problems	Count	24	9	0	33
		Percentage	26.1%	16.1%	0.0%	10.5%
	Language difficulties in expressing yourself properly	Count	36	12	4	52
		Percentage	39.1%	21.4%	33.3%	16.6%
	Other	Count	4	14	5	23
		Percentage	4.3%	25.0%	41.7%	7.32%
Total Number of Students			92	56	12	160
Total Number of Responses			178	110	26	314

$X^2(10) = 28.847$, $p = 0.001$

Table 4.14: Students' difficulties with respect to their particular school type

Since the p-value corresponding to the chi-square statistic in Table 4.14 is 0.001, one can conclude that there was a significant association between the characteristics of the difficulties faced by students and their respective school type.

Out of the six options provided, the highest percentage of students, 29.9%, admitted that their main difficulty during the A level Physics examination was to understand physics concepts, theories and laws. As many as 69.6% of this percentage of respondents were Church school students, followed by those coming from state schools at 53.3%, and private schools at 50.0%. After looking at the percentage of responses according to the type of school, it was concluded that there was a very low discrepancy among them. The high percentage that this difficulty attracted from students in the three types of schools was expected as, after all, most of the content in Physics revolves around concepts, theories and laws.

It is also interesting to note yet another conspicuously high percentage. This represents the majority of students coming from a private school, 58.3%, who found the meaning of symbols and symbolic equations rather confusing. In his research, Torigoe (2008) also mentioned that working with symbolic equations proves to be one of the main difficulties that students encounter. This percentage was followed by 29.3% of state school respondents and 26.8% of their Church school peers who share the same view. The researcher found the difference among the three types of schools rather 'interesting': one also needs to factor in the fact that the number of private school respondents was low compared to the other two groups, and this might skew the percentage outcome with the displacement of a few – even one or two - respondents. Nevertheless, the reason might be that these private school students did not have enough practice in physics problems as to be able to overcome any confusion caused by symbols in symbolic equations. Having said this, this difficulty might have been carried on from their respective SEC Physics level in different schools. However, none of these students indicated that they found difficulty in applying their mathematical skills to physics problems.

Other difficulties noted by the students included: remembering specific things which had to be learnt by heart, definitions and derivations, the structure of the question, the language used in the MATSEC examination, and having to deal with too much content in a very short amount of time.

Table 4.15 also shows teachers' responses about the difficulties encountered by their students according to school type. There were 54 responses in total. The percentages of the different school types were worked out of the total number of teachers while the total percentages (in the last column) of Table 4.15 were worked out of the total number of responses i.e. 54. These statistics will later be compared to the answers given during the focus group and the individual interviews.

			School Type		
			State	Church/ Private	Total
Are your students' difficulties in A level Physics related to:	**Discontinuity between what the students learnt in SEC Physics and A level Physics**	Count	1	1	2
		Percentage	8.3%	25.0%	3.70%
	Understanding physics concepts, theories and laws	Count	11	4	15
		Percentage	91.7%	100.0%	27.7%
	Confusion about the meaning of symbols and symbolic equations	Count	1	1	2
		Percentage	8.3%	25.0%	3.70%
	Applying mathematical skills to solve physics problems	Count	11	4	15
		Percentage	91.7%	100.0%	27.7%
	Language difficulties in expressing themselves properly	Count	10	2	12
		Percentage	83.3%	50.0%	22.2%
	Other	Count	4	4	8
		Percentage	33.3%	100.0%	14.8%
Total Number of Teachers			12	4	16
Total Number of Responses			38	16	54

$X^2(5) = 3.482$, $p = 0.626$

Table 4.15: Teachers' responses on students' difficulties with respect to school type

The p-value of the chi-square test in Table 4.15 exceeded the 0.05 level of significance, thus demonstrating that the teachers' responses with regards to their students' difficulties were independent of their school type. However, one can still compare the percentages of the students and those of their teachers. Out of the six options provided, the highest percentage of teachers at 27.7%, stated that their students' difficulties concerned understanding physics concepts, theories and laws. This was also the most chosen option amongst the students. Another difficulty that attracted the same percentage of teachers at 27.7%, (which conversely was not so highly ranked among students, at 10.5%), was the application of mathematical skills to solve physics problems. This was also found to be an issue in Tuminaro (2004) and Rebello et al. (2007).

Other difficulties that students may encounter and which were pinpointed by teachers included: lack of aptitude to revise problems and study at home; lack of motivation and perseverance to try to solve problems on their own; lack of independent thinking due to fear of getting things wrong; lack of understanding of what was being asked in examination questions; applying theoretical concepts to practical situations and errors in examination papers.

These difficulties, which were highlighted in the questionnaires by the teachers, might also be the ones that hinder present-day (2019) students. In fact, they were also mentioned during the face-to-face interviews with teachers E, F and H and highlighted in Section 4.4.1.

Two of the other comments made during the teachers' interviews included:

"In my opinion, the students' main problems are the mathematics, scientific writing and also lack of logical thinking and higher order thinking." – Teacher F.

"The main difficulties are to understand the physics concepts, then, mathematical problems." – Teacher D

4.4.3 Choice of Subjects for their Future Career

The 2017 MATSEC Statistical Report demonstrated that the percentage of students choosing Physics as one of their A level subjects had decreased by approximately 3% in the span of nine years.

Teachers were asked if they had observed such a trend in their particular schools and why they thought this had happened. The reasons presented below in fact corroborate the list published by Bennett et al. (2013) of considerations students make when they decide to choose their A level subjects.

> Students use A level Physics for architecture, engineering and BSc Physics courses only. BSc courses do not lead the students to specific jobs. However, I think that architecture and engineering are still popular. Also adding to your point, students choosing engineering at university have also decreased in number since they try to get a degree through an easier route by enrolling through an MCAST course. – Teacher E.

"Physics restricts students to certain courses only, such as BSc, architecture and engineering. On the other hand, mathematics is increasing in popularity due to greater job opportunities in statistics and computer studies." – Teacher G.

> It could be because of many things. I believe that subject choice has an element of trend as well. The fact that, some years ago, Physics did not remain an obligatory subject to a certain extent makes a huge difference in the subject choice at Sixth Form level. Obviously, the greater the number of students studying SEC level Physics, the greater the chances that they will choose it as one of their A level subjects. There is also the perception that Physics is a very difficult subject so students rule it out. – Teacher H.

> I think a lot of students choose Physics and Mathematics as A levels and then change them after the first two weeks. I have experienced it. They think that A level Physics is at par with SEC Physics but when they find that A level Physics is much harder and they opt to change the subjects. And besides, Biology and Chemistry open more job opportunities than Physics. – Teacher D.

> Nowadays, students are given the option to study one science subject only at Sixth Form. The majority are choosing Biology because it does not require any calculations and all the students need to do is remember. Those students who have a photographic memory will excel in Biology. When I was at Sixth Form,

> Physics was a type of subject which led us to every course that we wanted. I have students who are excellent in Physics; however, they confess that they will choose Biology and Chemistry as A levels as these subjects will give them more and better job opportunities than Physics. – Teacher A.

The comment by Teacher A stating that students who excel in Physics still choose Chemistry and Biology at Sixth Form tallies with what Smithers (as cited Sellgren, 2013) stated that it was always difficult to draw excellent students in choosing A level Physics.

> I believe that apart from teaching the content of the subject, we should also educate and change certain attitudes and misconceptions that the general public have about the subject. Sometimes, students fear that the subject will be too difficult for them to handle so they try to avoid it. There is also the wrong perception that Physics is a masculine subject. Also, are the students aware of all the types of different jobs that Physics can lead to? These are all myths that discourage students to choose the subject at A level. – Teacher C.

The comment provided by Teacher C also corresponds to the findings of Mujtaba and Reiss (2016) and Gill and Bell (2013), namely, that the deficit of girls choosing to study A level Physics might be due to the perception that Physics is more appealing to males. Teacher C's comment about the lack of knowledge about the careers available was also mentioned in the Introduction of this dissertation whereby by 2025, there will be a total of 26% of employment opportunities in STEM careers in Malta.

4.5 The Relationship between Mathematics and Physics

This section will present the respondents' views and opinions on the relationship between SEC Mathematics and A level Physics.

Students and teachers were asked whether mathematical concepts were important to study Physics. Table 4.16 shows the results from the students with respect to gender. The p-value corresponding to testing whether the responses depend on gender turned out to be 0.050 showing a strong evidence to reject the null hypothesis. Most students, 94.5%, reported that mathematical concepts were important for the study of Physics, with a higher percentage of females, 97.8%, saying so, although the percentage of males was also extremely high at 90.8%.

			Gender		
			Male	Female	Total
Are mathematical concepts important for the study of Physics?	Yes	Count	69	87	156
		Percentage	90.8%	97.8%	94.5%
	No	Count	7	2	9
		Percentage	9.2%	2.2%	5.5%
Total		Count	76	89	165
		Percentage	100.0%	100.0%	100.0%

$X^2(1) = 3.854$, $p = 0.050$

Table 4.16: Students' responses on the importance of mathematical concepts in the study of A level Physics with respect to their gender

Table 4.16 shows a discrepancy of 7% between the responses provided by females and males. The researcher presents two potential interpretations for this: it could be that since girls are known to have a more study-oriented culture than boys (Houtte, 2004), they might, most probably, know the subject more thoroughly. The other plausible explanation for this discrepancy is that even though, in modern research studies, girls are found to slightly outperform boys in STEM subjects (O'Dea, 2018), girls' confidence levels in such subjects may still be low (Perez-Felkner, 2017). Due to their low confidence levels, their perception of the amount of mathematics in Physics might be higher than that of the boys.

The teachers' responses were consistent with those of students' as all of them, 100%, believed that mathematical concepts were important to study Physics. These responses reinforced the statements made by Basson (2002), Hudson and

Rottmann (1981) and Sidhu (2006), who stated that mathematical skills and concepts are important in the language of physics.

To statistically analyse this relationship, a cross-correlational study between the 2015 SEC Mathematics grades and the 2017 A level Physics grades was carried out, based on the data provided by the MATSEC Support Unit office.

			Physics A level grade						
			A	B	C	D	E	F	Total
Mathematics SEC level grade	**1**	Count	13	22	19	4	1	2	61
		Percentage	5.2%	8.7%	7.5%	1.6%	0.4%	0.8%	24.2%
	2	Count	8	15	35	16	4	3	81
		Percentage	3.2%	6.0%	13.9%	6.3%	1.6%	1.2%	32.1%
	3	Count	0	10	27	24	9	3	73
		Percentage	0.0%	4.0%	10.7%	9.5%	3.6%	1.2%	29.0%
	4	Count	0	2	6	9	4	3	24
		Percentage	0.0%	0.8%	2.4%	3.6%	1.6%	1.2%	9.5%
	5	Count	0	2	2	0	5	3	12
		Percentage	0.0%	0.8%	0.8%	0.0%	2.0%	1.2%	4.8%
	6, 7 or U	Count	0	0	0	0	0	1	1
		Percentage	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%	0.4%
Total		Count	21	51	89	53	23	15	252
		Percentage	8.3%	20.2%	35.3%	21.0%	9.1%	6.0%	100.0%

$X^2(25) = 101.152$, $p < 0.001$

Table 4.17: 2015 SEC Mathematics grades and 2017 A level Physics grades obtained by the same cohort of students

The chi-square test above shows that there was a statistically significant relationship between the grades in SEC Mathematics and the grades in A level

Physics since the p-value was less than the 0.05 level of significance. This indicated that there was a very strong evidence to reject the null hypothesis, thus implying a relationship between the variables. This suggested that the students who were faring better in the SEC Mathematics examination tended to do well in the A level Physics examination as well. This result can be generalised because it is not attributed to chance. It also validates Baylon's (2014) and Delialioğlu and Aşkar (1999) affirmations that the relationship between Mathematics and Physics achievement is significant and positive.

It must be noted that the Spearman Rank Correlation Coefficient, r, between the 2015 SEC Mathematics grades and the 2017 A level Physics grades is 0.452. Gilchrist and Samuels (Birmingham City University, n.d.) consider this as a moderate correlation. The correlation coefficient found by Sutch (2013) for the same subjects was 0.557. Using the same statistical analysis, this is considered as a strong correlation. The difference in the level of correlation might be attributed to the fact that it involves a different year group in a different country.

It should also be noted that the chi-square test value of 101.52 is large, thus indicating a strong relationship between SEC Mathematics and A level Physics. In addition, the most common grade in SEC Mathematics is 2, 32.1%, while that in A level Physics is C, 35.3%. With regards to SEC Mathematics, the University of Malta Junior College Physics Department's guidelines advise that for a prospective student to succeed in A level Physics a grade 3 or better is usually required.

Another observation that can be drawn from this relationship is that 88.5% of the students who had obtained grade 1 in their SEC Mathematics examination, obtained grades A to C in their A level Physics examination. This percentage is followed by 71.6% of the students who had obtained a grade 2 and 50.6% of the students who had obtained a grade 3 in SEC Mathematics. A sharp drop in the students' achievement in A level Physics was noted in the case of students who had achieved a grade of 4 or lower in their SEC Mathematics examination since only 32.4% of these students achieved grades A to C in A level Physics.

> Mathematical skills are important in empowering students to work confidently in Physics' examinations. This in view of the use of graphs, subject of the formula, standard form and decimal places/significant figures, conversion of units, etc. … Otherwise, most probably there would be difficulties due to the logic implied in physics questions at A level. – Teacher B

To thoroughly investigate this relationship, students and teachers were asked to give an estimate of the percentage of the A level Physics syllabus which, according to them, requires mathematical skills and knowledge. The responses are presented in Tables 4.18 and 4.19 below.

			Gender		
			Male	Female	Total
Give an estimate of the percentage of the A level Physics syllabus that requires mathematical skills and knowledge.	**25%**	Count	23	14	37
		Percentage	30.3%	15.7%	22.4%
	50%	Count	24	41	65
		Percentage	31.6%	46.1%	39.4%
	75%	Count	29	32	61
		Percentage	38.2%	36.0%	37.0%
	100%	Count	0	2	2
		Percentage	0.0%	2.2%	1.2%
Total		Count	76	89	165
		Percentage	100%	100%	100%

$X^2(3) = 7.807$, $p = 0.05$

Table 4.18: Students' responses on the percentage of the A level Physics syllabus that requires mathematical skills and knowledge

Table 4.18 shows the students' responses. The null hypothesis of whether the percentage estimates are independent of the students' gender was investigated. The test presented a p-value of 0.05 thus showing a strong evidence to reject the null hypothesis. Furthermore, the Table 4.18 shows that out of the four options given, 39.4% of the students, thought that 50% of the content in A level Physics involved Mathematics. Considering gender difference, it is interesting to note that the highest percentage of the female population, at 46.1%, thought that 50% of the content in A level Physics concerned Mathematics. This response contrasted with the male population with the highest percentage of males, 38.2%, estimating as much as 75% of mathematical skills and knowledge at A level Physics. Moreover, this test does not tally with the researcher's second interpretation in Table 4.16 which suggested that the girls perception of the quantity of the Mathematics syllabus in Physics could be higher that that of boys.

Table 4.19 shows the teachers' responses to the same question. A chi-square test of independence between the teachers' percentage estimates and their school types was performed. Since the p-value of this chi-square test resulted to be 0.074, the null hypothesis cannot be rejected and so the responses were independent of the teachers' school types.

			School Type		
			State	Church/ Private	Total
Give an estimate of the percentage of the A level Physics syllabus that requires mathematical skills and knowledge.	**0% - 50%**	Count	9	1	10
		Percentage	75.0%	25.0%	62.5%
	51% - 100%	Count	3	3	6
		Percentage	25.0%	75.0%	37.5%
Total		Count	12	4	16
		Percentage	100.0%	100.0%	100.0%

$X^2(1) = 3.200$, $p = 0.074$

Table 4.19: Teachers' responses on the percentage of the A level Physics syllabus that requires mathematical skills and knowledge

This question in the original questionnaire, showed the same options as those presented in Figure 4.18, i.e. 25%, 50%, 75% and 100%. Since the sample of teachers was small, these percentages were grouped up as shown in Figure 4.19 for better SPSS computation.

As can be shown in Figure 4.19, most teachers, 62.5%, assigned 0%-50% of mathematical skills and knowledge within the A level Physics syllabus. When manually analysing the responses provided by the teachers, 50% of these (i.e. eight teachers) agreed that 50% of the A level Physics syllabus requires Mathematics. This percentage is comparable to the response given by most students to the same question.

Another question posed to the students and which is worth discussing was whether they would feel sufficiently prepared to work out the problems in A level Physics using knowledge from SEC level Mathematics only. Table 4.20 shows that the students' responses were independent of their school type since the p-value was 0.087.

			School Type			
			State	Church	Private	Total
How prepared would you feel to work out A level Physics problems using knowledge from SEC level Mathematics only?	**Very well prepared**	Count	3	3	1	7
		Percentage	3.1%	5.3%	8.3%	4.2%
	Prepared	Count	44	14	3	61
		Percentage	45.8%	24.6%	25.0%	37.0%
	Not prepared enough	Count	49	40	8	97
		Percentage	51.0%	70.2%	66.7%	58.8%
Total		Count	96	57	12	165
		Percentage	100.0%	100.0%	100.0%	100.0%

$X^2(4) = 8.139$, $p = 0.087$

Table 4.20: Students' responses on how prepared they would feel to work out A level Physics problems using knowledge from SEC level Mathematics only

The majority of the students, 58.8%, thought that SEC level Mathematics would not be enough to work out the problems in A level Physics. This response gave rise to the following two questions. Both teachers and students were asked what should be the minimum level of Mathematics that a student should have in order to be able to study confidently and with profit A level Physics. Table 4.21 and 4.22 show the students' and the teachers' responses respectively; both were independent of school type since both p-values, 0.396 and 0.551 respectively, were larger than the 0.05 level of significance.

			School Type			
			State	Church	Private	Total
What is the minimum level of Mathematics a student should have for A level Physics?	**SEC level**	Count	24	15	1	40
		Percentage	25.0%	26.3%	8.3%	24.2%
	Intermediate level	Count	69	38	11	118
		Percentage	71.9%	66.7%	91.7%	71.5%
	A level	Count	3	4	0	7
		Percentage	3.1%	7.0%	0.0%	4.2%
Total		Count	96	57	12	165
		Percentage	100.0%	100.0%	100.0%	100.0%

$X^2(4) = 4.074$, $p = 0.396$

Table 4.21: Students' responses on the minimum level of Mathematics a student should have to study A level Physics

According to the majority of the students, 71.5%, an Intermediate level in Mathematics should be enough for the students to study A level Physics. This contrasted with the majority of the teachers' responses, 62.5%, reported in Table 4.22 below, who indicated that a good grade in SEC level in Mathematics should be enough for the students to study A level Physics. The teachers' feedback concurs with Gill and Bell (2013), who similarly believe that students need to have a good grade in GCSE Mathematics for them to perform successfully in A level Physics. The teachers' responses could also be compared with data in Table 2.4, which shows that most mathematical requirements of A level Physics are covered during the secondary school years. It is to be noted that no teacher chose A level Mathematics as a requirement for A level Physics. Therefore, this category was deleted for better SPSS computation. The low percentage of students choosing A level Mathematics, at 4.2%, and the fact that none of the teachers chose the option of A level Mathematics to accompany A level Physics greatly contrasts with Swinback (1997) who stated that students who study A level Physics need A level Mathematics.

The researcher believes that the reason that some students opt to choose Intermediate level Mathematics alongside A level Physics is to ensure that they learn enough mathematical skills and knowledge to be able to cope with A level Physics problems. The researcher also believes that taking up A level Mathematics is not necessary to cope with A level Physics unless it is a requirement in a chosen career; however, an Intermediate level course in Mathematics would be an asset for students studying A level Physics. The reason is that although 62.5% of the teachers stated that SEC Physics is the minimum level of Mathematics a student should have to study A level Physics (Table 4.22), in the interviews these teachers emphasised that students were being underprepared in mathematical skills. They opined that students who had at least an Intermediate level knowledge of Mathematics would surely be in a better position to tackle problems in A level Physics. Section 4.5.1 below shows that some A level Physics teachers utilised some of their lessons to teach mathematical skills which they considered necessary to tackle problems in A level Physics.

			School Type		
			State	Church/ Private	Total
What is the minimum level of Mathematics a student should have to study A level Physics?	**SEC level**	Count	8	2	10
		Percentage	66.7%	50.0%	62.5%
	Intermediate Level	Count	4	2	6
		Percentage	33.3%	50.0%	37.5%
Total		Count	12	4	16
		Percentage	100.0%	100.0%	100.0%

$X^2(1) = 0.356$, $p = 0.551$

Table 4.22: Teachers' responses on the minimum level of Mathematics a student should have to study A level Physics

I try to emphasise that my A level Physics students should have at least an Intermediate in Mathematics. In my opinion, SEC Mathematics is not enough for the A level because we need to work with logs to change equations to a straight line graph, exponential decays and growths, radians, a great amount of trigonometry and algebra. Even the fact that they are still studying mathematics, they keep up to date with graph plotting, they know what cos and sin waves are, the limit goes to infinity, etc. Those students who stop studying Mathematics at SEC do not know what these are and I find it extremely stressful as I can't afford to use my lessons to teach the students Mathematics as the A level Physics syllabus is vast. – Teacher F

The students are allowed to study A level Physics having only SEC Mathematics. They are able to do it with a lot of practice, although I do not recommend it. I recommend at least an Intermediate level. This will help them especially in the rate of change and integral which is the area under the graph. – Teacher H

SEC Mathematics would be enough as long as the students have a good understanding of it. If the students achieved a good mark in their SEC Mathematics examination because they studied it by heart, it is not enough … they need to have a good understanding to feel confident in working out A level Physics problems. Logs and straight line graphs are the most difficult for the students. – Teacher G

4.5.1 Mathematical Difficulties

> Unfortunately, I have noticed that the students' level in mathematics has gone down. So, we decreased the level of the SEC Physics examination to meet that requirement. Therefore, the gap between SEC and A level Physics has increased and the students are totally shocked when they come for their A level lessons. A lot of things which were just explained in SEC Physics, are now tackled mathematically, for example: fields and magnetism. – Teacher F

> Students have the option to choose another subject with A level Physics instead of Mathematics. Students are choosing A level Physics lacking a lot of Mathematics so we are trying to simplify the Physics to suit them … in my opinion, we shouldn't simplify the Physics but rather they should study Mathematics! – Teacher H

Students were requested to identify and write down up to three of the most difficult mathematical concepts that are necessary for A level Physics. Their responses are presented in Figure 4.6.

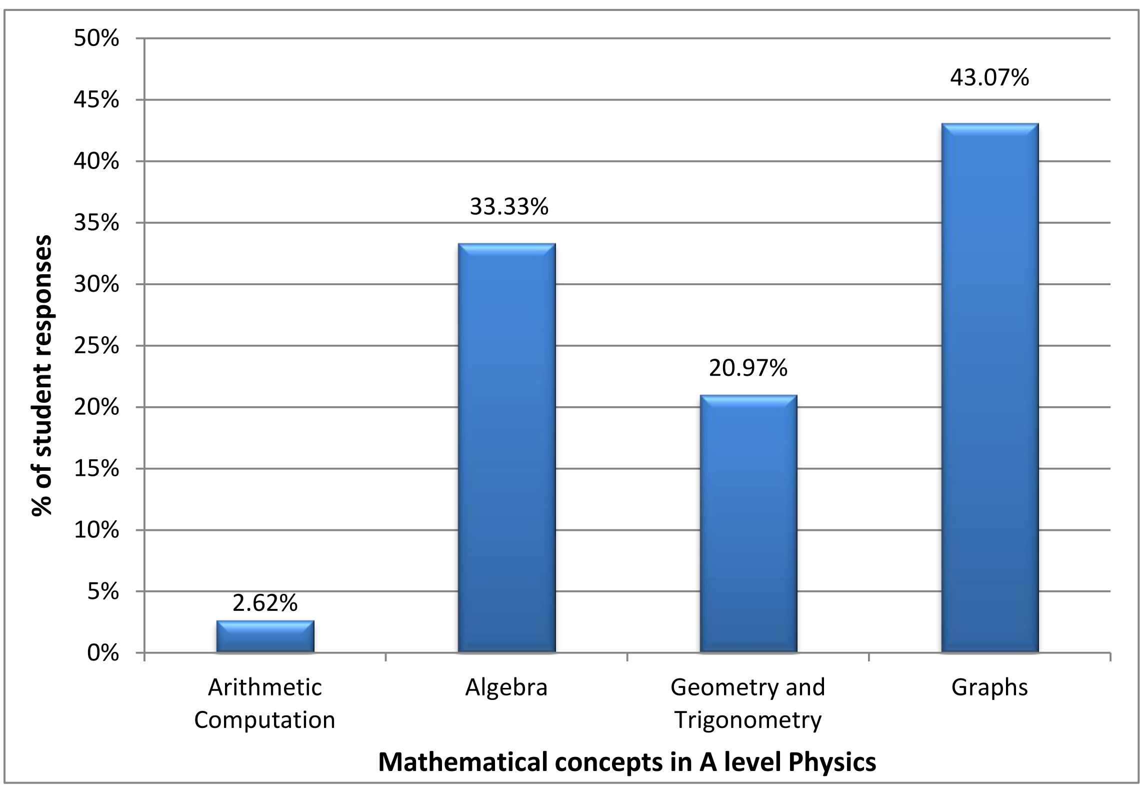

Figure 4.6: Mathematical concepts which the students find most difficult in A level Physics

As can be seen in the above figure, the mathematical topics which the students found to be the most difficult were Graphs (43.07%), Algebra (33.33%), followed by Geometry and Trigonometry (20.97%). Most of these difficulties concerned the sub-topics of differentiation, integration and trigonometric functions.

It was expected that these mathematical topics would be difficult to the students; it is evident in Table 2.4 that Graphs and Algebra were the mathematical topics in A level Physics which had the least support from SEC Mathematics. They were therefore likely to be regarded by A level Physics students as the most difficult.

> I see a lot of confusion when we start introducing new equations with new strange symbols such as the Greek letter omega. Even after a lot of practice, those students who are weak in mathematics still find it very difficult. A lot of mistakes occur in the subject of the formula of the equation y = mx + c; they try to carry the x first without carrying the c before. They find the charges equation and the force between two masses mostly difficult. – Teacher F

> The most pressing thing that we find during the Physics lessons is the students' mathematical level. It is something which is really worrying. The fact that students lack certain basic knowledge in Physics is not frustrating but the fact that students lack mathematical knowledge is extremely so for us. We are not supposed to be teaching that! In fact, as from this year, we started to dedicate some hours per week to Mathematics in Physics. We are teaching them logs, the use of the calculator, etc. – Teacher H

4.6 Language Skills and A level Physics

The responses in their questionnaire indicated that all the teachers believed that English language skills were important in the study of Physics. For that reason, students and teachers were asked to pinpoint ways in which these skills would help students achieve a good result in the A level Physics examination. The respondents could choose more than one option. Tables 4.23 and 4.24 show that both the students' and the teachers' opinions were independent of school type since both p-values of 0.845 and 0.96 respectively exceeded the 0.05 level of significance.

In Tables 4.23 and 4.24, students and teachers could tick more than one response. In total, the researcher recorded 342 student responses and 41 teacher responses. The percentages of the different school types were worked out of the total number of students or teachers in the respective Table. The total percentages (last column) of each table were worked out of the total number of responses i.e. 342 in the case of students and 41 in the case of teachers. These statistics will later be compared to the answers given during the focus group and the individual interviews.

			School Type			
			State	Church	Private	Total
How do your English language skills help you in your A level Physics examination?	**Understanding the concepts of physics well**	Count	57	33	6	96
		Percentage	60.0%	57.9%	50.0%	28.1%
	Understanding the question properly	Count	74	52	10	136
		Percentage	77.9%	91.2%	83.3%	39.8%
	Answering clearly by applying my English writing skills	Count	57	41	8	106
		Percentage	60.0%	71.9%	66.7%	31.0%
	Other	Count	2	1	1	4
		Percentage	2.1%	1.8%	8.3%	1.16%
Total Number of Students			95	57	12	164
Total Number of Responses			190	127	25	342

$X^2(6) = 2.703$, $p = 0.845$

Table 4.23: Students' responses on how English language skills help in A level Physics examinations

As shown in Tables 4.23 and 4.24, out of the four options given, the highest percentage of students, 39.8%, and teachers, 36.6%, agreed that English language skills were mostly helpful to help students 'understand the question properly'. The highest percentage was followed by 'answering clearly by applying English writing skills'. Another point worth mentioning is that for both students and teachers, the percentage levels of the three responses were very similar and the ranking of the answers were the same. Therefore, in the view of the researcher, and according to the responses given by students and teachers, all three factors help students to perform better in A level Physics examinations.

The results presented in these two tables (4.23 and 4.24) validated Taboada's (2012) view that students' proficiency in language increases their understanding of science texts. It also validated Cremer and Schoonen's (2013) finding that generally, language minority students are weak when trying to read and understand text.

			School Type		
			State	Church/ Private	Total
How do your English language skills help you in your achievement in A level Physics?	**Understanding the concepts of physics well**	Count	7	2	9
		Percentage	58.3%	50.0%	21.9%
	Understanding the question properly	Count	11	4	15
		Percentage	91.7%	100.0%	36.6%
	Answering clearly by applying my English writing skills	Count	9	4	13
		Percentage	75.0%	100.0%	31.7%
	Other	Count	3	1	4
		Percentage	25.0%	25.0%	9.75%
Total Number of Teachers			12	4	16
Total Number of Responses			30	11	41

$X^2(3) = 0.207$, $p = 0.976$

Table 4.24: Teachers' responses on how English language skills help students in their A level Physics examination

This issue was also discussed in the focus group with students and during some of the interviews with teachers, when respondents shared the same views on the matter.

"When I try to explain a concept, I feel stuck." – Student 7

"I feel I need to explain something and the way I write it, gives it a completely different meaning to my thoughts." – Student 1

> English is important. Some students have weak language skills and this inhibits them from studying Physics properly. They find it difficult to understand the question properly and find it even harder to express themselves in questions where they are asked to define or explain. – Teacher G

> Due to their weak skills in English, they waste a lot of their examination time to read and fully understand the question properly. This is not the examiner's fault but it is the fault of our educational system which allowed these weak students to progress from year to year. In my opinion, sometimes, some students should not even be accredited with a SEC English certificate! – Teacher E

> Some time ago, we had a question 'How long does it take to land?' One of my students said that we should find distance instead of time. The question was extremely simple and he was a student who had a pass in both SEC English Language and Physics. The problem is increasing every year! – Teacher F

> I see a lot of problems in the way the students express their scientific thoughts. When they have to explain something, they beat around the bush without actually targeting what is really happening and why. Also, they miss a lot on the keywords and they do not have a general structure in their writing. – Teacher F.

To statistically analyse and examine this relationship more deeply, a cross-correlational study between the 2015 SEC English Language grades and 2017 A level Physics grades was worked out based on the data provided by the MATSEC Support Unit office. These are presented in Table 4.25 below.

			Physics A level grade						
			A	B	C	D	E	F	Total
English SEC level grade	**1**	Count	5	7	6	1	0	0	19
		Percentage	2.0%	2.8%	2.4%	0.4%	0.0%	0.0%	7.5%
	2	Count	9	23	31	5	4	3	75
		Percentage	3.6%	9.1%	12.3%	2.0%	1.6%	1.2%	29.8%
	3	Count	6	11	27	22	4	3	73
		Percentage	2.4%	4.4%	10.7%	8.7%	1.6%	1.2%	29.0%
	4	Count	1	5	15	17	10	5	53
		Percentage	0.4%	2.0%	6.0%	6.7%	4.0%	2.0%	21.0%
	5	Count	0	4	9	4	4	4	25
		Percentage	0.0%	1.6%	3.6%	1.6%	1.6%	1.6%	9.9%
	6, 7 or U	Count	0	0	1	4	1	1	7
		Percentage	0.0%	0.0%	0.4%	1.6%	0.4%	0.4%	2.8%
Total		Count	21	50	89	53	23	16	252
		Percentage	8.3%	19.8%	35.3%	21.0%	9.1%	6.3%	100.0%

$X^2(25) = 67.694, p < 0.001$

Figure 4.25: 2015 SEC English grades and 2017 A level Physics grades obtained by the same cohort of students

This investigation shows that there was a statistically significant relationship between SEC English Language and A level Physics grades since the p-value was less than the 0.05 level of significance. This means that there was a very strong evidence to reject the null hypothesis, thus implying a relationship between the variables. In fact, the chi-square test value between the two subjects was 67.694. This means that the students who did well in the SEC English Language examination should do well in their A level Physics examination. This result can be generalised because it is not attributed to chance. It also corroborated with Baylon's (2014) view who stated that English and Physics achievement have a significantly positive relationship.

It must be noted that the Spearman Rank Correlation Coefficient, r, between the 2015 SEC English grades and the 2017 A level Physics grades is 0.411. Gilchrist and Samuels (Birmingham City University, n.d.) considered this as a moderate correlation. This value can be compared to the value in Sutch (2013), who found that the correlation coefficient for the same two subjects was 0.468.

The most common grade in SEC English was 2 (29.8%) while that in A level Physics was C (35.3%). The University of Malta Junior College Physics Department's guidelines for prospective students advise that to succeed in A level Physics one should usually have obtained a grade 3 or better in SEC English Language.

Furthermore, 94.7% of the students who had obtained grade 1 in their SEC English Language examination obtained grades A to C in their A level Physics examination. This percentage is followed by 84% of the students who had obtained a grade 2 and 60.3% of those who had obtained a grade 3. A sharp dip in performance was observed in the case of students who had achieved a grade 4 or lower in the SEC English Language examination since 41.2% of these students achieved grades A to C in A level Physics.

> The students need to have a good mastery of English. They need to understand the problem. There are students who write very long paragraphs with no quality whatsoever. There are other students who write their answers in one sentence straight to the point and without flowery language. So, yes, to understand the question and express themselves properly, the students need to be fluent in basic English. – Teacher A.

> Students are not training themselves to read in English. It might be because of the influx of technology and media in their lives. They feel lost when reading a problem in the form of a paragraph and they end up answering it incorrectly. – Teacher F

> I believe that in the very near future, there might be an experiment whereby we try to teach science subjects in Maltese. In my opinion, this will make things worse especially by making it even more confusing to dyslexic students. Student problems in the English language should be tackled at a primary level. - Teacher H

The teachers' comments go hand in hand with Mallick (2012), who stated that it is crucial for students to articulate their opinions in a clear and engaging way.

4.7 Correlation Coefficients of the Different Subjects Under Test

The following correlation coefficients were worked out and have already been presented in different sections above.

Correlating		Correlation Coefficient
SEC Physics	A level Physics	0.544
SEC Mathematics	A level Physics	0.452
SEC English Language	A level Physics	0.411

Table 4.26: The different correlation coefficients among the subjects under test

The researcher's first hypothesis with regards to the correlation coefficients between A level Physics and SEC Physics, Mathematics and English Language was that a very strong relationship will emerge. The actual Spearman correlation coefficient tests did not tally with the researcher's prediction because strong and moderate correlations emerged. This could be because students' examination grades do not depend only on whether students had achieved good grades in the subject in the previous examination, but also on other factors, such as parental involvement, socio-economic background, and the emotional, personal and cognitive conditions of the student. Moreover, the correlation between SEC Mathematics and SEC English Language with A level Physics resulted to be lower than that with SEC Physics because since these are different subjects, they involved other factors which could have affected the students' achievement. These include, among others: in the case of SEC Mathematics, mental mathematical questions, algebraic and trigonometric representations; in the case of SEC English Languae, spelling and grammar.

It is to be noted that the majority of students with grades 1 and 2 in SEC Physics obtained grades A, B and C in A level Physics while the majority of students with grades 1, 2 and 3 in SEC Mathematics and SEC English Language managed to obtain grades A, B and C in A level Physics. Therefore, the researcher can conclude that students who had managed to obtain SEC Physics grades 1 and 2 had a much better chance of obtaining higher grades in A level Physics than those with grade 3 and under. Thus, in the researcher's opinion, this narrower spectrum between SEC Physics and A level Physics indicates a clearer relationship between the two levels, that is, the better the result at SEC Level Physics, the greater the chances of better grades at A level Physics. In fact, this relationship showed a stronger correlation coefficient than with the other subjects.

4.8 What Does the Future Hold?

Even though the topic dealt with in this section is not strictly in line with the research questions of this study, it is highly relevant to the teaching of Physics. During the face-to-face interviews, several teachers highlighted the issue of the upcoming major changes in the education system based on the Learning Outcome Framework (henceforth LOF). This is what the teachers had to say about it:

> I agree with the new system as one has to keep in mind the diverse abilities of students in the classroom and check that these are met. Also, the students still need to learn the basic physics content to be able to understand the world around us better. – Teacher B.

"I agree with the new LOF because these will be there to emphasise and target the teacher's autonomy in the classroom. Moreover, because of these, the teacher can be more flexible in reaching decisions concerning continuous assessment." – Teacher C.

> I am still questioning whether the system of the LOF will work. This is because not all teachers work in the same way and with the same measure. Let's take the current lab report system as an example. There are teachers who do everything by the book; however, it is a known fact that there are other teachers who give a copy of lab reports to the students for them to copy. Since the new system of the LOF assigns almost half of the assessment mark to continuous assessment (30%), who will take the responsibility to check that all the students are doing the same effort for the same marks? for me, it is still a bit vague. – Teacher A.

> The new changes that will be introduced will include more practice work to help the low ability students. However, they still need to produce write-ups, which they consider to be difficult. In my opinion, these will unnecessarily increase the practice work, whereas this could have been tackled better by distributing the work in topics to prepare them better for the A level syllabus such as Mechanics. – Teacher D.

Considering that this change will bring about a huge amount of work to be performed by teachers in terms of preparation for their lessons, it is to be expected that they resist changes to their pedagogical approach. "Unless teachers understand and appreciate the need for change in their schools, their interest in maintaining the status quo will undoubtedly take precedence over their willingness to accept change" (Greenberg & Baron, 2000, in Zimmerman, 2006). In light of this, meetings with teachers could take place during which the need and the importance for this change is explained, and the benefits of shared decision-making and collaborative work emphasized, helping to clarify misunderstandings and overcoming resistance. But in spite of all efforts, only time will tell whether the new LOF system will eventually be a success.

4.9 Conclusion

This chapter has presented the data obtained by the research tools from the participants of this study. SPSS was used to present the statistical data obtained from the questionnaires. The aim of the Results and Discussion chapter was to answer the four research questions of this dissertation supported by statistical evidence and several opinions from people who, from day to day, are concerned by these research questions.

In the next chapter, the researcher will conclude this study by addressing the four research questions, outline the strengths, limitations and challenges of this study, and provide recommendations and suggestions and note any implications and challenges that could not be avoided during the journey of this dissertation.

Chapter 5

Conclusion

5.1 Introduction

During the four years of teaching Physics at SEC level, the researcher observed that some students were finding it difficult to answer written questions presented in the classroom, either as classwork or as homework despite seemingly having understood the lesson well. Written answers involved basic mathematical mistakes which lead to students losing marks regardless of their knowledge in Physics. When asking questions verbally some students were able to answer them correctly especially when they were allowed to answer in Maltese. Obviously, these mistakes marred the students' results in their half-yearly, annual and finally their SEC Physics examination.

Following further observation, questioning and reflection, the researcher thought that some of the incorrect answers might be due to the effects of other subjects on Physics. This prompted the researcher to investigate further by utilising national tests in Malta, namely SEC examinations and the A level Physics examination to analyse the relationship between SEC Physics, Mathematics and English Language and the performance of students in A level Physics.

This research took the form of a mixed methods approach involving questionnaires distributed among Sixth Form second year students studying A level Physics, a focus group with seven of these students, questionnaires for A level Physics teachers, five one-to-one interviews carried out with A level Physics teachers and four one-to-one interviews with SEC Physics teachers.

Therefore, this study developed theory by investigating the four research questions: the effects of the changes that were carried out in the SEC Physics syllabus in 2012, whether SEC Physics and SEC Mathematics prepare students adequately for A level Physics, any effects and correlation coefficients of some SEC subjects, namely SEC Physics, Mathematics and English Language and A level Physics were also examined.

As described in Sections 3.7.3 and 4.1, five main themes emerged from the thematic analysis of the qualitative data gathered. These included:

(i) The effect of the changes introduced in the 2012 SEC Physics syllabus on students who then study A level Physics;
(ii) The challenges and expectations of students;
(iii) The relationship between Mathematics and Physics;
(iv) Language skills and A level Physics and
(v) What does the future hold?

These helped in the interpretation of the data gathered statistically, and to provide an answer to the four research questions and thus fill in the identified gaps in knowledge:

1. Were the changes in the 2012 SEC Physics syllabus helpful or not to A level teachers and their students?
2. With the changes in the SEC Physics syllabus in 2012, does the syllabus provide the students with an adequate background for A level Physics?
3. Is SEC Mathematics enough for students to study A level Physics?
4. The correlation coefficients of SEC Physics, Mathematics and English Language with A level Physics considering the 2015 SEC and the 2017 A level cohorts of Maltese and Gozitan students.

In the following section, the main research findings which were analysed in Chapter 4 will be presented.

5.2 Research Findings

In the majority of the investigations carried out for the purpose of this study, the p-value of the chi-square test was larger than the 0.05 level of significance. This showed that there were no significant differences between either students or teachers, according to case, coming from different educational sectors. Moreover, the researcher concluded that any existing differences between the students were levelled off considering that they passed their SEC examinations and opted to study A level Physics in a post-secondary school.

5.2.1 What Were the Distinctive Changes in the SEC Physics Syllabus in 2012?

Appendix 8 shows that, amongst all the changes that were made in the 2012 SEC Physics syllabus, several LOs were introduced while others were removed. Moreover, the different topics of the SEC Physics syllabus were grouped into themes so that students would be in a better position to link similarities between the different areas.

Furthermore, a new section named 'Historical and STS connections' was introduced alongside the other learning outcomes. This presented an opportunity for students to link and relate physics concepts with everyday life situations and to instil in them the notion that scientists worked hard and went through a certain scientific procedure in order to develop science as we know it today.

Moreover, the weight of the practical section 'Design and Planning of Experiments' was increased from 15% to 20% and students could now opt to present either fifteen experiments or thirteen experiments and one long investigation. Candidates are now expected to present at least two experiments from each theme instead of simply the best fifteen experiments.

This study revealed that 68.8% of the Sixth Form teachers considered that the changes in the SEC Physics syllabus were 'not so helpful' to them while 62.5% of the teachers considered the changes to be 'not so helpful' to their students. When the teachers were asked about the changes in the extent and mode of preparation of students for the A level Physics syllabus before and after the changes in the 2012 SEC Physics syllabus, 56.3% of the A level Physics teachers stated that students were being prepared on 'the same' level while 43.8% believed that they were 'less prepared'. Although there was only a slight difference between the percentages, the majority of the teachers, during their interviews (section 4.3.1), declared that, following the changes introduced in 2012, the SEC Physics syllabus lacked the necessary detail to help students in higher order thinking, and thus, increasing the gap between the SEC and the A level syllabi. In actual fact, 63.0% of the students and 81.3% of the teachers concurred that the transition from secondary to post-secondary level was rather challenging.

5.2.2 Is SEC level Physics a Good Foundation/Background for A level Physics?

The majority of students in the sample, 55.8%, believed that SEC level Physics is a good foundation for A level Physics since they considered the two levels to be only slightly different from each other. This percentage was marginally different with teachers as half of them, 50%, believed that SEC Physics provided a 'not so good' foundation for A level Physics and claimed that some topics could be delivered in a better way.

As many as 63.6% of the students and 81.3% of the teachers considered A level Physics as a continuation to what is studied at SEC level but at a higher and harder level. When the students were asked about their difficulties, the result was statistically significant in terms of school type. Slightly less than a third of the students, 29.9%, admitted that their difficulties in A level Physics were characterised by 'understanding physics concepts, theories and laws' with the majority of these students, 69.6%, coming from Church schools. Out of the six options, the predominant percentage of teachers, 27.7%, also agreed with the highest percentage of the students since they considered that their students' difficulties were characterised by 'understanding physics concepts, theories and laws'. Another 27.7% of the participating teachers considered that student difficulties stemmed from inabilities in 'applying mathematical skills to solve physics problems'.

One notes that, according to 22.16% of the students, the most difficult topics in the A level Physics syllabus were Mechanics and Fields. Furthermore, Circular Motion and Rotational Dynamics, Electrical and Gravitational Fields were the sub-topics which presented most difficulties. These sub-topics, are in fact, taught at A level without prior preparation at SEC level.

A chi-square test conducted between SEC Physics and A level Physics resulted to be 133.235 showing a strong relationship with a statistically high significant relationship between the two levels. In fact, the majority of students with grade 1 (95.7%) and grade 2 (77.4%) in SEC Physics obtained grades A, B and C in their A level Physics examination. Also, the majority of the students, 57.4%, who had obtained a grade 1 in their SEC Physics examination also managed to achieve grades A and B in their A level examination.

5.2.3 Is SEC level Mathematics an Adequate Preparation for A level Physics?

Not less than 94.5% of the students and all the teachers agreed that mathematical concepts were important in the study of Physics. Again, out of the four options given, 39.4% of the students and 50% of the teachers, agreed that as much as 50% of the A level Physics syllabus requires Mathematics. In both these cases, the students' responses resulted to be statistically significant with respect to gender, with the highest percentages attributed to females.

The result of a chi-square test calculated between SEC Mathematics and A level Physics, resulted to be 101.52 showing a strong relationship with a statistically high significant relationship between the two subjects. Moreover, 88.5% of the students who obtained a grade 1, 71.6% of the students who obtained a grade 2 and 50.6% of the students who obtained a grade 3 in SEC Mathematics obtained grades A, B and C in their A level Physics examination.

However, 58.8% of the students did not feel that they were prepared to work out A level Physics problems by using knowledge gained from SEC level Mathematics. In fact, 71.5% of the students stated that, they required at least an Intermediate level in Mathematics to study A level Physics. On the contrary, 62.5% of the teachers stated that a good grade in SEC level Mathematics would be enough for students to proceed to A level Physics. However, in their one-to-one interviews, teachers stated that an Intermediate level in Mathematics or a very good understanding in SEC Mathematics would be a bonus because A level Physics was so vast that they found it difficult to find the time to teach mathematical concepts too.

For students studying A level Physics, the most common mathematical topics which were considered as difficult included Graphs (43.1%) and Algebra (33.3%) with most of the difficulties being caused by differentiation, integration and trigonometric functions. Indeed, one should note that these are the topics that featured least in the SEC level Mathematics syllabus.

5.2.4 What are the Correlation Coefficients between the Grades in SEC Physics, Mathematics and English Language and A level Physics?

All the teachers agreed that English Language skills were important for studying Physics. In fact, 39.8% of the students and 36.6% of the teachers agreed that English Language skills greatly helped the students to 'understand the question properly', with the second most popular reply being to 'answer accordingly by applying their knowledge into writing'.

A chi-square test conducted between SEC English Language and A level Physics resulted to be 67.694, showing a statistically high significant relationship between the two subjects. Moreover, those students who did well in the SEC English Language examination should have also done well in their A level Physics examination. Additionally, 94.7% of the students who obtained grade 1, 84.0% of the students who obtained grade 2 and 60.2% of the students who obtained grade 3 in SEC English Language also obtained grades A, B and C in their A level Physics examination.

When comparing the three chi-square tests conducted in this research study, between (i) SEC Physics and A level Physics; (ii) SEC Mathematics and A level Physics and (iii) SEC English Language and A level Physics, it was concluded that the chi-square value was largest (133.235) for SEC and A level Physics grades and smallest (67.694) when relating SEC English Language with A level Physics grades. Moreover, the correlation coefficient between SEC Physics and A level Physics was found to be 0.544, that between SEC Mathematics and A level Physics was 0.452 while for SEC English Language and A level Physics was 0.411.

5.2.5 Secondary Findings

During the course of this investigation, a number of secondary findings were established.

Students complained that the type of language used in the A level Physics examination was difficult as sometimes the questions were not straight to the point. Also, during examinations, students were expected to adopt certain assumptions such as constant temperature and pressure since these were not listed in the question. The time allotted for the A level Physics examination was not considered to reflect the amount of work which had to be done. This increased the students' anxiety and tension during the examination. Some teachers even stated that they themselves found it difficult to work out the paper in the time allotted, even not under examination conditions.

Teachers attributed the decline in the amount of students choosing A level Physics due to the following reasons: (i) due to the lack of information about the innovative careers involving Physics, students assume that Physics can lead them only to a very limited amount of careers, namely in architecture, in engineering and as scientist; (ii) prospective students consider that A level Physics is too difficult; and (iii) the erroneous conception that Physics is a subject for males.

There were mixed opinions amongst teachers whether the new system of the LOFs would be successful and fair to every student.

5.3 Strengths, Weaknesses and Challenges

This section will focus on the strengths and weaknesses of this study. It will also bring to the fore any challenges which the researcher encountered throughout this journey.

5.3.1 Strengths

The data for this study was collected from different persons of different age groups who occupied different roles in education. All Sixth Form second year students studying A level Physics in Malta and Gozo were invited to participate in this study. In this way, the researcher was confident that no student was being discriminated against and it was up to the students themselves to decide whether to participate or not. All A level Physics teachers in Malta and Gozo were also invited to participate in this study. This ensured a wide range of perspectives from students and teachers coming from different environments, have different intellectual abilities and socio-economic backgrounds. These various opinions were then merged together using triangulation, thus enhancing validity and reliability.

Another strength of this study was that the student sample of 165 questionnaires was quite large and therefore well representative of the cohort of Sixth Form second year students studying A level Physics in Malta and Gozo.

5.3.2 Weaknesses

Although all the A level Physics teachers were invited to participate in this study, the cohort was still small (16 out of 23 teachers). The researcher was very much aware that a different opinion from one teacher could generate a huge difference in the resultant percentages that were worked out. Also, due to this situation, some of the categories in the questionnaire distributed to teachers had to be grouped for SPSS computation, as in the case of teachers coming from Church and private schools. Furthermore, as shown in Table 3.1, the cohort of private school second year students studying A level Physics was also very small (10 out of 11 students).

The researcher is also aware that the ideal way to study the effects of the changes that were made in the SEC Physics syllabus in 2012 was to have a control group made up of participating students who would study the previous SEC Physics syllabus and sit for the same examinations as those students following the 2012 changes. In that way, the researcher could have compared the performance of both groups. This approach was not feasible for two reasons: (i) the limited time available for this research; and (ii) the strong unlikelihood of finding students willing to follow the pre-2012 syllabus.

5.3.3 Challenges

One of the most challenging aspects that the researcher found during this study was to manage time properly during the data collection period. This is because the data collection of this study had to be collected during school hours from different schools in Malta and Gozo. The fact that the researcher of this study is a full-time Physics teacher in Gozo made it rather difficult to find time to visit all the participating schools to collect the data.

The researcher could not start collecting the data as early as desired. This was the case because although the Ethics Committee approved the study in April 2018, the

Sixth Form second year students, as is customary, had stopped attending school in March. Thus, April was too late for the researcher to distribute questionnaires to Sixth Form second year students. As it turned out, the researcher had to wait for the start of the following scholastic year in October 2018 to start the data collection process.

Another challenge which arose during the data collection period was that one of the participating schools did not allow the researcher to visit the school. As an alternative, the researcher had to create online questionnaires and send them to the students through the school's secretary. The fact that the researcher did not meet the students and the fact that not all students were up to date with their email accounts might have reduced the number of students participating in this study.

5.4 Implications for Further Research

Along the course of this dissertation, the researcher noted that there is very little or no communication between teachers of SEC Physics and A level Physics. Accordingly, an interesting research would be to test whether better communication between teaching staff at these two levels would bring about an easier transition for students from secondary to post-secondary school.

Another interesting research proposition emerging from this present one would be an investigation about whether the A level Physics syllabus is an adequate preparation for the undergraduate degree course in Physics at the University of Malta.

5.5 A Final Conclusion – The Researcher's Personal View

During the course of this dissertation, it emerged that A level Physics cannot be regarded as a 'stand-alone' subject. It is not just the knowledge of the subject *per se* which determines the students' performance in the A level Physics examinations, as there are a number of other factors that influence the final results. Apart from the necessity of having a solid knowledge of the physics concepts and laws covered at SEC level, an A level Physics student requires the ability for higher order thinking, mathematical skills and reasoning, and sufficient English language competence as to enable the proper comprehension of the questions and articulation of the answers.

The researcher suggests that the SEC Physics course remains compulsory and, even though it might still be very early, students in Form 3 / year 9, might be given the option to choose one of two syllabi which need to be taught separately: (i) Syllabus 1 - a more in depth syllabus for those who want a good understanding of what the subject is all about. This ultimately may lead the students to achieve better grades at SEC level, help the students' progression to A level Physics, bridge the gap between SEC and A level Physics and hopefully increase the intake of students choosing a Physics university course; and (ii) Syllabus 2 - an easy syllabus which provides students with all the basic knowledge to pass the SEC Physics examination.

At an early stage, even at Form 3 / year 9 level, the Physics teacher has to be aware of those students who have an aptitude for Physics but are encountering difficulties in mathematical skills and/or comprehension and expression in English. Extra coaching in one or both of these two subjects may be suggested to these students by the school to address such difficulties before they become overwhelmed by them. According to Day (2018) presented in Section 1.1, this prevents students from giving up when they might have the potential to become amazing scientists.

The researcher considers that the GO4Industry internship is a step forward in promoting STEM careers. "The GO4Industry Teacher Internship Programme provides teachers an opportunity to upgrade their knowledge, skills and competences in STEM and in turn improve the teaching and learning of those subjects. The internship also aims to help teachers integrate 21st century skills and competences into their teaching – thus providing students insights into skills necessary at the workplace" (Directorate for Learning and Assessment Programmes MEDE, 2019, para. 1). Moreover, the researcher also reflects that it might be highly advantageous if this scheme is introduced to students during their summer months from Form 3 / Year 9 to Form 5 / Year 11, where the students will be able to experience different STEM careers at first-hand. Apart from helping students to mature and learn the necessary skills for a particular workplace, this experience will definitely help in the promotion of innovative careers in Physics.

The researcher believes that, as suggested by Erickson et al. (2013) mentioned in Section 2.2, a smoother transition from secondary to post-secondary school can be achieved if at least one meeting between SEC and A level teachers is held each year. During such a meeting, students' difficulties, needs and hardships are discussed together for the benefit of the Sixth Form students. This will enable SEC teachers to prepare students better for the challenges that the students might face at A level. Hopefully, this will decrease the gap that students feel at the beginning of post-secondary school and also minimize frustrations, anxiety and ultimately drop-outs.

The researcher considers short introductory sessions in Physics at the beginning of Sixth Form as potentially advantageous to students. Through such sessions, the students can familiarize themselves with the new school, teachers and even the new subjects that they will be studying, and thus the first few months of school are not lost in adjustment.

On reflection, it would be very practical for a prospective A level Physics student to be required to choose at least Mathematics and English at Intermediate level.

Continuous practice and development in these two subjects may ultimately help the students' confidence and performance.

The researcher also considers that schools might be provided with special science funds to be used to link topics with outside school agencies, for example: exposure of students to astronomy, aviation and career fairs (introducing innovative careers in Physics), amongst others. These funds can also motivate teachers to reach science teaching targets by enjoying financial incentives for organising interesting scientific seminars even after school hours: such as science live-ins and science trips abroad. Funds can also be used for Physics and Science teachers' continuous educational programmes leading to teachers' specialisation in all aspects of Science and rewarded by a grading system. The ultimate aim of such funds and programmes is to motivate students in choosing science subjects for their careers, to reverse the diminishing progression rates from SEC to A level Physics and therefore enhance the uptake of STEM careers.

One of the researcher's Science teachers used to say, "Science is fun when it is well done." The Physics teacher today faces the challenge of presenting Physics as an 'attractive' subject that leads to a sound knowledge of how the world around us works and of the great discoveries of science that have made the impossible possible for all mankind to enjoy a more comfortable life. All this can be really and truly achieved by understanding student difficulties and addressing them in the most effective and appropriate manner so that no student who has the potential to study Physics will give up on his studies.

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Appendices

Appendix 1

Information Sheets

Information Sheet – Head of School (6th Form Teachers)

Dear Head of School,

I am full-time Physics Teacher and am currently reading for a Masters degree in Science Education part-time. As part of this course, I will be conducting a dissertation with the name 'The Effect of a Number of SEC subjects on Advanced Level Physics'. My dissertation supervisor is Dr Martin Musumeci.

In my research, I will be investigating if:

i. SEC Level Physics is a good foundation for Advanced Level Physics;
ii. SEC Level Mathematics is an adequate preparation for Advanced Level Physics;
iii. There are any correlation coefficients between the grades in SEC Mathematics, Physics and English Language and Advanced Level Physics.

I would like to inquire whether it will be possible to conduct part of this research in your school. The research will be conducted in all post-secondary schools in Malta and Gozo.

To investigate the above research questions, I need to distribute 220 questionnaires to sixth form second year students who study Physics at Advanced Level. Some of these students will be later recruited for a focus group which will allow the researcher to obtain in-depth information about the subject.

To do so, I will be distributing consent forms to all sixth form second year students who study Physics at Advanced Level. The questionnaires will not be conducted during lessons. I will accept the first batch of questionnaires which reach the quota.

To compare and contrast the students' ideas, I will also need to distribute a questionnaire to teachers who teach Physics at an Advanced Level. Very few teachers of this sample, will be later recruited for interview to delve deeper into the subject.

The students' focus group is expected to take an hour while teachers' interviews are expected to take half an hour each. The students and the teachers respectively will be asked some questions about the matter and will be invited to discuss these questions in detail.

Both the focus group and the interviews will be voice recorded as I would need to transcribe all the answers and analyze them. Full honesty will be greatly appreciated as each and every answer will be contributing to create a fairly tested subject.

All the responses gathered during the focus groups, interviews and questionnaires will be kept anonymous. The data will be stored on an external hard drive and the file will only be accessed through a password which only I will know and which will not be divulged to anyone else. Back-ups will be stored in secure environments. All data will be destroyed two years after my graduation as I do not intend to use it for other researches.

If you give me your approval, I will send you information sheets and consent forms which need to be distributed to sixth form second year students who study Physics at Advanced Level and to the teachers who teach 2nd year Physics students. These will contain all the necessary information with regards to the students' rights during the research process.

I would like to assure you that the name of your school will only be known to me and to my supervisor and will not be disclosed in any way. Confidentiality of names of students will also be kept.

I would also like to assure you that I will abide by the ethical guidelines issued by the University Research Ethics Committee of the University of Malta throughout the course of my research.

Once I graduate I will be willing to share the results of my research with you.

If you require more information please do not hesitate to contact me.

Thank you very much for your kind attention.

Yours truly,

Nicola Cutajar
Email address: nicola.cutajar.11@um.edu.mt
Mobile Number: 79210848

Dr. Martin Musumeci
martin.m.musumeci@um.edu.mt

Information Sheet – Parent/Guardian for Student's participation

Dear parent/guardian,

I am full-time Physics Teacher and am currently reading for a Masters degree in Science Education part-time. As part of this course, I will be conducting a dissertation with the name 'The Effect of a Number of SEC subjects on Advanced Level Physics'. My dissertation supervisor is Dr Martin Musumeci.

In my research, I will be investigating if:

i. SEC Level Physics is a good foundation for Advanced Level Physics;
ii. SEC Level Mathematics is an adequate preparation for Advanced Level Physics;
iii. There are any correlation coefficients between the grades in SEC Mathematics, Physics and English Language and Advanced Level Physics.

To investigate these factors, I will need to distribute questionnaires to 6th form students who study Physics at Advanced Level. This questionnaire will take about 10 minutes to complete.

If you give your approval for your son/daughter to participate in this research, kindly fill in the attached consent form and return it to the assistant head. I will be collecting these forms one week from the date you received this sheet. These consent forms contain all necessary information about your rights and the rights of your son/daughter.

Seven of the students who complete the questionnaire will be later recruited for a focus group to allow the researcher to acquire detailed opinions about the matter. The focus group is expected to take an hour. The students will be asked some questions about the matter and will be invited to discuss these questions in detail. The focus group will be voice recorded as I would need to transcribe all the answers and analyze them. Full honesty will be greatly appreciated as each and every answer will be contributing to create a fairly tested subject.

All the responses gathered during the focus group and questionnaires will be kept anonymous. The data will be stored on an external hard drive and the file will only be accessed through a password which only I will know and which will not be divulged to anyone else. Back-ups will be stored in secure environments. All data will be destroyed two years after my graduation as I do not intend to use it for other researches.

I would like to assure you that the names of the students participating in this questionnaire will only be known to me and to my supervisor and will not be revealed in any way. In order to assure confidentiality I will be using other names in my write-up. I would also like to assure you that I will abide by the ethical guidelines issued by the University Research Ethics Committee of the University of Malta throughout the course of my research.

If you require more information please do not hesitate to contact me.

Thank you very much for your kind attention.

Yours truly,

Nicola Cutajar
Email address: nicola.cutajar.11@um.edu.mt
Mobile Number: 79210848

Dr. Martin Musumeci
martin.m.musumeci@um.edu.mt

Karta ta' Informazzjoni –
Ġenituri u Gwardjani għall-parteċipazzjoni ta' uliedhom

Għażiż ġenitur/gwardjan,

Jien għalliema tal-fiżika u bħalissa qiegħda nħarreġ lili nnifsi f'kors tal-Masters fl-Edukazzjoni tax-Xjenza ġewwa l-Università ta' Malta. Bħala parti minn dan il-kors, jien se nkun qiegħda nagħmel riċerka bl-isem 'L-Effett ta' Numru ta' Suġġetti fil-Livell tas-SEC fuq is-Suġġett tal-Fiżika fil-Livell Avvanzat'. Is-'supervisor' ta' din ir-riċerka hu Dr. Martin Musumeci.

F'din ir-riċerka, jien ħa nkun qiegħda ninvestiga jekk:

i. Il-fiżika fil-livell ordinarju hija bażi soda għall-fiżika fil-livell avvanzat;
ii. Il-matematika fil-livell ordinarju hiex preparazzjoni tajba għall-fiżika fill-livell avvanzat;
iii. Hemmx xi koeffiċjent tal-korrelazzjoni bejn il-marki li l-istudenti jakkwistaw fil-livell ordinarju tal-Matematika, Fiżika u fil-lingwa Ingliża mal-Fiżika fil-Livell Avvanzat.

Biex ninvestiga dawn il-fatturi, jien se nkun qiegħda nqassam kwestjonarji lill-istudenti tas-6th form li qegħdin fit-tieni sena jistudjaw il-Fiżika fil-Livell Avvanzat. Il-kwestjonarju jieħu madwar 10 minuti.

Jekk int tapprova li t-tifel/tifla tiegħek jieħu/tieħu sehem f'din ir-riċerka, jekk jogħġbok, imla l-karta ta' kunsens li hi mehmuża ma' din il-karta ta' informazzjoni u rritorna l-karta lill-Viċi Kap tal-iskola. Jien se nkun qed niġbor dawn il-karti ta' kunsens ġimgħa wara li tintbagħat din il-karta d-dar. Il-karta ta' kunsens tinkludi wkoll l-informazzjoni kollha dwar id-drittijiet tiegħek kif ukoll tat-tifel/tifla tiegħek waqt ir-riċerka.

Iktar 'il quddiem, seba' studenti se jkunu mitluba li jipparteċipaw f''focus group' biex jien inkun nista' niġbor informazzjoni iktar fid-detall dwar l-opinjonijiet tal-istudenti fuq dan l-aspett. Il-'focus group' se jieħu madwar siegħa. L-istudenti se jkunu mitluba biex iwieġbu l-mistoqsijiet tar-riċerkatur fid-dettall. Dan il-'focus group' se jiġi rrekordjat biex jien inkun nista' nirrevedi u nanalizza fid-dettall dak li jkun intqal waqt il-'focus group'. L-onesta' fit-tweġibiet se tkun apprezzata sabiex ikun jista' jintlaħaq riżultat ġust.

L-informazzjoni kollha li se nkun qed niġbor mill-kwestjonarji kif ukoll mill-'focus group' se tkun anonima. Din l-informazzjoni se tiġi miżmuma fil-laptop tiegħi u tista' tiġi aċċessata biss b'password. Back-ups ta' din l-informazzjoni se jiġu miżmuma f'postijiet siguri. Din l-informazzjoni se tiġi meqruda sentejn wara l-gradwazzjoni tiegħi.

Nixtieq naċċertak li l-ismijiet tal-istudenti li se jipparteċipaw f'din ir-riċerka se nkunu nafuhom biss, jien u s-'supervisor' ta' din ir-riċerka. Għaldaqstant minħabba dawn l-aspetti ta' kunfidenzjalità, ser jintużaw ismijiet fittizji. Nixtieq naċċertak ukoll li matul din ir-riċerka, se nkun qed nobdi l-linji ta' gwida etiċi maħruġa mill-Kumitat tar-Riċerka Etika fl-Universita' ta' Malta.

Jekk tixtieq iktar informazzjoni dwar din ir-riċerka, jekk jogħġbok ikkuntattjani.

Grazzi ħafna tal-attenzjoni.

Dejjem tiegħek,

Nicola Cutajar
Email address: nicola.cutajar.11@um.edu.mt
Mobile Number: 79210848

Dr. Martin Musumeci
martin.m.musumeci@um.edu.mt

Information Sheet – Student

Dear Student,

My name is Ms. Nicola Cutajar. I am a full-time Physics teacher and reading for a Masters degree in Science Education.

As part of my course I am conducting a study with the name 'The Effect of a Number of SEC subjects on Advanced Level Physics'. Thus, I need your help to investigate if:

i. SEC Level Physics is a good foundation for Advanced Level Physics;
ii. SEC Level Mathematics is an adequate preparation for Advanced Level Physics;
iii. There are any correlation coefficients between the grades in SEC Mathematics, Physics and English Language and Advanced Level Physics.

It will only take 10 minutes to fill up. If you approve to participate in this research, kindly fill in the attached consent form including your email address and return it to the assistant head. I will be collecting these forms one week from the date you received this sheet. These consent forms also contain all the necessary information about your rights during the research.

Later on, seven of you will be recruited for a focus group to allow me to gather detailed information about the subject. The focus group is expected to take an hour where you will be asked some questions about the matter. You will be invited to discuss these questions with four other students. The focus group will be voice recorded as I would need to transcribe and analyse all the answers.

Participation in this study is voluntary. Full honesty will be greatly appreciated as each and every answer will be contributing to create a fairly tested subject. All the responses gathered will be kept anonymous. The data will be stored on an external hard drive and the file will only be accessed through a password which only I will know and which will not be divulged to anyone else. Back-ups will be stored in secure environments. All data will be destroyed two years after my graduation.

I would like to assure you that your names will only be known to me and to my supervisor and will not be revealed in any way. In order to assure confidentiality I will be using other names in my write-up. I would also like to assure you that I will abide by the ethical guidelines issued by the University Research Ethics Committee of the University of Malta throughout the course of my research.

Thank you.

Yours sincerely,

Nicola Cutajar
Email address: nicola.cutajar.11@um.edu.mt
Mobile Number: 79210848

Dr. Martin Musumeci
martin.m.musumeci@um.edu.mt

Information Sheet – 6th Form Physics Teachers

Dear teacher,

I am full-time Physics Teacher and am currently reading for a Masters degree in Science Education. As part of this course, I will be conducting a dissertation with the name 'The Effect of a Number of SEC subjects on Advanced Level Physics'. My dissertation supervisor is Dr Martin Musumeci.

In my research, I will be investigating if:

i. SEC Level Physics is a good foundation for Advanced Level Physics;
ii. SEC Level Mathematics is an adequate preparation for Advanced Level Physics;
iii. There are any correlation coefficients between the grades in SEC Mathematics, Physics and English Language and Advanced Level Physics.

To investigate these factors, I need to distribute a questionnaire to all 6th Form Physics teachers. Thus, I would be able to compare and contrast teachers' and students' responses. The questionnaire will take about 10 minutes to complete.

To allow me to delve into further detail, you might also be recruited for an interview which will take around 30 minutes. You will be asked some questions on the matter and will be invited to discuss these questions in detail. The interview will be voice recorded as I would need to transcribe all the answers and analyze them. Full honesty will be greatly appreciated as each and every answer will be contributing to create a fairly tested subject.

All the responses gathered from the interviews and questionnaires will be kept anonymous. The data will be stored on an external hard drive and the file will only be accessed through a password which only I will know and which will not be divulged to anyone else. Back-ups will be stored in secure environments. All data will be destroyed two years after my graduation.

I would like to assure you that your names will only be known to me and to my supervisor and will not be revealed in any way. In order to assure confidentiality I will be using other names in my write-up. I would also like to assure you that I will abide by the ethical guidelines issued by the University Research Ethics Committee of the University of Malta throughout the course of my research.

If you require more information please do not hesitate to contact me.

Thank you very much for your kind attention.

Yours truly,

Cutajar

Nicola Cutajar
Email address: nicola.cutajar.11@um.edu.mt
Mobile Number: 79210848

Dr. Martin Musumeci
martin.m.musumeci@um.edu.mt

Information Sheet – Head of School (SEC Physics Teachers)

Dear Head of School,

I am full-time Physics Teacher and am currently reading for a Masters degree in Science Education part-time. As part of this course, I will be conducting a dissertation with the name 'The Effect of a Number of SEC subjects on Advanced Level Physics'. My dissertation supervisor is Dr Martin Musumeci.

In my research, I will be investigating if:

i. SEC Level Physics is a good foundation for Advanced Level Physics;
ii. SEC Level Mathematics is an adequate preparation for Advanced Level Physics;
iii. There are any correlation coefficients between the grades in SEC Mathematics, Physics and English Language and Advanced Level Physics.

I would like to inquire whether it will be possible to conduct part of this research in your school. The research will be conducted in all post-secondary schools and some secondary schools in Malta and Gozo.

To investigate these factors, I need to conduct six interviews with teachers who taught Physics at SEC level before and after 2012 i.e. before the changes in syllabus. Each interview will take around 30 minutes.

The teachers will be asked some questions on the matter and will be invited to discuss these questions in detail. The interview will be voice recorded as I would need to transcribe all the answers and analyze them. Full honesty will be greatly appreciated as each and every answer will be contributing to create a fairly tested subject.

All the responses gathered from the interview will be kept anonymous. The data will be stored on an external hard drive and the file will only be accessed through a password which only I will know and which will not be divulged to anyone else. Back-ups will be stored in secure environments. All data will be destroyed two years after my graduation.

I would like to assure you that the name of your school and the names of the teachers who participate in this research will only be known to me and to my supervisor and will not be disclosed in any way.

I would also like to assure you that I will abide by the ethical guidelines issued by the University Research Ethics Committee of the University of Malta throughout the course of my research.

Once I graduate I will be willing to share the results of my research with you.

If you require more information please do not hesitate to contact me.

Thank you very much for your kind attention.

Yours truly,

Nicola Cutajar
Email address: nicola.cutajar.11@um.edu.mt
Mobile Number: 79210848

Dr. Martin Musumeci
martin.m.musumeci@um.edu.mt

Information Sheet – SEC Physics Teachers

Dear teacher,

I am full-time Physics Teacher and am currently reading M.Ed. Science part-time. As part of this course, I will be conducting a dissertation with the name 'The Effect of a Number of SEC subjects on Advanced Level Physics'. My dissertation supervisor is Dr Martin Musumeci.

In my research, I will be investigating if:

i. SEC Level Physics is a good foundation for Advanced Level Physics;
ii. SEC Level Mathematics is an adequate preparation for Advanced Level Physics;
iii. There are any correlation coefficients between the grades in SEC Mathematics, Physics and English Language and Advanced Level Physics.

To investigate these factors, I need to conduct six interviews with teachers who taught Physics at SEC level before and after 2012 i.e. before the changes in syllabus. This will allow bring forward teachers' views and opinions about such changes. The interview will take around 30 minutes.

You will be asked some questions on the matter and will be invited to discuss these questions in detail. The interview will be voice recorded as I would need to transcribe all the answers and analyze them. Full honesty will be greatly appreciated as each and every answer will be contributing to create a fairly tested subject.

All the responses gathered from the interview will be kept anonymous. The data will be stored on an external hard drive and the file will only be accessed through a password which only I will know and which will not be divulged to anyone else. Back-ups will be stored in secure environments. All data will be destroyed two years after my graduation.

I would like to assure you that your name will only be known to me and to my supervisor and will not be revealed in any way. In order to assure confidentiality I will be using other names in my write-up. I would also like to assure you that I will abide by the ethical guidelines issued by the University Research Ethics Committee of the University of Malta throughout the course of my research.

If you require more information please do not hesitate to contact me.

Thank you very much for your kind attention.

Yours truly,

Cutajar

Nicola Cutajar
Email address: nicola.cutajar.11@um.edu.mt
Mobile Number: 79210848

Dr. Martin Musumeci
martin.m.musumeci@um.edu.mt

Appendix 2

Consent Forms

Consent Form – Parent/Guardian for Son/Daughter's Participation

I, the undersigned, have read the information sheet and agree to let my son/daughter ______________________ participate in Ms. Nicola Cutajar's research with the name 'The Effect of a Number of SEC subjects on Advanced Level Physics.'

✓ I also understand that no form of coercion will be used to force my son/daughter to participate in this research.

✓ I understand that this dissertation study is being carried out by Ms. Nicola Cutajar as part of her Masters degree at the University of Malta.

✓ I understand that if I let my son/daughter participate in Ms. Nicola Cutajar's research, then I may withdraw my son/daughter at any time without having to justify my actions.

✓ I understand that my son/daughter's name will not be divulged to third parties except to Ms. Nicola Cutajar's supervisor.

✓ I understand that my son/daughter may refuse to answer any of the questions asked by Ms. Nicola Cutajar without having to justify her/his actions and without any prejudice.

I agree to let my son/daughter fill in the questionnaire provided by Ms. Nicola Cutajar.

YES ☐ NO ☐

I give consent that my son/daughter might participate in a focus group with Ms. Nicola Cutajar and other students.

YES ☐ NO ☐

Name of parent: ______________________________________

Signature of Parent	Signature of Researcher	Signature of Supervisor
______________	Cutajer. ______________	[signature] ______________

Personal Information: Mobile Number: 79210848
E-mail address: nicola.cutajar.11@um.edu.mt

Karta ta' Kunsens - Ġenituri/Gwardjani

Jien qrajt l-ittra ta' informazzjoni u naqbel li t-tifel/tifla tiegħi, ______________________________ , jipparteċipa/tipparteċipa fl-istudju 'L-effett ta' numru ta suġġetti fil-livell tas-SEC fuq is-suġġett tal-fiżika fil-livell avvanzat' li se twettaq Ms. Nicola Cutajar.

✓ Jien nifhem ukoll li ibni/binti mhux se jkun/tkun sfurzat/a biex jipparteċipa/tipparteċipa f'din ir-riċerka.

✓ Jien nifhem li dan l-istudju huwa parti mill-kors li Ms. Nicola Cutajar qiegħda tattendi fl-Universita` ta' Malta.

✓ Nifhem ukoll li jekk ibni/binti jaċċetta/ taċċetta li jipparteċipa/tipparteċipa f'dan l-istudju, hu/hi tista' jieqaf/tieqaf meta irid/trid mingħajr ma jati/tati l-ebda raġuni u mingħajr ma jkun/tkun preġudikat/a.

✓ Jien nifhem li isem ibni/binti se jkun magħruf biss mis-'supervisor' ta' Ms. Nicola Cutajar.

✓ Jien nifhem li ibni/binti jista'/tista' ma jweġibx/tweġibx għal xi mistoqsijiet fil-kwestjonarju mingħajr ma jati/tati l-ebda raġuni u mingħajr ma jkun/tkun preġudikat/a.

Jien naqbel li ibni/binti tiegħi jimla l-kwestjonarju provdut minn Ms. Nicola Cutajar.

IVA ☐ LE ☐

Jien naqbel li ibni/binti jista'/tista' jiġi/tiġi mgħajjat/mgħajjta għal focus group magħmul minn Ms. Nicola Cutajar u xi studenti oħra.

IVA ☐ LE ☐

Isem tal-Ġenitur/Gwardjan: ______________________________

Firma tal-ġenitur/gwardjan	Firma tar-riċerkatur	Firma tas-'supervisor'
______________	Cutajar.	[signature]

Informazzjoni Personali: *Mobile Number: 79210848*
E-mail address: nicola.cutajar.11@um.edu.mt

Assent Form for Students

I, _________________________________ have read the information sheet and agree to participate in Ms. Nicola Cutajar's research with the name 'The Effect of a Number of SEC subjects on Advanced Level Physics.'

✓ I also understand that no form of coercion will be used to force me to participate in this research.

✓ I understand that this dissertation study is being carried out by Ms. Nicola Cutajar as part of her Masters degree at the University of Malta.

✓ I understand that if I participate in Ms. Nicola Cutajar's research, then I may withdraw at any time without having to justify my actions.

✓ I understand that my name will not be divulged to third parties except to Ms. Nicola Cutajar's supervisor.

✓ I understand that I may refuse to answer any of the questions asked by Ms. Nicola Cutajar without having to justify her/his actions and without any prejudice.

I agree to fill in the questionnaire provided by Ms. Nicola Cutajar.

YES ☐ NO ☐

I agree to participate in a focus group with Ms. Nicola Cutajar and other students.

YES ☐ NO ☐

Email address of student: _________________________________

Signature of Student	Signature of Researcher	Signature of Supervisor
____________	Cutajar. ____________	____________

Personal Information: Mobile Number: 79210848
E-mail address: nicola.cutajar.11@um.edu.mt

Consent Form – 6th Form Physics Teachers

I, ________________________________, have read the information sheet and agree to participate in Ms Nicola Cutajar's research with the name 'The Effect of a Number of SEC subjects on Advanced Level Physics.'

✓ I understand that no form of coercion will be used to force me to participate in this research.

✓ I understand that this dissertation study is being carried out by Ms Nicola Cutajar as part of her Masters degree at the University of Malta.

✓ I understand that if I agree to participate in Ms Nicola Cutajar's research, then I may withdraw at any time without having to justify my actions.

✓ I understand that my name will not be divulged to third parties except to Ms Nicola Cutajar's supervisor.

✓ I understand that I may refuse to answer any of the questions asked by Ms. Nicola Cutajar without having to justify my actions and without any prejudice.

✓ I understand that I may stop answering questions asked by Ms. Nicola Cutajar without having to justify my actions and without any prejudice.

I agree to fill in the questionnaire provided by Ms. Nicola Cutajar.

YES ☐ NO ☐

I agree to participate in an interview conducted by Ms. Nicola Cutajar

YES ☐ NO ☐

Email address: ________________________________

Signature of Teacher	Signature of Researcher	Signature of Supervisor
____________	Cutajar	[signature]

Personal Information: Mobile Number: 79210848
E-mail address: nicola.cutajar.11@um.edu.mt

Consent Form – SEC Physics Teachers

I, ______________________________, have read the information sheet and agree to participate in Ms. Nicola Cutajar's research with the name 'The Effect of a Number of SEC subjects on Advanced Level Physics.'

- ✓ I also understand that no form of coercion will be used to force me to participate in this research.
- ✓ I understand that this dissertation study is being carried out by Ms. Nicola Cutajar as part of her Masters degree at the University of Malta.
- ✓ I understand that if I agree to participate in Ms. Nicola Cutajar's research, then I may withdraw at any time without having to justify my actions.
- ✓ I understand that my name will not be divulged to third parties except to Ms. Nicola Cutajar's supervisor.
- ✓ I understand that I may refuse to answer any of the questions asked by Ms. Nicola Cutajar without having to justify my actions and without any prejudice.
- ✓ I understand that I may stop answering questions asked by Ms. Nicola Cutajar without having to justify my actions and without any prejudice.

I agree to participate in an interview conducted by Ms. Nicola Cutajar.

YES ☐ NO ☐

Email address: ____

Signature of Teacher	Signature of Researcher	Signature of Supervisor
____________________	Cutajar [signature]	[signature]

Personal Information: Mobile Number: 79210848
E-mail address: nicola.cutajar.11@um.edu.mt

Appendix 3

Questionnaires distributed to
Sixth Form second year students

Questionnaire – Sixth Form Students

Dear student,

I am a full time Physics teacher and currently reading for a Masters degree in Science Education at the University of Malta.

I am conducting this questionnaire for my dissertation with the name "The Effect of a Number of SEC subjects on A level Physics". The questionnaire will be conducted once to help out in answering two of the four research questions.

This questionnaire is confidential. Your opinions DO count, so honesty throughout the questionnaire will be highly appreciated.

Thank you,
Nicola Cutajar

---

1. Gender:
   ☐ Male ☐ Female

2. Tick appropriately:
   ☐State School ☐ Church School ☐ Private School

3. Looking back at your transition from secondary to post-secondary do you consider it to be:
   ☐ Smooth ☐ Challenging

4. Do you consider that SEC level Physics is a good background/foundation for Physics at 'A' Level?
   ☐ Very good ☐ Good ☐ Not so good ☐ Not good at all

5. When studying Physics at A level, do you consider it to be:
   ☐ A continuation of what you studied in Physics at SEC level, but harder;
   ☐ Completely different from the SEC level

6. How different do you consider Physics at A level from Physics at SEC level?
   ☐ Completely different ☐ Slightly different ☐ Not so different

7. List **up to 3 topics** in Physics A level which you consider as NOT HAVING a good preparation at SEC Level.
   i. ______________________________
   ii. ______________________________
   iii. ______________________________

8. Are mathematical concepts important for studying Physics?
   ☐ Yes ☐ No

9. Give an estimate of the percentage of the A level Physics syllabus that needs Mathematics?
   ☐ 0% ☐ 25% ☐ 50% ☐ 75% ☐ 100%

10. How prepared do you feel to work out A level Physics problems using knowledge from SEC level Mathematics only?
    ☐ Very well prepared ☐ Prepared ☐ Not prepared enough

11. What is the least level of Mathematics a student should have for A level Physics?
    ☐ SEC Level ☐ Intermediate Level ☐ Advanced Level

12. List **up to 3** of the most difficult mathematical concepts necessary for A level Physics.
    i. ____
    ii. ____
    iii. ____

13. Are your difficulties in A level Physics characterised by: *(You can tick more than one)*
    ☐ Discontinuation between what you have learnt in SEC Physics and A level Physics
    ☐ Understanding physics concepts, theories and laws
    ☐ Confusion about the meaning of symbols and symbolic equations
    ☐ Applying mathematical skills to solve physics problems
    ☐ Language difficulties in expressing yourself properly
    ☐ None of the above
    ☐ Any other/s - Explain briefly. ____

14. How do your English Language skills help you in your achievement in A level Physics? *(You can tick more than one)*
    ☐ Understanding the concepts of Physics well
    ☐ Understanding the question properly
    ☐ Answering accordingly by applying my knowledge in writing
    ☐ None of the above
    ☐ Any other/s - Explain briefly. ____

Appendix 4

Questionnaires distributed to Sixth Form teachers

Questionnaire – Sixth Form Teachers

Dear teacher,

I am a full time Physics teacher and currently reading for a Masters degree in Science Education at the University of Malta.

I am conducting this questionnaire for my dissertation with the name "The Effect of a Number of SEC subjects on A level Physics". The questionnaire will be conducted once to help out in answering my research questions.

Should you need any help regarding the questions in the questionnaire, do not hesitate to ask.

This questionnaire is highly confidential. Your opinions DO count, so honesty throughout the questionnaire will be highly appreciated.

Thank you,
Nicola Cutajar

---

1. Gender:
   ☐ Male ☐ Female

2. Do you teach in a:
   ☐ State School ☐ Church School ☐ Private School

3. Do you think that the transition from secondary to post-secondary of the majority of the students you teach is:
   ☐ Smooth ☐ Challenging

4. Comparing the students you used to teach before the 2012 changes (in the SEC Physics syllabus), how are the students you are teaching now being prepared to study Physics at A level?
   ☐ More prepared ☐ The same ☐ Less prepared

5. How much do you consider the changes in the Physics SEC syllabus to be helpful for the students?
   ☐ Extremely helpful ☐ Helpful ☐ Not so helpful ☐ Not helpful at all

6. On a personal level as a Physics teacher, how much do you consider the changes in the SEC Physics syllabus to be helpful to you?
   ☐ Extremely helpful ☐ Helpful ☐ Not so helpful ☐ Not helpful at all

7. Do you think that SEC level Physics gives the students a good background/foundation to study Physics at A level?
   ☐ Very good ☐ Good ☐ Not so good ☐ Not good at all

8. Do you consider Physics at A level to be:
   ☐ A continuation of Physics at SEC level, but harder;
   ☐ Completely different from the SEC level

9. Are mathematical concepts important for studying Physics?
   ☐ Yes ☐ No

10. Give an estimate of the percentage of the Physics A level syllabus that needs Mathematics?
    ☐ 0% ☐ 25% ☐ 50% ☐ 75% ☐ 100%

11. What is the least level of Mathematics a student should have for A level Physics?
    ☐ SEC Level ☐ Intermediate Level ☐ Advanced Level

12. Do you think that the students' difficulties in A level Physics are characterised by:
    (You can tick more than one)
    ☐ Discontinuation between what they have learnt in SEC Physics and A level Physics
    ☐ Understanding physics concepts, theories and laws
    ☐ Confusion about the meaning of symbols and symbolic equations
    ☐ Applying mathematical skills to solve Physics problems
    ☐ Language difficulties in expressing themselves properly
    ☐ Any other/s - Explain briefly. ____

13. Are English Language skills important for studying Physics?
    ☐ Yes ☐ No

14. How do students' English Language skills help them in their achievement in A level Physics? *(You can tick more than one)*
    ☐ Understanding the concepts of Physics well
    ☐ Understanding the question properly
    ☐ Answering accordingly by applying their knowledge in writing
    ☐ Any other/s - Explain briefly. ____
    ☐ None of the above

Appendix 5

Focus Group Questions to Sixth Form second year students

Focus Group – guide sheet

Remind the students to give examples from the syllabus during the discussion. This will help to understand more what they are actually talking about.

1. Describe any challenges you encountered in your transition from secondary to post-secondary school.

2. Do you consider that SEC level Physics is a good background/foundation to study Physics at A level? Explain further.

3. Is A level Physics a continuation of SEC level Physics? Explain further.

4. IF RESPONDENTS FEEL IT IS NOT 'RELATED' ….

   Do you have any recommendations/suggestions of how this could be changed?

5. Do you think that there is a relationship between Mathematics and Physics? How?

6. Do you think that a student who studies Physics at A level would be able to work out the problems using Mathematics at SEC level only? Explain further.

7. Do you have any recommendations/suggestions of how this could be changed?

8. What are the difficulties you encounter when studying A level Physics?

9. Do you think that your skills in English have any effect on your achievement in Physics at A level? In what way?

Appendix 6

Interview Questions to Sixth Form Physics Teachers

Interview – Sixth Form Teachers

Invite the teachers to, as much as possible, provide examples from the syllabus and even from their previous experience in the classroom as Physics A level teachers.

1. Comparing the students you used to teach before and after the 2012 (changes in the SEC Physics syllabus), do you see any particular changes in their preparation to study Physics at A level? Explain.

2. The table below shows the trends of the number of students choosing a science subject as one of their A level.

   Biology is the most popular subject amongst the three sciences. Chemistry was the least popular till 2009, however, it shows a general increase. Physics was the second most popular subject however, chemistry has now surpassed it.

   Did you observe these trends in the number of A level students you teach? In your opinion, what is the reason behind these trends? Do you have any suggestions of how educators can motivate students in choosing A level Physics?

	2008	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
% AM **Biology**	21.1%	24.4%	24.1%	22.1%	27.2%	27.6%	29.9%	32.7%	32.1%	30.6%
% AM **Chemistry**	14.9%	16.7%	17.7%	15.6%	18.9%	19.7%	22.7%	25.1%	24.1%	21.9%
% AM **Physics**	20.9%	19.5%	17.2%	18.5%	21.2%	19.4%	19.3%	21.2%	18.3%	18.0%

3. Can you mention any distinctive changes in the SEC Physics syllabus that greatly affected you and your teaching?

4. How and in what ways were these changes in the SEC Physics syllabus helpful or otherwise to the students?

5. In your opinion, does SEC level Physics give the students a good background/foundation to study Physics at A level? Explain briefly.

6. Is there a continuation from SEC Level Physics to A level Physics? In what ways? Give reference to chapters in syllabus.

7. With regards to Mathematics in Physics, could a student study Physics at A level without choosing Mathematics at Intermediate or A level? Explain briefly.

8. Can you give examples from the Physics A level syllabus of the difficult mathematical content that the students need to know to go through in the A level syllabus?

9. In your opinion, what are the majority of the students' difficulties characterised by?

10. With regards to English Language skills, do you think that there is a correlation between English and the students' achievement in Physics? In what ways?

Appendix 7

Interview Questions to SEC Physics Teachers

Interview – SEC Physics Teachers

Invite the teachers to, as much as possible, provide examples from the syllabus and even from their previous experience in the classroom as Physics teachers.

Research Question 1: What were the distinctive changes in syllabus in 2012?

1. In your opinion, what might be the reasons behind the changes in syllabus in 2012?

2. Do you agree with the reduction of some chapters from the SEC Physics syllabus? Why?

3. What are your first impressions with regards to the changes in the upcoming syllabus and the introduction of LOFs?

Research Question 2: Is SEC Level Physics a good foundation for Advanced Level Physics?

4. Are these changes making the students more prepared for the SEC Level Physics exam? In which ways?

5. If the students decide that they want to further their knowledge in Physics and choose it as one of their A level subjects, do these changes in Physics SEC level affect the way in which the students are prepared? How?

6. Do you feel that the current Physics syllabus gives the students an adequate background/ foundation to study Physics at A level? Why?

7. The table below shows the trends of the number of students choosing a science subject as one of their A level.

   Biology is the most popular subject amongst the three sciences. Chemistry was the least popular till 2009, however, it shows a general increase. Physics was the second most popular subject however, chemistry has now surpassed it.

   Did you observe these trends in the number of A level students you teach? In your opinion, what is the reason behind these trends? Do you have any suggestions of how educators can motivate students in choosing A level Physics?

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
% AM **Biology**	21.1%	24.4%	24.1%	22.1%	27.2%	27.6%	29.9%	32.7%	32.1%	30.6%
% AM **Chemistry**	14.9%	16.7%	17.7%	15.6%	18.9%	19.7%	22.7%	25.1%	24.1%	21.9%
% AM **Physics**	20.9%	19.5%	17.2%	18.5%	21.2%	19.4%	19.3%	21.2%	18.3%	18.0%

Research Question 3: Is SEC level Mathematics an adequate preparation for Advanced Level Physics?

8. Do you think that the students' mathematical skills might play an important role in their achievement during Physics examinations? In what ways?

9. Can you mention any mathematical difficulties that the students encounter/find most difficult during the Physics lesson?

10. In your opinion, if the students do not chose Mathematics to accompany Physics at A level, would they be adequately prepared to work out problems in Advanced Level Physics? Why?

Research Question 4: What are the correlation coefficients between the grades in SEC Maths, Physics and English Language and A level Physics?

11. Do you think that the students' English/language skills might play a role in their achievement during Physics examinations? In what ways?

12. Do you think that there are any other subjects which might affect the students' achievement in their Physics examinations? If yes, please specify.

Appendix 8

Changes in the 2012 SEC Physics syllabus

Changes Physics SEC 2012

2011	2012
Scheme of assessment	

2011

Ability	Paper I	Paper IIA or Paper IIB	% Mark
Knowledge and Understanding	*	*	40%
Problem Solving	*	*	30%
Design and Planning of Experiments		*	15%
Practical Assessment	*		15%
Approximate % of total mark	55%	45%	100%

2012

Ability	Paper I	Paper IIA or Paper IIB	% Mark
Knowledge and Understanding	15	20	**35%**
Problem Solving	15	15	30%
Design and Planning of Experiments	10	10	**20%**
Practical Assessment	15		15%
Approximate % of total mark	55%	45%	100%

2011	2012
Practical Work: Marks	
• The marks of the practical work is to be based on the average mark of the best fifteen *(15)* experiments.	• The mark of the practical work is to be based on the average mark of Either: the best fifteen (15) experiments, OR: the best thirteen experiments and a longer investigation which will be given two marks out of 15 marks.
	Candidates are expected to present at least two experiments for each theme 1-6.

New in syllabus

The sections of the learning programme are divided into three columns:
The actual learning outcomes
Suggested teaching activities
Historical and Science, Technology, Society (STS) connections.

Below is a list of new learning outcomes included in the syllabus. The historical and STS connections and suggested activities are not included in this list.

Theme 1: On the Move

1.14 Be able to understand that the longer the time of impact, the smaller is the force of impact and apply it to practical situations.

1.15 Understand the concept of energy as the ability to do work.

Theme 2: Balancing Forces

2.1 Describe situations where different types of forces such as weight (gravitational force), tension, contact forces and frictional forces occur.

2.2 Draw the forces acting on an object and understand that each force acts in one direction.

2.5 ***Vector and scalar quantities and classification of basic quantities in Physics.***

Theme 3: The Nature of Waves

3.5 Includes terms displacement, amplitude, crest and trough

3.6 Recall of frequency as the number of waves per second that are produced by the source or that pass through any particular point.

3.8 Recall that the wavelength of waves is the distance between the same point on two

adjacenet disturbances.
3.13 Draw and interpret wave diagrams to show a) reflection of plane water waves b) narrow beams of sound and c) light from a plane mirror
3.18 Associate refraction of light with apparent depth of water. (formula)
3.21 Use semicircular glass block to demonstrate that the direction of the emergent ray depends upon the angle of incidence in the glass block.
3.22 ***Included action of a thin diverging lens on a beam of light.***
Theme 4: Staying Cool
4.1 ***Describe qualitatively the molecular structure of solids, liquids and gases and the motion of their particles.***
4.3 Use of density to explain floating and sinking.
4.4 Appreciate that the hotter a substance is, the more energy its particles have, resulting in expansion.
4.6 Relate a rise in the temperature of a body to an increase in internal energy.
4.7 Describe evaporation in terms of the escape of the escape of the more energetic molecules from the surface of a liquid.
4.8 Relate evaporation to cooling.
4.13 Know the meaning of the term conduction and insulation.
4.17 Understand the different rates of emission and absorption of heat energy of matt black and silver.
Theme 5: Electricity in the Home
5.13 Be able to draw current diagrams showing how an ammeter and/or voltmeter can be converted appropriately to measure current and voltage respectively.
5.21 Calculate the combined resistance of two resitors in parallel using the equation...
5.30 Use the equation for Energy, E = Pt in Joules and Kilowatt hours.
5.32 Calculate the cost of electrical energy given the power, time and the cost per unit.
Theme 6: Magnets and Motors
6.1 Explain that magnetic poles exist in pairs.
6.4 State the forces between: like poles; unlike poles; magnetic and non-magnetic materials.
6.6 Describe how demagnetisation can be achieved using...
6.8 Simple experiments to identify pattern and direction of field lines includes also a straight wire carrying a current; a solenoid.
6.10 Understand that the Earth has its own magnetic field and that the magnetic north pole and true North Pole are not on the same place on the Earth.
6.12 Investigate how changing the current or number of turns may vary the strength of the field of the solenoid.
Theme 7: Radiation and its Uses
Theme 8: The Earth and the Universe
8.3 Season
8.7 characteristics of a planet to include also: has a nearly round shape; has cleared the neighbourhood around its orbit.
8.8 Name the major planets of the Solar system.
8.9 Recognise that Pluto is a dwarf planet because it has not cleared the neighbourhood around its orbit.
8.11 State that distances in space are measured in light years and that one light year is...
8.12 Name the instruments which can be used to observe the night sky.
8.13 Identify a few of the social and economic benefits of space explorations.
8.14 Recognise that there are still many unanswered questions about the Universe.

Appendices:
Table of symbols
Mathematical Notations
SI units and Symbols
Two examples of Practical Investigations
Deleted from previous syllabus
Measurement: Length: Use and describe the use of rulers and measuring cylinders to determine a length or a volume
Time: Use and describe the use of clocks and stopwatches to determine an interval of time
Mass: Use and describe the use of balances, including an electronic balance, to determine the mass of an object
Units: All physical quantities should be accompanied by SI units
Forces
Streching materials: Deleted rubber band under Hooke's Law.
Pressure in liquids: Apply the equation of pressure to simple hydraulic machines.
Atmospheric pressure: know that atmospheric pressure may be measured by a barometer. Appreciate that changes in atmospheric pressure may indicate a change in the weather.
Forces and Motion
Newton's Laws of Motion Understand that for a body moving through a medium, resistive forces depend on body and speed. Understand that forces acing on a body which has reached terminal speed are balanced.
Energy Work and Power
Energy efficiency: internal combustion engine
Heat Energy
Temperature: know that temperature is a measure of degree of hotness
Heat: Definition of specific heat capacity. Describe one everday effect due to the relatively large specific heat of water.
Heat Transfer: Describe the role of convection in space heating. Understand that insulation reduces energy transfer by conduction and convection. Appreciate that power radiated increases with increase in temperature.
Waves
Waves: Understand that the wave frequency is determined by the source. Identify wavelength and amplitude in transverse and longitudinal waves. Describe the effect on wavelength of change in frequency of the vibrator in a ripple tank.
Reflection: Describe the formation, and give the characteristics of an optical image by a plane mirror.
Refraction: partial reflection.
Converging lenses: Describe the action and use of optical fibres.
Diffraction: wide gaps Appreciate that diffraction of light is evidence that light behaves like waves.
Sound
Sound: Describe the production of sound by vibrating sources State the approximate range of audible frequencies Describe how reflection of sound may produce echoes Describe how a signal generator and loudspeaker may be used to produce sounds of varying frequency and loudness

Describe how an oscilloscope and a microphone may be used to obtain a signal trace on the oscilloscope screen Describe the effect on loudness of change in amplitude and the effect on pitch of change in frequency
Section on Resonance
Section on Stretched Springs
Electrostatics
Section on Induced charges
Current Electricity
Voltage: Show understanding that e.m.f. is defined as the energy supplied by a source in driving 1C round a complete circuit
Resistance: Know how to use an ammeter and voltmeter Use a variable resistor to control current.
V-I characteristic graphs: Describe experiments by with V-I graphs for a metallic conductor kept at constant temperature and a filament lamp can be drawn.
Alternating current: Describe how a diode may be used to rectify an alternaling current and how an oscilloscope may be used to demonstrate this action of a diode. NOTE IN NEW SYLLABUS HALF WAVE RECTIFICATION IS INCLUDED.
Magnetism
Magnetism: State the properties of magnets. Distinguish between the design and the use of permanent magnets and electromagnets.
Radioactivity
The nucleus: Appreciate that the number of protons in a nucleus distinguishes one element from another.
Stability of nuclei: Appreciate that an element may change into another element when radioactivity occurs.
Section on nuclear equations
The Earth and the Universe
Solar system: appreciate that stars stay fixed in position. Appreciate that the planets reflect light from the sun.
Satellites: Understand that satellites can be used to send information between places on the Earth which are far apart, to monitor conditions on Earth, including the weather, and to observe the Universe without the atmosphere getting in the way. Understand that communications satellites are usually put into orbit high above the equator and that they orbit the Earth once a day so that they appear stationary when viewed from Earth. Understand that monitoring satellites are usually put in low polar orbit so that the Earth spins beneath them and they can scan the whole Earth each day.
The universe: Appreciate that galaxies are often millions of times further apart than the stars within the galaxy
Section on Formation of stars
Section on Origin of Universe