Is SEC Level Physics An Adequate Preparation for Studies at Advanced Level?

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The change from Physics intended for a small group of high achievers to Physics for all brought about a change in syllabus content. The Physics syllabus at Secondary School level is seen to have a dual role: to introduce students to Physics as a preparation for life and to prepare students who wish to continue studying Physics at higher levels. The study reported in this paper attempted to evaluate how far the second aim is reached: it investigated whether in students' and teachers' views, the Secondary Education Certificate (SEC) syllabus gave an adequate preparation to students who eventually studied Physics at Advanced level. Seventeen sixth-form teachers were interviews and 411 students filled in questionnaires by means of which they identified content areas and skills that were adequately covered at SEC level and others that were not. Most students felt that preparation in practical work and quantitative aspects of Physics was lacking. They felt best prepared in Mechanics and least prepared in Fields and Nuclear and Particle Physics. Most teachers described the SEC syllabus as superficial and failing to provide the students with the appropriate tools for the deeper Advanced level syllabus.

Introduction

Physics was first introduced in Malta as a subject intended for a small number of high achievers, initially offered only for boys and eventually also for girls (Mizzi, 1996). It remained so until 1979 when the subject became one of the four core subjects together with Mathematics, Maltese and English (Zammit Mangion, 1992). Between 1979 and 1994 all students in Maltese secondary schools studied Physics; in fact Physics was one of the compulsory requirements for entry into sixth-forms and University . As from 1995, students are required to possess a pass in any science subject for entry to sixth-form . (University of Malta, 2006) but all state schools and a number of non-state schools still offer Physics as the compulsory science subject, with the other science subjects offered as option subjects. The change from Physics designed for a small group of high achievers to Physics for all brought about a change in syllabus content.

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. In this case, it also aims to prepare students to enable them to continue studying Physics at these higher levels. In the syllabus for Physics intended for local students between age 14 and 16 years, there are two aims related to the two roles that the syllabus is expected to cater for:

"… to contribute to the pupils' general education by helping them to make sense of the physical environment through scientific enquiry; to provide the basis for further study of the subject …"
(SEC Physics 2006-7, MATSEC 2003b, p. 2).

This shows the intention of providing students with an educational experience that caters for the needs of students who wish to further their studies as well as those who do not. But whether these aims are reached at all, and how these aims may be reached is another matter. A similar concern was expressed about the science curriculum in England in a recent House of Commons Select Committee report:

"The science curriculum at 14-16 aims to engage all students with science as a preparation for life. At the same time, it aims to inspire and prepare some students to continue with science post -16. In practice it does neither of these well …"
(HMSO, 2002, p.57).

When investigating the predictive validity of SEC level examinations for success at Advanced level (A -level), Farrugia and Ventura (2005) observed that students who do well in Physics at SEC level are likely to do well at A-level. In fact students with Grades 1 to 4 at SEC level were found to have 62.1% chance of obtaining Grades A to C at Advanced level (86.5% if starting with Grade 1; 82.7% if starting with Grade 2; 61.3% if starting with Grade 3 and 34.2% if starting with Grade 4). However determination of the Spearman Rank Order Correlation Coefficient resulted in a moderate correlation of 0.57. In a similar study based on results obtained by Junior College students, Pace and Bonello (2006) investigated the correlations between the SEC Physics results, the results of four informal assessments and the formal test held at the end of the first year at the Junior College and the students' performance in the A-level Physics examination. Their data consisted of the results of 159 students who finished their two-year course in 2000 and another group of 153 students who finished the course in 2002. They found correlations of $r = 0.488$ and $r = 0.442$ between SEC and A-level results. They noted no gender differences in the students' performance in the SEC and A-level examinations. They also found that students who had sat for Paper IIB at SEC level and had obtained Grade 4 still stood a fair chance of obtaining a good grade in the AM Physics examination.

A more recent study (Farrugia and Ventura, 2007) involving the whole Physics population sitting for Advanced level Physics in 2006 and SEC level Physics in 2004 (372 candidates) showed a correlation (Spearman Rank Order Correlation Coefficient) of 0.62. Most of the students with Grades 1 and 2 in Physics at SEC level were able to acquire Grades A to C at Advanced level. Quite a good number of candidates with Grade 3 at SEC level (68%) were able to obtain Grades A to C at Advanced level but a very sharp drop in performance was observed in the case of students with Grade 4 at SEC level. In fact only 33.6% of these students obtained Grades A to C at Advanced level. The authors observed that students with Grade 5 or lower at SEC level were unlikely to sit for the examination in Advanced level Physics or failed to obtain the higher grades if they did sit for the examination. In fact only 17 candidates out of the 372 included in the study sat for Advanced level Physics having started with a Grade 5 at SEC level. There were no candidates with Grade 6 or lower at SEC level who sat for A-level Physics in May 2006. The absence of students from the lower end of the SEC level range taking Physics at A level contributed to the moderate correlation obtained between the two levels. These results showed that while there is a relationship between the two levels, further investigation of the adequacy of the preparation provided by the syllabus at SEC level was required. The study reported in this paper attempted to evaluate how far one of the aims of the Physics syllabus was reached: it investigated whether in students' and teachers' views the SEC level syllabus for Physics gave an adequate preparation to students who eventually studied Physics at Advanced level. This was the main aim of the study carried out as a B.Ed (Hons) dissertation (Caruana and Muscat, 2006). The study considered different areas of the Physics preparation required such as the different Physics topics, practical work and Mathematical content.

Method

The first decision was whether to adopt a qualitative or a quantitative approach in order to tackle the research questions. Quantitative research is considered to be accurate and value free, since its tools help the researcher to be objective in the results and leave little space to divert from the actual facts.

One of its purposes is to provide predictions. Qualitative research, on the other hand is concerned with why a particular phenomenon is occurring. The study was based on a combination of both qualitative and quantitative methods since:

"the differences between the two approaches are often unclear and occur in a continuum; quantitative and qualitative approaches and methods are often combined to achieve the best results"

(Patton, 1987 p. 169).

The qualitative research tools adopted in this study were semi-structured interviews with teachers of Advanced level Physics while quantitative data were obtained through questionnaires with sixth-form students. These two methods were used in parallel in order to be able to compare and contrast the opinions of teachers and students and obtain the most reliable outcomes on which valid conclusions could be based through triangulation. Interviews conducted with teachers were semi-structured, which offered the opportunity for extensive questioning. Questions were addressed without excluding opportunities for adding on comment, opinions and personal experiences. Interviews were conducted with 17 teachers teaching in six sixth-form colleges. This provided the views of a relatively large number of teachers who come across students with a range of abilities. Due to the large number of respondents involved and the limited time available, students' views were collected by means of questionnaires. Many questions included in the questionnaire were based on responses obtained during eight interviews conducted with sixth form students. The questionnaire included questions designed to obtain the students' views about the level of preparation provided by SEC level Physics for their Advanced level studies and covered the areas of subject content together with information like gender, type of secondary school attended and year of study. Most questions were of a closed type where the numerical graphic rating scale, better know as Likert-type scale, was used to indicate the level of preparation acquired at SEC level. Some open-ended questions were included for the students to propose their opinions regarding particular issues, and to avoid any sort of bias, since closed-ended questions:

"do not enable respondents to add remarks, qualifications and explanations to the categories, and therefore there is a risk that the categories might not be exhaustive and that there might be a bias in them"

(Oppenheim, 1992, p. 115).

With the help of the teachers in the respective schools, 411 filled questionnaires were collected from students attending seven different sixth-form colleges. This ensured that the views obtained were coming from students with a range of different backgrounds and abilities. The students responding were from both the first year and second year of study and included both male and female students in order to investigate whether there were any differences in their opinion. Data for each question were analysed looking for differences according to gender, type of secondary school attended and year of study at sixth form.

Results

Teachers' views

The views about the gap between SEC and A-level Physics obtained from teachers who actually teach the Physics Advanced level syllabus was of utmost importance in this study. These people have a first-hand experience of what knowledge and skills a variety of students coming from different secondary schools bring with them. In this study, the questions presented to teachers during the interviews, touched on several issues related to the physics syllabi: the Physics content, the mathematical abilities required, practical skills and also the students' ability to communicate ideas in English. In general none of the 17 teachers interviewed were satisfied with the preparation of SEC level Physics for Advanced level. Many teachers described the SEC syllabus as becoming more and more 'superficial' with time:

SEC Physics provides students only with superficial information, whereas at A-level specialisation of the subject commences."

[Teacher A]

Teachers are deluded by the habits that students bring with them from SEC level Physics. They think that students are 'spoon-fed' at SEC-level and that they are not trained to link different topics to apply Physics in different situations as required at A-level.

"SEC-level is not so challenging and students tend to study by memorising most things. This is not possible in A-level. In A-level you get deeper into the subject and the topics are more linked."

[Teacher B]

For this reason many teachers said that students do not find what they expect in A-level Physics. They tend to choose it with the idea that the subject is much easier than it actually is and are shocked when they realize that it is hard. This problem is even bigger for students who had sat for Paper IIB in the SEC Physics examination Paper IIB. The syllabus for this paper is covered in lesser depth, which then results in further difficulty in adapting to the A-level content. As regarding practical sessions eleven of seventeen teachers interviewed, strongly think that students are not prepared well enough in practical work. They show lack of experience in handling the apparatus and using measuring instruments. Most explained that when A-level students enter the laboratory for their first session they look 'lost' as if they had never conducted an experiment on their own:

"In secondary schools, experiments are done mostly by teachers since students are given 15% of the SEC exam mark. So when students proceed to A-level they have to be taught to conduct the experiment on their own."

[Teacher C]

This problem was also mentioned by examiners in the SEC examiners' reports:. Teachers are doing demonstrations of experiments that can be done by students and this is definitely not recommended (SEC Examiners Report May 2002 and 2003MATSEC 2002, 2003a). Moreover, at A-level students find greater difficulty in accepting to conduct an experiment individually that is different from experiments done by their classmates.

When it comes to writing the report, students encounter several difficulties according to teachers. Many think that a practical report is just changing the tense from a typed instruction sheet, which is not and should not be the case at both levels. In addition, students encounter great difficulties in finding the results. Teachers expressed their disappointment in finding students who do not even know how to find gradients from a simple graph equation.

In fact the mathematical problem were mentioned several times. Teachers said that students do not appreciate the "beauty and creativity of solving a problem" and thus they encounter great difficulties in simple substitutions and problems which can be reasoned out. Although some blamed the SEC level Mathematics syllabus for this problem which is constantly being reduced, some pinpointed that the problem is more due to the fact that students are unable to link Mathematics and Physics.

When it comes to content, all the teachers are against the modifications that were made in the SEC Physics syllabus in recent years. Teachers said that many of the concepts which were eliminated from the Physics syllabus such as equations in electrical circuits and optics at A-level used to be useful at A-level. On the other hand the new topics introduced, specifically the Earth and the Universe do not help as much. Moreover teachers feel that certain phenomena such as the red-shift, are too complex for SEC-level and this gives more ground to the argument that this topic should not have replaced the previous sections.

With regard to the other topics, teachers affirmed that the bigger the gap between SEC and A-level in the topic, the bigger the difficulty students find in the same topic at A-level. In fact the sections liked most are usually those which are done in depth at SEC Physics such as *Mechanics*. However when it comes to *Circular Motion* students seem to struggle. This confirms that students find most difficulty with topics which are completely new to them. Among the 'difficult' A-level topics mentioned, *Electric Fields* and *Gravitation* were very common especially since these are abstract and intangible topics and thus the impossibility of visualising the concept contributes further to the problem.

The interviews carried out with teachers of A-level Physics have identified a number of areas in the SEC level preparation which call for improvement. Many of the views expressed by teachers are corroborated by the views offered by students in the second part of the study.

Students' views

The views of Physics students were of utmost importance in this study. However, the fact that certain factors and attitudes could have had a deep influence on the responses given in questionnaires had to be taken into consideration. In fact responses were analyzed keeping in mind the reasons given for choosing to study Physics at A-level, the grade obtained in SEC-level Physics, gender, the type of secondary school attended and their experience of SEC and A-level Physics. In this paper a brief outline of the students' responses will be reported, focussing mainly on their perception of the degree of difficulty of SEC level and A-level Physics, their views about the gap between the two levels and their views about the adequacy of the preparation in Mathematical skills, Practical skills and the different content areas.

It was interesting to note that out of 411 respondents 64.5% were coming from non-state secondary schools and 294 students were male. More specifically, 50.4% of all respondents were males coming from non-state schools who overall had obtained very good grades at SEC Physics. Most students had in fact sat for SEC Paper IIA and it was also evident that students do not usually choose to study Physics at A-level if they obtained a pass at SEC level by re-sitting the examination in the supplementary session.

Although many students claimed that the main reason for choosing A-level Physics was because it was a requirement for their future careers, 61.7% of students acknowledged that they liked Physics. Yet, results also indicated that the percentage of female respondents who do not like Physics is slightly higher than the percentage of male respondents who do not like it. A good number of students (57.1% of the male respondents and 60.7% of the female respondents) also stated that they chose to study the subject at A-level because it was actually among their favourites. This contradicts White (1996) who stated that it seemed unlikely that students choose Physics because they find it interesting since they consider it as a challenging subject.

Over 20% of the students chose Physics because they obtained a good grade at SEC level and a few others chose it just because subject options were restricted in their school and Physics was offered with their favourite subject. Over 20% of the students chose Physics because they obtained a good grade at SEC level and a few others chose it just because subject options were restricted in their school and Physics was offered with their favourite subject.

When comparing the difficulty of SEC level and Advanced level Physics, as expected, nearly all students said that A-level is harder. Figure 1 is a summary of the results of the correlation of the difficulty level of SEC and A-Level Physics according to students. Students ticked on a Likert scale the difficulty from 1 to 5: 1 being easy and 5 being difficult. Respondents were grouped according to the level of difficulty they rated the SEC level. Each group of respondents is represented in Figure 1 according to their judgement of the difficulty of A-level Physics. Their rating of the difficulty of A-level Physics is represented by the different coloured bars. For example taking the 85 students who considered SEC Physics to be easy (rating it 1), we find one student who also found A-level easy, seven who rated A-level Physics 2 in difficulty, 36 who rated A-level Physics 3 in difficulty and so on.

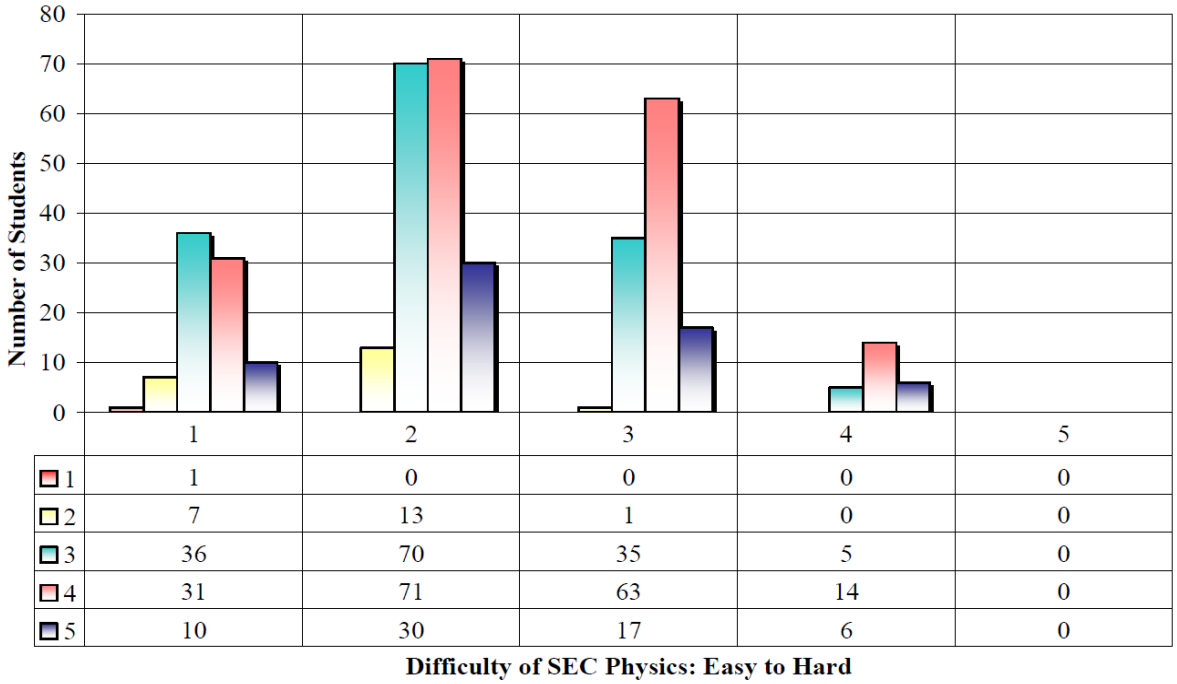
It is evident that no student said that SEC-level Physics was very difficult, so rating it 5. Con versely, only one student rated A-level Physics to be easy indicating that students find Advanced Physics harder.

Most of the students claimed that they found A-level Physics to be as they expected and only two

students claimed that they found it easier than they had expected. A number of students, 29%, felt

that A-level is not a continuation of SEC level Physics because they felt that SEC level Physics is basic and misleads students to choose it at a higher level. This corresponds with what teachers said in interviews and implies that some students do choose Physics because they think it is an easy subject. A student commented:

"At SEC-level Physics is practically easy and so misleads the student that A-level Physics is easier than it actually is!"



	1	2	3	4	5
1	1	0	0	0	0
2	7	13	1	0	0
3	36	70	35	5	0
4	31	71	63	14	0
5	10	30	17	6	0

Figure 1: The relationship between the difficulty level of SEC and A-Level Physics expressed by students

The main question investigated by this study was: What do students think about the gap between SEC level and A-level Physics? One of the questions required the students to rate on a Likert Scale how much they thought that SEC Physics prepared them for the A-level content. Only 28.3% of the students felt that the preparation was adequate, 38.3% felt that they had a fair preparation while 33.4% rated the preparation as poor. Males coming from non-state schools were the most positive in this question whereas males coming from state schools were the most negative. When comparing non-state school respondents in general, the percentages of both males and females who thought that the preparation was adequate was higher than that of students coming from state schools. Moreover it was interesting to note that many females seemed to think that the preparation was fair. In the rest of the questionnaire the students were given a list of the topics and the sub-topics covered both in SEC level and A-level Physics as well as other skills required in A-level Physics. They were asked to tick on a Likert scale the level of preparation they received in each of the topics and sub-topics.

One section dealt with practical skills. When referring to practical sessions, 55% of the respondents felt that the preparation at SEC-level was adequate, although there were more male than female respondents

who claimed this. According to teachers this may be due to the low self esteem which many girls tend to have. The specific area in which all students felt that they needed more preparation was in analysing results obtained through practical work. The majority (67%) felt best prepared in graph plotting, which was the opposite of what the teachers had claimed. There was a vast discrepancy in how they gauged their preparation in handling of apparatus between boys coming from the state and non-state sector. In fact 64% of boys coming from non-state schools claimed that they were adequately prepared, as opposed to 30% of boys coming from state schools. Conversely, more females coming from the state sector felt adequately prepared in handling apparatus rather than those coming from the non-state sector. A student who felt that he needed more preparation in handling apparatus commented:

"At SEC-level, we were prepared very well except in the handling of apparatus since the experiments were carried out by the teacher herself."

Slightly over half the respondents (51%) thought that the level of preparation in mathematical skills was adequate, while the rest believe that this needs improvement. A particular student claimed that:

"SEC Physics has less mathematical calculation compared to A-level. It has more straight to the point questions like just filling an already prepared equation; unlike A-level which has extensive problem solving involved."

Students felt best prepared in working with equations whereas 57.7% of the male respondents and 71.3% of the female respondents stated that the preparation in trigonometric functions definitely needs to improve. Males felt better prepared in plotting graphs whilst girls felt better prepared in converting units. The majority of all respondents claimed that they were adequately prepared in Physical Quantities. A comparison between first year and second year students was made, in order to see whether they had converging or diverging opinions. Less second year than first year students felt that the preparation was adequate. The largest gap between SEC and A-level was seen in Scalars and Vectors where respondents from both sexes agreed with a similar percentage (46.2% of males and 44.7% of females) that the level of preparation was very poor.

On the whole, all students felt well prepared in the topic Heat, especially girls. However, both genders felt least prepared in two sub-topics: Heat and Temperature, and Pressure and Temperature. This might indicate that the removal of gas laws from the SEC syllabus, as suggested by one of the teachers, might have had a negative effect on the students at A-level.

Only 44.3% of the respondents believed that the preparation in Materials was adequate. The A-level topic Materials is not covered as a single unit at SEC-level. Stretching Materials is usually covered with Forces, whereas Energy in Materials is only mentioned in Energy Conversions. As regards to Stretching Materials, the vast majority of students claimed that they were well prepared at SEC-level. Conversely, the majority of the respondents thought that the level of preparation in Energy in Materials needs to be improved. This could be due to the fact that even though students are introduced to Stretching Materials where they investigate the relationship between the force and the extension in a spring, the connection between Energy Conversion and Stretching Materials might often be missing at SEC-level.

Another topic investigated was Electric Currents, where 53% of the students felt that in general, this topic was not adequately covered at SEC-level. It was interesting to note that Electric Circuits was the only sub-topic which was considered to be adequately prepared by the majority of both male and female respondents. Regarding Voltage, Resistance and Electrical Power, the majority of the respondents claimed that the preparation needs to be improved. Male respondents (62.9%) felt least prepared in Graphs, whereas female respondents (65.7%) felt least prepared in Voltage. As regards to Charge and Current, the responses were approximately divided evenly between adequate and non-adequate preparation. A student commented:

"More electricity topics need to be done, perhaps a project together with some mechanical practicals"

Fields is another topic covered in both SEC and A-level Physics. In general, the majority of the students (60.1%) felt that they were not adequately prepared in this topic. Fields includes Gravitational, Electrostatic and Magnetic Fields. The majority of both male and female students felt that they were not well prepared in Gravitational Fields. This might reflect the fact that Gravitational Fields are hardly mentioned at SEC-level, whereas at A-level, students have to learn the theory which is quite abstract as indicated by the teachers in the interviews. On the other hand both male and female respondents felt best prepared in Magnetic Fields, even though the percentages involved were not so high (51.5% for male and 50.7% for female respondents).

In general students seemed to be quite content with the preparation the SEC syllabus offered in Vibrations and Waves. In fact 58% of the students felt that they had adequate preparation. Teachers suggested that Waves is a descriptive topic in which girls tend to do slightly better. This might be the reason why a larger percentage of girls than boys, felt the preparation of The Progressive Wave and Sound Waves as adequate. Still, high percentages of both male and female respondents claimed that the preparation in The Progressive Wave needs to be improved. Students felt best prepared in Optics, even though this was not in accordance with the views expressed by teachers who claimed that since several parts were removed from Optics at SEC-level, students were finding the topic harder than they once did.

Most students felt that they were not well prepared at SEC-level in the topic Nuclear and Particle Physics. Teachers suggested that this could reflect the fact that the topic is often done at the end of the second year of the A-level course, when exams are very near. It could also be due to the challenging mathematical applications including logarithmic graphs. Indeed students felt least prepared in the section of Stability of Nuclei and Isotopes. Table I summarises the level of preparation by the SEC-syllabus in the different topics as indicated by the respondents.

	Adequate Preparation	Inadequate Preparation
Mechanics	72.6%	27.4%
Vibrations and Waves	58.0%	42.0%
Heat	57.3%	42.7%
Physical Quantities	52.1%	47.9%
Electrical Currents	47.0%	53.0%
Materials	44.3%	55.7%
Fields	37.9%	62.1%
Nuclear Particle Physics	35.6%	64.4%

Table I: Adequacy of the preparation in the different topics by the SEC level syllabus according to students

Conclusions and Implications

This study provided interesting findings worth taking note of especially since discussions intended to improve syllabi usually regard mainly the content and rarely consider the students' opinions about the subject.

Both 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. Teachers often described the SEC syllabus as superficial and which does not provide the students with the appropriate tools for the deeper Advanced level syllabus. The majority of the students felt that preparation in practical work and in mathematical skills was lacking.

Students felt best prepared in Mechanics and least prepared in Fields and Nuclear and Particle Physics. One of course expects a gap between SEC level and Advanced level as they are different levels of study after all. The question is whether this gap is too wide. It seems that with time, as SEC level Physics has sought to cater for students with a wide range of abilities and needs, this gap has widened and students and teachers alike feel the need to narrow this gap.

It 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. With regards to mathematical skills it seems that students may need to acquire mathematical skills beyond what is covered in SEC level Mathematics but perhaps more important is the need for students to get more experience of the use of Mathematics in the context of Physics at SEC level. This implies the need to re-introduce greater stress on the quantitative aspects of Physics in the SEC syllabus.

Another point regarded the practical work. The SEC syllabus requires students to submit the best 15 experiment reports. This may result in schools giving students only 15 practical sessions. The syllabus does not specify any restrictions about which experiment reports may be presented. This may lead to the presentation of experiment reports requiring the same practical and analysis skills or the presentation of reports for experiments which were carried out as teacher demonstrations. Such situations are likely to lead to the lack of practical and analysis skills observed by sixth-form teachers and experienced by students taking A-level Physics. This implies the need to make the syllabus requirements more specific with respect to the range of practical skills and analysis of results that must be involved in the 15 experiment reports submitted.

Obtaining or failing to obtain the Advanced level certificate in Physics will determine whether a student will be able to pursue a course and eventually a career in a Physics-related discipline. With such high stakes involved, it is evident that more effort must be put towards the alignment and bridging of the two levels and to ensure that the SEC level is an adequate preparation for studies at Advanced level.

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