

## Language and Achievement in Science in a Bilingual Context: A Maltese Perspective

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**Abstract:** The great majority of international studies on language in science education relate to oral interactions in monolingual settings. Only a few local studies focus on the bilingual setting of Maltese science classrooms. This paper reviews a small number of research studies on the influence of language on the Maltese students' performance in science tests and examinations. The research includes a study of correlations between achievement in English language and in a science examination at Ordinary level, an investigation of the Cummins thresholds hypothesis that proficiency in *both* Maltese and English produces differences in achievement in a Physics examination, and an extensive study of the influence of students' passive and active English language skills on their performance in Advanced level Physics. Another two studies investigate the effect of setting tests in a different or modified language. In one study, three versions of a science test with questions set in English, in English and Maltese side by side, and in modified English were randomly distributed to 380 Form 5 students. The other study set a Maltese and an English version of a carefully designed Integrated Science test to a sample of 284 Form 1 students. The implications of these studies are discussed.

**Keywords:** Language in science, science education, bilingualism, achievement

### Learning science through language

Learning science involves more than just an effort to grasp scientific concepts. It involves the need to understand the technical and non-technical language, as well as the mathematical and graphical forms used to present the subject. Lemke (n.d.) has highlighted this complexity succinctly when she noted that "the language of science is a unique hybrid: natural language as linguists define it, extended by the meaning repertoire of mathematics, contextualized 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." Considering just the language component of this mix of forms of communication, Wellington and Osborne (2001) began their investigation of language and literacy in science education from three basic starting points:

1. "Learning the language of science is a major part (if not *the* major part) of science education. Every science lesson is a language lesson.
2. Language is a major barrier (if not *the* major barrier) to most pupils learning science.
3. There are many practical strategies which can help to overcome these barriers."

The widespread recognition of the importance of language in learning science can be gauged, for example, from the review of the extensive literature on this theme during the period 1978 - 2003, which was published to celebrate the 25<sup>th</sup> anniversary of the *International Journal of Science Education* (Yore et al., 2003). Among the various topics concerning the relationships between language and science generally and language and science education specifically, this review discussed the research carried out on oral and written language, reading and writing-to-learn science. This research was analysed from a perspective that reflected the gradual shift in teaching methodology from the behaviourist stimulus-response-reinforcement mode to an interactive-constructivist approach. The latter approach highlights the importance of verbal discourse between teachers and students and students among themselves for meaningful learning to occur. Despite the wide ranging scope of the review, there was hardly any reference to literature on learning science in a bilingual context or on how the language used to assess the students' knowledge of science can affect their achievement.

### **Learning science in a bilingual context**

Considering that most of the relevant literature referred to mono-lingual situations and that it concluded that language is influential in learning science, it is clearly even more important to investigate the effect of language on learning science in a bilingual context. Such investigations are of particular interest in the Maltese context where science 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. However, written communication is carried out in the English language only almost invariably by teachers and students alike. This includes lesson notes, reading of textbooks, students' reports of laboratory work, homework and assessment instruments, including tests and examinations. Camilleri (1995) has conducted a comprehensive study of bilingualism in education in Malta involving a study of language choice in Maltese classrooms including an

analysis of oral communication in Biology, Physics and Integrated Science lessons. The present paper concerns research studies that have attempted to explore the interaction between language and achievement in science at secondary school level in Malta.

While it is recognized that there are various methods by which achievement can be assessed, this review is restricted to studies of the students' performance in science written tests and examinations. In these situations, since science subjects are examined in English, students need to read and understand the questions and then produce answers of varying length in that language. Objective type questions are an exception since they simply require students to read the questions and tick the correct answer, sometimes quite randomly. However, practically all recent science tests and examinations avoid this type of question and consist of structured questions and free response questions which require students to understand the questions and to write an answer under time constraints. Thus, in most cases, science tests and examinations require students to demonstrate their understanding of science by using both their passive and productive language skills to produce answers. Given these requirements, 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. The studies under review will be considered as attempts to investigate whether this presumption is corroborated by the empirical evidence.

### **Research Studies in the Maltese Educational Context**

The general educational context in the secondary schools in which the studies have been conducted can best be described as consisting of single-sex schools for students aged 11 to 16, except for the co-educational independent schools. Until 2007, there were two types of state schools: junior lyceums for students who passed an entrance examination in five subjects, and general area secondary schools for those who failed in one or more subjects. Since then, the two types of schools have been merged into state secondary schools and co-education has been introduced in the junior classes. Church schools for boys admitted students who passed a common entrance examination while church schools for girls and independent schools had a wider intake. In most classes, science lessons were characterised by code-switching in oral explanations while only English was used for textbooks, written notes, laboratory reports, homework, tests and examinations. Generally and understandably, science educators and researchers concerned with the improvement of students' science achievement have concentrated on the science aspect of science teaching and learning. Only a few educators have investigated the language aspect, and in this limited pool of investigations researchers have used a wide range of methods including correlation studies of achievement in language and science; analyses of results in tests in which

students are presented with papers set in either English or Maltese or different versions of English; the analysis of the language used in scripts written in a normal science examination; and questionnaires or interviews intended to obtain the students' opinions about the possible influence of the language of the test on their comprehension and overall performance.

One of the first contributions which addressed the possible relationship between language and achievement in science stemmed from two analyses of results obtained by large samples of boys and girls in the lower secondary school classes and at the end of compulsory education. The first analysis noted that in the Form 1 and Form 2 annual examinations in state schools, girls obtained consistently higher scores than boys in several subjects and the difference was particularly significant in General Science (Falzon and Sammut, 1976). The authors then hypothesised that the girls' greater verbal ability could have been one of the reasons for the observed difference. Interestingly, these results contrasted with international research studies which showed that, almost invariably, boys performed better than girls in science examinations. The second analysis considered the pass rates of 80 boys and 37 girls from all school sectors who sat for UK GCE O-level examinations in Biology, Chemistry, Physics, Mathematics and English in the same session during 1975 -1978. These results showed that girls performed as well as or better than boys in Biology, Chemistry and Mathematics, while boys obtained much better grades in Physics. In English, 57% of the girls passed the examination as opposed to 39% of the boys (Ventura, 1982). These analyses and the observation that in the abovementioned GCE O-level results, relatively high correlation coefficients were observed between the results in English and the Biology, Chemistry and Physics results, which were 0.56, 0.42 and 0.45 respectively, led to a separate investigation (Cuschieri, 1982). Based on the evidence of these correlations, the contrasting gender differences in science achievement noted in international and local results, and the superiority of girls in English language achievement, Cuschieri suggested that since girls are more proficient than boys in English they possess a tool which enables them to compete on equal terms with boys in those subjects which have traditionally been considered to be the territory of males.

The fact that students in state schools sit for common end-of-year examinations provided an opportunity to use the results of junior lyceum Form 3 students in the core subjects English, Maltese, Mathematics and Physics to investigate whether the Cummins (1981) thresholds hypothesis applies with respect to achievement in Mathematics and Physics in the Maltese context (Farrell, 2011). The hypothesis predicts that different levels of bilingualism in *both* L1 and L2 produce different cognitive effects which in turn reflect on achievement. High level in both languages (Maltese and English) - proficient bilingualism - leads to positive cognitive effects; native-like level in one language only - partial bilingualism - leads to neither positive

nor negative cognitive effects; low levels in both languages - limited bilingualism - results in negative cognitive effects and consequently low levels of achievement. The dataset consisted of the results of 1262 students (770 girls and 492 boys) which were standardised to facilitate the analysis. Following rank ordering of the results in each subject, the students in the top one third of the ranks were classified *High* level, the middle one third were classified *Intermediate* level, and the bottom one third were classified *Low* level achievers.

Generally, the results showed that the threshold hypothesis is upheld in the science subject as illustrated by two cross tabulations of Physics achievement against the level of bilingualism. This is illustrated in Table 1 which presents the distribution of the 420 students who were classified as *High* achievers in Physics, while Table 2 presents the distribution of the 402 *Low* achievers in Physics according to their level of bilingualism (Farrell, 2011).

	<i>High English</i>	<i>Intermediate English</i>	<i>Low English</i>
<i>High Maltese</i>	184	68	13
<i>Intermediate Maltese</i>	67	32	19
<i>Low Maltese</i>	16	15	6

Table 1. Distribution of students with *High* performance in Physics (N=420) according to their level of bilingualism

	<i>High English</i>	<i>Intermediate English</i>	<i>Low English</i>
<i>High Maltese</i>	7	21	9
<i>Intermediate Maltese</i>	12	43	72
<i>Low Maltese</i>	21	71	146

Table 2. Distribution of students with *Low* performance in Physics (N=402) according to their level of bilingualism

Table 1 shows that the 184 students with high scores in Maltese *and* English had the highest probability of obtaining a high score in Physics. Students with a high score in only one language had a much lower probability of being among the top students in Physics whether the dominant language was Maltese or English. Correspondingly in Table 2, the 146 students with low scores in the two languages had the highest probability of obtaining low scores in Physics. Both tables show that there are a few exceptional cases. In Table 1, six students with low scores in both languages were among the top achievers in Physics, while in Table 2 seven students with high scores in both languages were among the low achievers in Physics. These results suggest that the Cummins' hypothesis should be modified and expressed in terms of probability. It also seems that other factors besides language affect the students' performance in Physics examinations at least at Form 3 level. The possibility that the main factor could be the students' general intelligence *g*, which affects performance in all subjects, was discarded by Farrell by quoting



an extensive study by Deary et al. (2007) in the UK who correlated the general ability test scores at age 11 of over 70,000 students with their performance in GCSE examinations five years later. Though the general abilities of boys and girls were similar, girls performed better than boys in almost all subjects. This difference led the researchers to remark that the girls' higher scores in the verbal tests of the Cognitive Ability Test (CAT2E) battery contributes some additional variance to examination performance and then conclude that "...in English school examinations, there is a further advantage to girls and to those strong in verbal skills (after *g* is controlled)".

Farrell (1996) conducted an investigation at a higher educational level when he explored in detail the influence of English language proficiency on Maltese students' attainment in Physics at GCE Advanced Level. Interestingly, his research was inspired by a comment in a UK Physics A-level examiners' report that "... a teacher who can successfully tackle the problem of making candidates aware of the importance of English at an early stage in their preparation would probably improve their results by two or three grades." In the investigation a group of 200 Physics students were followed during the two-year course in 1993-1995 at the then newly formed Junior College and information was obtained from (a) a self-completion questionnaire about the language, Maltese or English or a mix of both, they used at home and the language teachers used in Physics classes, their perceived effect of the language on achievement, their habit of reading English texts, and any help they received from the college to improve their writing skills; (b) a comprehension test of 75 words commonly used in Physics, including 50 non-technical and 25 purely technical terms; (c) a test of knowledge of words such as *because, therefore, however, consequently* which serve as 'logical links' in Physics texts; (d) a cloze test to investigate the readability of the set Physics textbook; and (e) an analysis of the annual examination Physics scripts of 267 students (87%) in that year group. Among the interesting results that emerged from the questionnaire, 33% of the students claimed that they found the language used in Physics questions often or very often difficult to understand and confusing. This is not surprising considering that in test (b) the correlation between the words students claimed they understood and what they actually understood was just 0.290 for all the words used, with a difference between non-technical words where the correlation stood as 0.442 and technical terms where it was just 0.275. Considering that the students were among the top 15% of their age cohort in educational attainment, it was surprising that less than 80% of them gave correct explanations of 31 out of 50 non-technical words and all of the 25 technical words. In some cases, students gave the opposite meaning of the words (Farrell and Ventura, 1998). For the analysis of examination scripts, a set of criteria for assessing the quality of language used was established with the help of teachers of English. The scripts were classified into four categories according to the level of the language used and the following percentages were observed: (i) satisfactory

(33%); (ii) not satisfactory but comprehensible (51%); (iii) difficult to comprehend (14%); and (iv) exceptionally poor (2%). Thus the 16% of candidates presenting scripts in categories (iii) and (iv) would certainly lose marks in an examination because of an inadequate ability to express themselves in writing in English.

In another interesting investigation, a stratified sample of 380 Form 5 students from state, church and independent schools were involved directly in a bilingual study. They completed a questionnaire, sat for a Physics test in different language versions and responded to an interview on their performance in the test (Borg, 2010). The study investigated the opinion that for Maltese students, language acts as a barrier to learning Physics and demonstrating their knowledge of the subject in examinations at Secondary Education Certificate (SEC) level. The questionnaire asked the students' opinion about their own level of English language with the result that 22 (5.8%) reported that it was low, 274 (72.7%) that it was average, and 81 (21.5%) that it was above average, three students did not complete the questionnaire. The majority of students (48.3%) preferred English as the language of the Physics examination, 35.2% preferred a mix of Maltese and English, and 16.5% preferred Maltese. Correspondingly, 75.6% claimed that they understood the *language* used in the SEC Physics examination questions, which is invariably English, while only 21.3% reported that they did not understand the *subject content* of the questions. This result indicated that the great majority of students had little difficulty with reading comprehension, however, 71.3% went on to claim that they found it difficult to communicate their answers in English even though they knew the answer. This reply implies that students may spend an appreciable time of the examination trying to formulate an answer in correct English rather than to solve the Physics problems.

The students then took the test which consisted of four questions on four different topics, namely, density, energy, electrostatics, and the Earth and the universe from SEC Physics Paper 1 examination papers. Three versions of the test were prepared. One version consisted of the questions as originally presented in the examination papers. A bilingual version presented the questions in English and Maltese written side by side and students had the option to answer in either language. Another version had the same questions presented in simpler English and with some simplification of the diagrams. Language experts were consulted in the translation into Maltese and the modification of the carrier language of the questions in the third version. The test was administered by the researcher during 45-minute lessons in each class separately and the different versions were distributed randomly. The average percentage scores obtained by the 380 students (176 boys and 204 girls) who sat for the test are given in Table 3.

Test	Version 1	Version 2	Version 3
Language	Original English	Bilingual	Modified English
Average Score	57.2%	56.1%	60.5%

Table 3. Average score obtained by Form 5 students in a Physics test presented in three language versions

Although the overall result showed a better performance by students who sat for the modified paper, the analysis of each question separately by gender and by school sector did not show significant differences in scores between versions generally. There was one small but significant exception, however, in the question which required students to read data from a table and answer which group of countries caused more pollution. Girls in Junior Lyceums who answered the modified version of the question obtained a significantly better score than their peers who answered the other versions. A close look at the language of the question showed that the latter girls probably confused the terms 'developed' and 'developing' used in the original question with reference to countries while the modified version described the countries as 'industrialised' and 'developing'. During interviews with a sample students who answered the three versions, students showed a preference for a paper set in English since their lesson notes and books are in English but they would like to be given the opportunity to answer in Maltese as they felt more confident to express themselves in that language.

An attempt to test the Integrated Science teachers' opinion that the language of the examination acts as a barrier preventing secondary school students in Forms 1 and 2 from demonstrating their full knowledge of science was carried out by Ventura (1991). An English and a Maltese version of a test consisting of 50 multiple-choice items, each with four options, was designed using 34 items from past end-of-year examinations and 16 items specifically constructed for this test. The new items introduced vocabulary and syntax that might influence the students' answers and balanced out the spread of topics. Extra care was taken in the translation of the items, which were originally written in English, and the format and layout of the text and diagrams so that both versions were as equivalent as possible. The test was set to 284 Form 1 students (130 girls and 154 boys) from three boys' and three girls' area secondary schools in the state sector in 13 classes ranging from high ability to low ability streams.

The overall results indicated a very significant difference in scores. Students who answered the Maltese version of the test obtained an average score of 53.4% while those answering the English version obtained an average of 48.0% with no appreciable difference between boys and girls. Furthermore, the global results and an item analysis showed that both tests were equivalent as they had practically the same test characteristics, that is, a high reliability



as measured by their internal consistency, the same order of topic difficulty and the same relative difficulty of the strength of the distractors in each item. A further analysis of the difference in scores of the two versions immediately indicated that it was due to the weak performance of the low achievers. In fact, while only 22% of those who answered the Maltese version scored 40% or less, slightly over 40% of those who answered the English version obtained a score in this range. This was confirmed when differences in the scores of the top and the bottom 25% achievers in both tests were compared separately. It was found that the scores of the top group were almost the same in both versions while there was a very significant difference of almost 8% in the bottom group in favour of the students who answered the Maltese version of the test. The conclusion drawn from these analyses was that the 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. It seems that there is a threshold effect on the influence of language on science achievement. Students who can cope with the language demand show their true knowledge of science; others who do not have this minimum grasp of the language perform below their ability in the subject.

## **Discussion**

All the studies under review support the hypothesis that the language of the assessment has a variable effect on performance in science tests and examinations depending on the students' ability in the language. Considering that the formal assessment of science is carried out in English at all levels, the main focus of the studies has been on the students' achievement in science and its dependence on their proficiency in this language. However, two studies explored the idea that science tests in Maltese could help students to achieve better results since they were expected to be more proficient in their native language than in English. The results showed that a science test in Maltese at Form 1 level only favoured the weaker students in science (Ventura, 1991). At a later stage, students who sat for a Physics test in Maltese at Form 5 level did not achieve better results than their counterparts who sat for the same test in English. In the latter study, only the students who sat for the test set in simpler English and slight modification in diagrams achieved better results (Borg, 2010). From these, admittedly limited studies, one can infer another hypothesis, namely, the dependency of the students' performance in science on proficiency in the language of the test decreases with age as the students develop sufficient skills to overcome the language barrier. However, the results obtained by Farrell (1996) indicate that the difficulties with the language of the examination persist at sixth-form level at least for a small proportion of Advanced Level Physics students. Therefore there are students at this level who need support to overcome their linguistic challenges even though they may have a high ability in science. Moreover,

Farrell (2011) showed that by focusing on proficiency in either English or Maltese, previous studies could hardly produce useful results since, according to Cummins' thresholds hypothesis, it is the students' proficiency in *both* English and Maltese that affects the students' ability and hence their achievement in tests and examinations. Yet, it was shown that Cummins hypothesis indicates a *probability* rather than a *certainty* that proficiency in both languages will lead to high achievement in Physics. Indeed as indicated earlier, a consideration of other factors besides language proficiency is needed to account for the results. In Physics, these factors could include proficiency in mathematics and the ability to interpret tables, graphs and diagrams, as already noted by Lemke in the quote mentioned in the introduction. Other factors, which cannot be ignored, have been highlighted recently by a study of science achievement of 1761 primary school grade 4 students (average age 9.76 years) from 67 schools across Flanders (Belgium) with relatively diverse linguistic populations, while the language of instruction was Dutch (Van Laere et al., 2014). The study collected extensive data on student level and school level characteristics and analysed the dataset using multilevel analysis to produce various models to explain the relationships between the variables. In the conclusions, the researchers highlighted three major findings. First, home language has a significant impact on science achievement, confirming that students whose home language is different from the language of instruction are disadvantaged. Secondly, higher achievement is associated positively and significantly with a higher self-reported proficiency in the language of instruction and a better score in reading comprehension in that language. Thirdly, at the school level 'teachability expectations', that is the teachers' expectations that their students possess or do not possess the potential to learn the subject, have a strong effect on science achievement. Presumably, the latter factor has the greatest influence in the case of low ability students and students experiencing language and other learning difficulties.

## Conclusion

One of the limitations of the Maltese studies under review is that only the language used in Integrated Science and Physics tests and examinations has been investigated. Clearly, a wider focus is needed to include Biology and Chemistry since the questions set in these subjects generally expect students to read long questions and write longer answers in English. In fact, questions in these subjects may include comprehension of short articles adapted from scientific journals and essay writing. This recommendation is supported by the examiners' reports on the students' performance in these subjects at SEC level which include remarks such as:

One needs to point out the fact that in many cases the language and expressions used were indicative of very poor command of both English

and Scientific language. Candidates seem to prefer using ‘animals go’ rather than ‘animals migrate’ to mention one. In the opinion of the examiner the ability of expression is getting weaker by the year. (SEC Biology, May 2013, Paper 2A, Q5)

Very often the descriptions are incorrect because candidates find difficulty in describing and giving the necessary detail. (SEC Biology, May 2013, Paper 2B, Q7).

The answers ranged from very good to very poor. In the weaker answers it was obvious that the choice of words was very haphazard since the final sentences made no sense. (SEC Chemistry, May 2014, Paper 1, Q2)

The ability of candidates to give coherent and logical explanations with the use of correct terminology was not very high across the whole cohort. (SEC Chemistry, May 2014, Paper 2A and Paper 2B, Q.6)

Another limitation is that the studies do not provide any clear indication whether students find comprehension more challenging than writing or whether both are equally challenging. Further investigations in this direction may provide better evidence on what action is needed to help students to express themselves clearly in science examinations. For example, although one study shows that questions set in simple English language have a positive effect at Form 5 level, more evidence is needed about the effect of setting questions in Maltese and English. Furthermore, new investigations are required if students are allowed to answer in Maltese and code-switch in writing their answers, which reflects the code-switching that takes place during science lessons. Theoretically, this concession would increase the validity of the examination since the answers would be a better reflection of the students’ exposure to the subjects in class and presumably also a better indication of their true knowledge of the subject. 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. Besides the possible immediate consequences for results obtained in science examinations which may be brought about by a re-consideration of the language of science teaching, learning and assessment, it is important to consider the wider consequences for the students’ further education in science and competence to communicate effectively with a wider audience in an increasingly globalised society.

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