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The Role of Language in Physics Education in Bilingual and Multilingual Classrooms

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Abstract

In view of the challenges that students learning sciences in their native language face, identifying pedagogical ways to improve the performance of first-language Maltese speakers who lack adequate proficiency in the English language is crucial. This is so, as these students are faced with a double challenge; learning the language of physics and learning physics in their second language. Since language and understanding are intertwined, Maltese students need to overcome these two obstacles. This study was carried out with my own class in the form of action research. It focused on language use combined with an inquiry-based learning (IBL) pedagogy. This study consisted of three IBL activities where the students were encouraged to use their preferred language when engaging in discussions. This study has shown that much of my students' learning was gained through interaction with others who are more or differently knowledgeable in some way (peers or teachers) but functioning within their "zone of proximal development" and so making that learning accessible, which is consistent with Vygotsky's social constructivist theory of learning. This study thus highlights that policy makers should allow an alternative way of science teaching. Such a way should promote code-switching as a mode of instruction for classroom talk alongside a translanguaging pedagogy, as language plays an important role in enabling students to develop their ideas in and through language, as the language the students use to each other and to their teacher enables learning and enables them to verbalise their scientific knowledge. Thus, the use of the students' mother tongue in the science classroom should be promoted as it offers a rich means for learning science, especially since classrooms in the Maltese context are becoming more linguistically diverse.

Keywords

Pedagogy, language, bilingualism, translanguaging, code-switching, inquiry-based learning

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Introduction

The motivation to carry out this research stemmed from my background as a Physics secondary level teacher in a state school in Malta. During my years of teaching, I noticed how many of my students experienced difficulties understanding basic concepts in physics. They struggled to express their ideas and to find the right words to explain their reasoning in English. They lacked the linguistic fluency to use the appropriate scientific language to fully discuss the scientific concepts they engaged with, and to interpret their observations when carrying out experiments or investigations. I also noted how they encountered this language barrier even when writing about their scientific work. They often did not manage to use the right terminology to explain how they applied their scientific understanding to different contexts in their formal reports, as well as in homework, as part of their formative assessment. I noted a similar difficulty when they had to elaborate their answer in their responses in examination papers as part of their summative assessment.

My students' struggles reflect both limited understanding of new scientific concepts and the language skills to use correct scientific expressions to articulate clearly their reasoning and understanding. They often remarked that they did not know how to respond to my questions or to questions in the worksheets. This indicated that there could be a language problem coupled with difficulty in conceptual understanding. I felt that these two issues impeded my students from learning physics effectively. I wanted to understand how I could help them learn by adapting my pedagogical approaches with better designed inquiry-based learning activities. I was also intrigued by the language barrier which possibly was contributing to the difficulties my students experienced when talking about Physics content. Students were possibly struggling with the technical language of physics and English language, which for many was their second language.

There are different levels of student proficiency in the English language (Ministry for Education and Employment, 2015). This raises the question of whether there may be a correlation between the students' proficiency in the English language and their performance in Physics. If students can understand questions better, they can also express themselves better in their responses, leading to those with higher English proficiency performing better. I believe that without sufficient command of the English language, students may not perform to their highest potential, despite possessing the required scientific knowledge. This indicates that the language used in assessments may influence Maltese students' academic achievement. This concern was flagged by 60% of the teachers who participated in a study analysing the teachers' views on international tests (Costa, 2018). These teachers highlighted how students may require a basic level of English proficiency to be able to properly demonstrate understanding of physics. Students with low English proficiency tend to be at a disadvantage (Kieffer et al., 2009). The correlation between proficiency in the test language and subject performance has been noted by researchers (Deguara, 2009; Henry et al., 2014). This low performance may not necessarily reflect lack of scientific knowledge but also difficulty with linguistic expression.

Research Aim

The complex linguistic learning context in classrooms in Malta may be hindering students' learning. This reveals a great need to provide students with opportunities to both understand physics concepts as well as to learn how to express themselves both orally and when writing in English, the official language of assessment. It is my opinion that only when students can "talk science" (Lemke, 1990) effective learning has taken place. This is why my study focused on both improving my pedagogical techniques as well as language use and proficiency. The aim was to support my students' learning process to understand physics concepts as well as to be able to "talk physics". I intended to study the effect of using the pedagogy of inquiry-based learning while also being sensitive to the language used when students explain phenomena in their own words and to express themselves well in English when demonstrating their learning of physics.

The language of physics is already a challenge to students learning physics in their native language (Wellington & Osborne, 2001). Maltese students are faced with a double challenge: learning the language of physics and learning physics in their second language. Since language and understanding are intertwined, Maltese students need to overcome these two obstacles. Research has shown that when students are provided with opportunities to discuss and use their ideas, they are actively involved in the learning process. These discussions enable the learners to "feel a sense of ownership towards the knowledge gained" (Halim et al., 2012, p. 120) as well as to enhance their understanding of content (Harris & Rooks, 2010; Windale, 2001).

Adopting an inquiry-based learning (IBL) approach in Physics has been promoted as a pedagogy to enhance the students' ability to discuss what they are doing, improving their ability to "talk science". In wanting to improve my pedagogical approach, I wanted to experiment further in how I can use the IBL approach to help students develop their language proficiency alongside understanding. I also wanted to research whether it was possible to transform linguistic barriers into pedagogical tools which promote better understanding and greater awareness and proficiency in the language of assessment among my students. The use of IBL falls within the policy stated by the National Curriculum (Ministry of Education, Employment and the Family, 2012), which envisaged a pedagogical shift claiming that "traditional ways of teaching will now be replaced by a more student-centred and inquiry-based approach to learning" (p. 25). IBL has often been used interchangeably with other terms such as hands-on, active learning and student-centred (Goodchild et al., 2013). Through an IBL approach, students need to engage with the concept or context they are presented with, explore together, explain their observations, and elaborate on their observations as well as on their previously acquired knowledge in order to draw a conclusion. In an IBL approach, students need to be minds-on, thus, they are actively engaged with physics concepts. This might result in my students understanding physics better, as IBL approaches provide opportunities and experiences to "construct and solidify scientific understanding" (Huerta and Jackson, 2010, p. 207). The aim of this research was to find out whether it was possible to adopt an inquiry-based learning approach with a focus on promoting language use (technical and everyday) as a "vehicle" that promotes better understanding of concepts as well as greater proficiency in talking about scientific concepts in physics.

The potential benefits of interactions between students for understanding (Mercer et al., 2004) awakened my interest in studying talk within a bilingual context when using an inquiry-based approach in my classroom. Since English is the official language for formative and summative assessments in Malta, I wanted to promote more talk and discussions within an inquiry-based learning strategy in a Physics classroom that supports students' understanding of physics and their ability to talk formal physics in English. This study was thus guided by the following research question:

1. How does a bilingual approach impede or support students in constructing knowledge of physics concepts in a linguistically mixed group?

This research was carried out with the students I taught, and who struggled with physics. I wanted to focus on the students' language level that varied in proficiency while also tackling the conceptual difficulty they experienced in learning physics. This investigation focused on finding out whether adopting an IBL approach supported learning within a bilingual approach, developing their proficiency in the scientific language in the process of learning physics.

I carried out this research with my own class as action research. It involved planning, implementing and analysing the trial of a number of structured and guided inquiry activities, as well as different approaches to language use during discussions and formal exchanges. Reflections on one activity guided the planning of the activity that followed. More than one method for data collection was adopted to ensure triangulation. These included document collection such as field notes, audio recordings of lessons, and transcripts of class conversations.

The study could help me develop my practice and help my students learn physics more effectively. It could also shed light on whether an IBL methodology sensitive to the students' complex language context use could promote better learning of physics.

Literature Review

It is not enough for students to understand physics concepts and demonstrate their understanding in everyday language but then struggle with the vocabulary of science, because in science education, learning the vocabulary of science is essential (Brown & Concannon, 2016). There is growing evidence that supports the idea that a "synergistic relationship" (Ricketts, 2011, p. 56) exists between inquiry and scientific language development. This gave rise to my interest in finding out, whether, when a language barrier coupled with difficulty in understanding seems to impede students from learning physics effectively, adopting an inquiry-based learning approach might result in a "vehicle" that encourages learners to share their thoughts and findings during the Physics lesson, promote a better understanding of concepts and in the process, and enhance their proficiency in talking science by using scientific language appropriately.

A study carried out in Malta provides a clear example of how the technical language of science is a barrier to most Malta-based pupils learning science (Farrell & Ventura, 1998). Their study aimed to find out whether word understanding in post-secondary science education is a problem amongst Maltese students. The study focused on polysemous words: words possessing "diverse everyday meanings from the specific scientific denotations they require in Physics" (p. 247). Their findings showed that words such as "power", "naked", "field" and "marked" were understood in one particular sense and misunderstood when used in a different context. The expected threshold was not reached despite the sample being pre-university students and amongst the top 15% to have made it to that level. Though it might have been precisely the polysemy that created the problem, it can also be inferred that the findings provided the insight that the technical language of science is indeed a barrier to learning physics in Malta. This shows the need for students to learn the "very specific ways of using these words appropriately in a scientific context" (Schwartz et al., 2009, p. 83), as an explanation is not enough for the students to become proficient in the scientific vocabulary (Carre', 1981). Moreover, teaching the students the technical language of science supports learning science and language learning (Lemke, 1990). Taking a social constructivist view of learning, Vygotsky (1987) understood this phenomenon as language being productive of thought, and so as directly supporting conceptual development. In social constructivism, the teacher's (and more knowledgeable peers') role is in part to scaffold a transition between the current use of language and, in this context, the physics community's use of the subject-specific lexis.

Experiencing a difficulty in the technical language of science might be assumed to be the only problem faced by learners learning science. In a bilingual context like Malta, learning science is even more complicated, since in the case of Maltese students one finds patterns reflecting a mix of two languages. Moreover, the proficiency in the English language among our students varies. For some, the English language is a second language, and in the literature, learning science in a second language has been pointed out to be a barrier for students (Lodge, 2017; Nyika, 2015; Miller, 2009; Rollnick, 2000). These learners might experience difficulty in the language of instruction, possibly as a result of the difference between what the teacher says and what the students understand (Muralidhar, 1992). This means that in classrooms where students are expected to demonstrate their understanding of concepts in a language they are not competent in, their lack of competency presents various challenges.

The Role of the Language of Instruction in Learning Science in a Bilingual Context

Available literature shows that a monolingual pedagogy is a key factor in bilingual and multilingual students' academic underachievement in science exams, even when it focuses on students achieving conceptual understanding (Charamba, 2021; Charamba, 2020a).

Language is viewed as the most important resource for communication and learning (Dewey, 1993; Charamba, 2020b), and spoken language is often "used as a means for teaching and for students to demonstrate to teachers what they have learned in the classroom" (Low, 2016, p. 38). Thus, all students should be given opportunities to participate in interactional practices, regardless of their proficiency in the language of instruction and language of assessment. Therefore, it is important to create an academic space that values different language repertoires, as such a space is key to promoting science literacy among bilingual learners (Garza & Arreguín-Anderson, 2018). Bilingual learners are referred to in the literature as speakers who make "use of more than one language" (Moore et al., 2018, p. 343). The idea that a competent bilingual performs as a monolingual in different languages is referred to as parallel monolingualism (Heller, 1999) or linguistic solitudes (Cummins, 2008). In fact, bilingual individuals are expected to be balanced bilinguals (Charamba, 2020b) and are assumed to have "developed an equal measure of competence in two languages across any given context and with any given speaker" (Infante & Licona, 2021, p. 914). This means that bilingual students are expected to perform exactly as a monolingual speaker of each language (Charamba, 2020b). In theory, balanced bilingualism is totally possible, but in practice, it is not so likely, as one can be fluent in everyday conversation in both languages, but fluent only in the home language when taking into consideration academic sentence structures (which are a separate form of literary). Despite this, the idea that students are balanced bilinguals is still dominant in Maltese state schools. This means that Maltese students "not only must acquire the discursive practice of the scientific field" (Poza, 2019, p. 2), which is like a "foreign culture" (Aikenhead & Jegede, 1999, p. 269) to most students, but they also have to learn the content in a second language.

The Use of the Students' First Language in Learning Science

When teaching science in a second language, research has demonstrated that effective science teachers "make use of the students' home language to support science learning" (Lee & Buxton, 2013, p. 40) and to clarify their thinking. After all, the emphasis should be "on making meaning, on hearing and understanding the contributions of others, and on communicating their own ideas in a common effort to build understanding of the phenomenon" (Lee et al., 2013). Garza and Arreguín-Anderson (2018) contend that in their research with 16 fourth-grade students, the students could navigate between languages as language flexibility was encouraged in the classroom. They reported that when the students wanted to explain a scientific concept or idea, "they expressed it by reverting to the language they felt most comfortable with to demonstrate their understanding of the concept" (Garza & Arreguín-Anderson, 2018, p. 112). Their study further showed that when the students were encouraged to use language flexibly, the students seamlessly navigated "language-intensive and cognitively-demanding scientific tasks" (p. 113), which allowed the lesson to move forward. Allowing the students to use languages flexibly has also been reported to improve students' academic performance (Low, 2016).

Karlsson et al. (2019) studied the effect of the students' use of their first and second languages in a science classroom at a primary school in southern Sweden for three years. Their study also demonstrated that bilingual and multilingual students should be enabled and encouraged to use all available language repertoires in class, as the use of the students' mother tongue promoted a deeper understanding of the science concepts, resulting in improved academic performance. Using different language repertoires in the science classroom does not only mean that different languages are used for different purposes, but it also refers to the use of code-switching, which has been defined as the ability to alternate between two languages when speaking. Code-switching can involve a word, a phrase, a sentence or sentences (Msimanga & Lelliott, 2014).

The Role of Code-Switching in a Bilingual Context

In the 1980s and 1990s, studies of code-switching focused on how it "contributes to the interaction between teachers and learners" (Low, 2016, p. 49). These studies have shown that in bilingual education, it is common that at least two languages are used as a medium of instruction in the classroom. Several researchers have pointed out that code-switching has many advantages and useful pedagogical functions in the classroom (Baker, 2011; García, 2009; Low, 2016), and that it is also often used for classroom management and to build relationships (Ferguson, 2003). Focusing on the pedagogical functions of code-switching in classrooms, the most common function pointed out by researchers is that code-switching is "a way of guiding the students to understand the academic goal" (Low, 2016, p. 52). In science classrooms, code-switching can facilitate the explanations of scientific concepts (Low, 2016) as well as facilitate the "elimination of misconceptions and formulating ideas" (Rollnick & Rutherford, 1996, p. 101). Furthermore, code-switching is useful to encourage and elicit students' participation (Martin, 1999) and to enable the students to discuss logistical matters during group work.

Though many studies have provided evidence that code-switching is beneficial as a classroom practice, many still lambast the use of code-switching as "bad practice" (Martin, 2005, p. 88). A common concern expressed among researchers against the practice of code-switching in classrooms is that although teachers explain a concept in the students' mother tongue, "students are still required to produce the content in English when it comes to formal examination" (Low, 2016, p. 57). Thus, adopting a code-switching approach may affect students' ability to answer questions in English and consequently make it harder for them to demonstrate fully their content knowledge, as the use of code-switching will decrease the students' exposure and use of the formal language of assessment in science (Gauci & Camilleri Grima, 2012). This would "counter the productive effects code-switching has on the lessons" (Low, 2016, p. 59).

After discussing the advantages and disadvantages pointed out in the literature about classroom code-switching, it can be concluded that code-switching is like a double-edged sword. In fact, the use of English as the medium of instruction in classrooms where the students' first language is not English, which is the case in many Maltese state schools, might lead to a greater gap in performance between students who are exposed to the English language outside school and those whose home language is Maltese. Thus, code-switching can help reduce the gap in learning science between students with limited knowledge of English, and even help students who "come from socio-economically disadvantaged backgrounds with limited access to English resources" (Low, 2016, p. 57). Thus, allowing the students to use the language they feel most competent in can be considered a move that may be necessary for "improving the performance of students, particularly the less able" (Low, 2016, p. 29), as well as "mitigating the inequalities" (p. 29) of accessing education between those who are knowledgeable in English and those who have little or no knowledge of English. It can be concluded that the use of code-switching is "congruent with a 'science for all' perspective for closing the achievement gap" between students who are more fluent in English and those for whom the English language is more like a second language.

Those who are sceptical about the use of code-switching can take into consideration a translanguaging pedagogy, which has been advocated in the literature as a pedagogy that might promote better content understanding. In the science classroom, a translanguaging pedagogy offers students increased possibilities for content learning (Gort, 2015) as they are able to "access academic content with the resources already part of their repertoire, while simultaneously acquiring new ones" (Charamba, 2020b, p. 660). Sticking to the use of the language of instruction implies that the students "can only use a limited part of their resources to make meaning of the lessons" (Charamba, 2020b, p. 666). On the other hand, providing the students with opportunities to use their first language enables them to "select features in their linguistic repertoire in order to communicate appropriately and effectively" (p. 666). Thus, translanguaging can be considered a powerful foundation for complex cognitive skills such as processing scientific concepts as it "serves as a vehicle through which thinking is articulated and transformed into an artefactual form" (Swain, 2006, p. 97).

In Maltese state schools, instances where a translanguage pedagogy is being adopted have been recently noted (Camilleri Grima, 2013). A common occurrence in a translanguage pedagogy in Maltese state schools is the teacher posing a question in English and the Maltese students answering in Maltese. The teacher possibly uses the English language to expose the students to the way questions are set in summative assessments, or even because there are foreign students present in class who do not understand Maltese. Although aspects of classroom communication practices in Maltese schools have been investigated by a number of researchers from the University of Malta (Farrell, 1996; Farrell & Ventura, 1998; Mifsud, 2012; Ventura, 2016), the role of the language used and its effect on the students' understanding of Physics in secondary schools have not yet been studied fully.

Methodology

Since in my study I wanted to acquire a better understanding of how I could help my students overcome their struggles when learning Physics in a language that might not be their preferred language, I concluded that adopting a qualitative approach would be the best option. I was actually looking at the social reality of my classroom, that first-language Maltese speakers were experiencing difficulty in learning Physics in their second language (my ontology), but this is not fully provable since knowing it depends on communication and then interpretation of that. Thus, my research followed the epistemological premise that as a researcher, I could only offer my interpretations of the phenomenon I was studying (Guba & Lincoln, 1994). Therefore, this research adopted an interpretative approach. A different researcher might not only elicit different responses from the students, but interpret them differently, though in equally valid ways. Working across two languages, as well as the scientific register, exacerbates the problem of knowing the reality, since some of what is expressed will have limited accuracy.

One advantage of the interpretive approach is that the data collection and analysis can proceed simultaneously (Smith, 2004). The analysis and evaluations obtained enable the researcher to correct any flaws in the research tools adopted before further data are collected.

Careful attention was paid to choosing the sample of the respondents, as the participants needed to fit the phenomena studied (Elbardan & Kholeif, 2017). The sample for this cycle was a group of students in a class to which I taught Physics. It involved a foreign student who, although understanding Maltese, communicated only in English, and four first-language Maltese speakers of different levels of proficiency and preference in English. These students (aged between 13 and 14 years) were in their third year at secondary school and in their first year of learning Physics.

The main design of this study was action research, which falls within the interpretive approach. Action research is a means through which practitioners study their own institutions, making it "one powerful tool for improving the quality of teaching and learning within a school community" (Tillotson, 2000, p. 32). Action research involves a cyclical process of diagnosing a problem and reflecting on practice; planning an action to tackle the problem; implementing the planned action; reflecting on the insights obtained from the implemented action; suggesting modifications and improvements to the action implemented; and taking further action (Riel, 2016). This enables the cycle to be repeated with the modified action plan to address the problem better and gain better insight with each cycle. The literature suggests that the "entire action research cycle is traversed at least twice" (Bhattacherjee, 2012, p. 108) so that the insights obtained from the first cycle can be applied in the second cycle in order to see whether the problem has been successfully resolved.

Research tools used in action research are generally common to the qualitative research paradigm, and more than one method for collecting data is usually adopted. The pluralism of data collection methods can provide thorough understanding of the research phenomena (Devetak et al., 2010). Although interpretive research tends to rely mainly on qualitative data, quantitative data may be included to provide a clearer understanding of the focus of the study. Generally, quantitative data used tend to be tabulations of the codes used for the content analysis in order to see and note their frequencies (Bhattacherjee, 2012). Such data are, however, not statistically analysed. The methods adopted for this study included field notes from lessons at the end of each IBL activity and audio-taped class conversations of each IBL activity implemented, which were then transcribed word for word. The combination of multiple methods helps the researcher acquire a broad picture of the changes occurring and the changes that are required.

For my study, the fundamental justification for choosing action research was that I was a teacher and I was unhappy with my students' depth of learning and understanding of physics concepts, as well as their limitations in talking about the concepts learned in a proficient manner and using proper scientific talk. I was thus researching my own pedagogy and considering in what ways I could improve my teaching to help my students. I was taking what Riel (2016) calls a living and learning stance to teaching.

Data Collection

This section presents the research design adopted during this study, which was composed of three inquiry-based activities. The first two activities involved going through the experience, the reflections, the hypotheses generated from the reflections, and planning the following activity. The third activity also consisted of a cycle. However, since it was the last IBL activity implemented, its final stage did not focus on planning but on identifying what needed to be further clarified in the conclusions drawn. During these three IBL activities, the students were not expected to speak solely in the English language when discussing in groups but were instead encouraged to express themselves freely in any of the two languages (English or Maltese) or a mixture of both (code-switching), whichever they felt most comfortable with. For this study, two structured and one guided/open inquiry-based activities were planned and implemented. I opted for structured inquiries followed by a guided/open one because I believed that students needed to be doing science "with judicious teacher assistance and support" (Hodson, 2014, p. 2547) until they become more skilled and more confident to engage in inquiries, and then the role of the teacher can become less active (Burgh & Nichols, 2012) since unguided inquiry gives students more independence. The table below (Table 1) presents a brief idea of these activities.

The data was collected by me as both the teacher and the researcher. Firstly, I wrote field notes explaining what the students' contributions were (to report observation, to ask a question, to reply to a question, to explain their observations). Then, the interactions of each activity were analysed separately based on the sets of main codes and sub-codes that emerged: science codes and language codes. This aimed at obtaining insights on whether these activities promoted better understanding of concepts among my students and at understanding the role of language during the discussions. The main science codes for the inquiry-based learning in science used to analyse the data generated from this study were adapted from Hogan et al. (1999). Adopting and adapting their codes

Table 1
Activities Implemented

Activity 1	A structured-inquiry activity on the topic of Energy and Work Done	One double lesson (2 lessons of 40 minutes each)
Activity 2	A structured-inquiry activity on the topic of Light	One double lesson (2 lessons of 40 minutes each)
Activity 3	A guided/open-inquiry activity on the topic of Forces	Two double lessons (4 lessons of 40 minutes each)

was useful to my study in generating knowledge about classroom practices where knowledge is constructed through peer and teacher discussions. Taken together, these three activities provided a comprehensive and deeper picture of whether using more discussions and promoting more talk within an IBL setting resulted in better understanding of physics concepts and improved the students' ability to talk science when expressing their scientific knowledge and understanding.

The analysis of the data aimed at identifying whether students benefitted from such activities by looking for valid explanations, ideally accompanied by the good use of specialized technical language.

The following are the main codes for inquiry-based learning in science that were adopted and adapted from Hogan et al. (1999) and used to analyse the students' contributions:

- Observation statement (when the student reports directly what they observe);
- Replying to questions (when the student answers questions either posed by the teacher or by peers);
- Using knowledge to explain (when the student uses their knowledge to explain);
- Student elaboration (when the student attempts to give more detail on previously shared ideas);
- Student asking questions (when the student asks the teacher or his peers a question);
- Student uncertainty statement (when the student voices their uncertainty about a topic);
- Student rebuttal (when the student refutes the ideas or suggested methods put forward by their peers);
- Student acknowledgement by affirmation (when the student acknowledges by agreeing with contributions put forward by peers);
- Logistical (when the student discusses aspects of the task, for example, what to do and how to carry it out);
- Off-task (when the student discusses something that has nothing to do with the topic/task); and
- Teacher input (when the teacher intervenes).

As mentioned earlier, this study looked at the relationship between the language used when the students were encouraged to use their preferred language, i.e., English, Maltese or a mixture of both (code-switching), and their ability to talk science. As a result, a set of codes focusing on the language used was needed. The first set of language codes was quite simple and predetermined: English, Maltese, code-switching. The first activity (Burning off the calories of a Mars bar) was coded. Each contribution put forward was assigned one of the codes. This did not provide enough insights into when and how different language repertoires were used, and thus, it was decided to look at the students' contribution and at whether when code-switching, the students used English either for specialised technical words, non-technical words related to the activity, for a mixture of both technical and non-technical words, or for words which, although they cannot be considered as specialised technical terms, are part of the physics repertoire. Though this gave a better picture, i.e., the first-language Maltese speakers used the three different language repertoires to different degrees depending on their proficiency in the English language, it still felt that such coding was not providing enough insights into when and why these language repertoires were used. Therefore, a new way of looking at the data needed to be found. It was decided to go through the whole group discussion of Activity 1 and adopt an interpretive approach. While keeping the main codes (English, Maltese and code-switching), side notes explaining each contribution put forward, for example, "reasoning", "recording data" and "explaining data", were added. This enabled the following codes to emerge: Reasoning and explaining, Investigative design, Data, Observation, Accuracy, Predicting, Questioning, and Demonstrating misconceptions or incorrect scientific knowledge.

Analysis

The analysis focused on the students' language preference and speaking proficiency when sharing their scientific ideas and demonstrating their understanding. In order to analyse the language use, I first identified the overall linguistic strengths and preferences of the students. This helped me map the varying linguistic competences within which I, as the teacher, was operating while collecting my data in the particular context of the three inquiry activities implemented. The group consisted of five students from whom contributions were gathered during the data collection process. These students are referred to by pseudonyms. Out of the five students, there was one foreign student (Yuri) from Eastern Europe. Yuri had been in Malta for 5 years and could understand

Maltese well, but he preferred to express himself in English. Both his parents were university graduates. The other students in the group (Matthew, Keith, Noel and Robert) were all Maltese and were mainly Maltese-speaking. Keith and Noel possessed a very good level of vocabulary (Level B2 on the Common European Framework of Reference for Languages (CEFR)) and were thus more proficient than the others in the English language. Matthew and Robert had enough language knowledge to get by but struggled to express themselves fully in English (somewhere between A2 and B1 on the CEFR), making them uncomfortable using English. Thus, the overall linguistic diversity of the classroom was one where all the students understood the Maltese language, with one foreign student preferring not to speak it, and all students understood English, with two first-language Maltese speakers struggling to find the right words to express themselves in English.

As their teacher, although I feel comfortable expressing myself in both languages, I do have the tendency to code-switch as I speak, especially when engaged in informal discussions with colleagues and students during break time. However, during this study, I was careful to adhere to speaking in English during class discussions and explanations and only resorting to code-switching when I noted that some students could not grasp the content I was explaining.

A first snapshot of language use can be obtained by tallying the language of the students' contributions over the three activities: English; Maltese; or code-switching. Table 2.0 presents the number of contributions made by the first-language Maltese speakers according to these three different language repertoires, when interacting among themselves as well as with the teacher during the three activities. The percentage of the contributions put forward by these students were calculated by looking at how many contributions were put forward by the four Maltese students in English, Maltese and by code-switching out of the total number of contributions they put forward. Yuri was not included at this point as all his contributions were in English.

Table 2

Use of Different Language Repertoires by First-Language Maltese Speakers

	English	Maltese	Code-switching
Activity 1	17 (31.5%)	12 (22.2%)	25 (46,3%)
Activity 2	27 (32.9%)	19 (23.2%)	36 (43.9%)
Activity 3	11 (19.0%)	21 (36.2%)	26 (44.8%)

Design and Implementation of the First Activity: Burning off the Calories of a Mars Bar

The first activity, named 'Burning off the calories of a Mars bar', was an IBL activity, where the students were presented with an inquiry challenge related to forces and energy. This activity was a structured activity because it provided the students with the key inquiry question and the steps needed to follow during the investigation. The inquiry focused on the relation of body weight and the work done, taking walking up versus running up a flight of stairs as a context. This activity was carried out over one double lesson in order to allow enough time for the task to be completed.

Design and Implementation of the Second Activity: Exploring Light Through Prisms

Based on my reflections on Activity One, I planned another structured IBL activity, this time on the topic of light. The students were presented with an inquiry related to the dispersion of white light on the surface of bubbles. Colours are formed over the soap bubble's surface when light falls on its surface. The spectrum observed represents the multiple refractions that occur when white light gets split into its seven component colours. This phenomenon is known as dispersion of white light. The activity did not go into the physical phenomenon of interference, which results due to the multiple refractions, as this is not included in the Physics secondary syllabus. The aim was to introduce and target the phenomenon of dispersion of white light. This activity was implemented over one double lesson, a total of 80 minutes, in order to allow enough time for the task to be completed.

On analysing the three activities, I concluded that:

IBL Activities Engaged the Students. The structured IBL activities were straightforward as they provided the students with the key inquiry question and the steps needed to follow during the investigation. These made it easier for the students to understand what they had to do and what they needed to investigate. The guided/open IBL activity demonstrated how the students were evidently getting accustomed to the IBL approach. They were becoming accustomed to talking and discussing as they worked.

The Students Understood the Physics Concepts Well. The aim of the first activity was to implement an IBL activity which enables the students to understand the relationship between force and work done and also to understand that the amount of calories burnt during an exercise depends on the weight of the person as well as on the time taken to perform the exercise. The aim of the second activity was to implement an IBL activity which enabled the students to understand that white light is refracted when it passes from one medium to another and a spectrum is produced. The aim of the third activity was to implement an IBL activity which enabled the students to understand that increasing the contact time between colliding bodies decreases the force of impact. The students managed to explain their observations fully during the three investigations. This meant that the students achieved a good level of understanding of the three concepts, as I had planned.

There Was Talk During the Activities. The students talked during the first activity, both during the investigation, as well as during the plenary. There was a significant improvement in the degree of talk taking place during the second activity, both during the investigation, as well as during the plenary. The quality of the talk also shifted from only describing observations to trying to explain what was happening. While I considered that there was a significant improvement in the degree of talk taking place and an improvement in learning, this improvement was still not observed in all the students participating in the study. In the third activity, a significant improvement in the degree of talk taking place during the activity, both during the investigation, as well as during the plenary, was also noted. The quality of the talk improved further into the students trying to explain what was happening using scientific language.

The Students' Language Preference Appears to Influence Their Choice of Language to Use. Yuri stuck to speaking in English. Robert preferred Maltese and code-switched when referring to physics aspects. Noel tended to speak in English when talking physics and suggesting what to write in response to the questions in the worksheet and resorted to Maltese and code-switching when interacting directly with Robert and Matthew. He also spoke entirely in Maltese when the conversation was less scientific and thus, no technical words were needed. This also applied to Keith, who also spoke either in English or code-switched when talking physics. He code-switched mainly when interacting directly with Robert. This showed that while there was an increase in talk, all the students reflected their language proficiency.

Talking exclusively in English by first-language Maltese speakers took place either when interacting with the teacher or with Yuri, and when drawing conclusions about the investigations carried out. This highlights how the students considered talking to the teacher to be a formal exchange and thus resorted to using the formal language of assessment. It also highlights that the students considered Yuri as English speaking and spoke in English to include him in the learning experience. The students also reverted to the English language when presenting the final formal conclusions of their investigations.

Conclusion

This study has shown that the Maltese language and the use of code-switching played an important part when students came to articulate their thinking during the IBL activities. The contributions to the discussions were often put forward in the students' first language in the case of Maltese speakers. Maltese and code-switching were used for sophisticated processes, such as when using knowledge, elaborating and demonstrating reasoning with and without a scientific concept. The students preferred to use their highest proficiency language when trying to understand what was happening conceptually. The more the students spoke in their preferred language, the greater was the amount of their sequences in response to my questions. The language the students used seemed to limit or facilitate verbal exchanges depending on their proficiency, highlighting the role that language plays in shaping thought and development of appropriate (here, both dialogic and scientific) language (Vygotsky, 1987). Another possibility could be that working within a community of practice, the students learned from the more knowledgeable other and became acquainted with the tasks, and the vocabulary: both aspects appeared to contribute to their learning. This led to a shift in power, possibly as a result of the guidance that I provided to carry out the inquiry-based activities (Mercer, 2008), highlighting that students need to be doing science "with judicious teacher assistance and support" (Hodson, 2014, p. 2547).

To summarise, this study has shown that adopting an inquiry-based learning approach which is sensitive to the students' preferred language has enabled my students to understand the physics concepts better when they were encouraged to talk science, improving also their use of scientific language, as well as becoming more responsible for their learning. These findings are consistent with the study carried out by Borg (2010) which showed that allowing students to use their first language makes it easier for them to express themselves. Though the study underpinning this study is limited to one particular group where the students were faced with three border-crossings, two linguistic and the third border being that of learning physics through an unfamiliar approach to many, i.e. through an inquiry pedagogical approach, it has provided insights which contribute to a gap in knowledge in the Maltese context of learning Physics in secondary schools.

Previous research carried out in the Maltese context has focused on the language used by the teachers such as code-switching (Mifsud, 2012) and translanguaging (Camilleri Grima, 2013) during lesson delivery, and whether students are familiar with polysemous words (Farrell & Ventura, 1998). This study has dug deeper into language use at different points of learning physics, and how language used by students varied as they worked through different activities including discussions, groupwork and formal presentation of results. The switching from one language to another supported the learning process for second language learners, with first language used mainly when grappling with understanding among students with limited English proficiency (Nyika, 2015), and second language (also the official language of assessment) used in presenting results and preparing writeups for assessment. This research indicates that students probably prefer to think and to construct knowledge in their first language (Lodge, 2015). They can then learn to express themselves in the formal language of physics, whether this is in their first or second language.

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Notes on Contributor

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