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LANGUAGE ISSUES IN MATHEMATICS AND SCIENCE: An Analysis of Examiners' Reports on Students' Performance in Caribbean Secondary Education Certificate Examinations (2010-2011)

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This study adopted a systemic-functional approach to analyse the language issues that examiners referred to in their reports on candidates' performance in mathematics and science examinations administered by the Caribbean Examinations Council (CXC) in 2010-2011. Content analysis of reports in mathematics, chemistry, biology, physics, human and social biology, and integrated science identified four salient areas of language challenges for students—subject discipline terminology, data representation, content area reading, and content area writing—as these related to students' understanding and expression. Examiners' recommendations to address these issues were also analysed. It is suggested that Caribbean students may be facing challenges in accessing academic language through a language that is not their first language, and that this influences their ability to use conventional tools of the disciplines to show their understanding of mathematics and science in examinations. The article also makes recommendations for curricular review to provide greater opportunities for students to develop critical language skills in content areas

Introduction

Over the last two decades, a growing body of literature has emerged with a focus on the nature of the language proficiencies that learners need to develop in order to experience success in academic contexts (Janzen, 2008; Schleppegrell, 2007). Researchers and educators generally agree that schools require students to use an academic variety of language which differs from the kind of language that students use in their everyday life (Lager, 2006; Schleppegrell, 2001). This variety is most frequently called "academic language" (Fang & Schleppegrell, 2010; Zwiers, 2005, 2007). Although the definition of the term is contested (Valdés, 2004), growing evidence suggests that the linguistic demands of schooling create challenges for students across the curriculum. In fact, students who are not instructed in their first language face two challenges when they are schooled: they must develop competence in the academic language that schooling typically demands, while they must simultaneously acquire content knowledge using a second language or dialect.

In the Caribbean region, the question of language and language education has also been well researched (Simmons-McDonald, 2004). However, there is not a significant body of literature exploring the kind of language challenges that confront Caribbean students when they are taught subject disciplines in schools, and when they are asked to show their understanding in examinations. Byron's (1988) study, which focused on the effects of language variables on problem-solving in mathematics, is one example of such studies. The issue of language in the Caribbean school curriculum assumes even greater significance when one considers the complex linguistic situation in the region. In the Anglophone Caribbean, the official language of teaching and learning, Standard English, is not the first language of many students, which is usually an English-related Creole. The consequences of teaching students in a language that is not their first language or vernacular have been extensively debated (Carrington, 1990; Craig, 2006; Simmons-McDonald, 2004). Robertson (1999) argued that the absence of informed and consistent language policies has had a negative effect on regional educational systems and, by extension, student learning.

This paper is an initial exploration that attempts to join these two strands of language research in education: academic language learning, and learning in a second language. To achieve this, it analyses the language issues highlighted in the reports of examiners on students' performance on mathematics and science examinations offered by the Caribbean Examinations Council (CXC). The findings are discussed in the context of pertinent research literature and the implications for classroom practice. The paper concludes with recommendations for curricular review in the Caribbean region, in order to provide greater opportunities for students to develop language competence in content areas.

Academic Language: The Language of Schooling

Different terms are used in the literature to refer to the type of language that students are required to use in order to learn in schools. This variety is most often called "academic language." Zwiers (2005) defined academic language as "the set of words and phrases that describe content-area knowledge and procedures, express complex thinking processes and abstract concepts, and create cohesion and clarity in written and oral discourse" (p. 60). This suggests that competence in academic language is not limited to the acquisition of content vocabulary, but encompasses subject-specific ways of thinking and acting using all language modes. Zwiers (2005) argued that for English language learners, academic language is almost a third language, the acquisition of which is limited to the classroom. In a study of teacher practices and students' development of academic language, Zwiers (2007) concluded that classroom discourse patterns and activities have the potential to both develop and impede students' language growth. He suggested that teacher knowledge of the cognitive skills of content areas and the language that supports such skills is crucial, if educators are to devise appropriate pedagogy to help students acquire and use academic language. In the absence of this, students' language competence in the school discipline may actually be hindered rather than promoted.

Students' mastery of academic language is also thought to affect their level of success in school. For example, Bielenberg and Wong Fillmore (2004/2005) found that academic language is a critical factor in the disparity in achievement levels between high-performing and low-performing students in schools. With specific reference to examinations, these researchers suggested that teachers need to use instructional activities that facilitate the development of students' mastery of academic English, in order to enable them to learn cognitively challenging content and successfully transact the language of examinations. This is because of the nature of academic language, which is characterized by subject-specific vocabulary, grammatical forms and structures, figurative expressions, and prescribed ways of communicating (Fang, 2005; Schleppegrell, 2007).

Some of these features were identified in one of the earliest documents to highlight the importance of language across the school curriculum—the Report of the Committee of Inquiry into Reading and the Use of English (Great Britain [Bullock Report], 1975). Although the report specifically addressed instruction in the secondary school system, the recommendation that teachers need to be aware of the linguistic processes by which their students acquire information and develop understandings is also relevant to the primary level. It is especially crucial for teachers in the Caribbean region to be aware of the role of language across the curriculum, since many adopt an approach that assumes that students are learning through their first language or dialect, when this is not necessarily the case (Craig, 2006).

As the Bullock Report (Great Britain, 1975) demonstrated, and other researchers have asserted since then (Fang, 2005; Fang & Schleppegrell, 2010; Lager, 2004; Schleppegrell, 2007), educational institutions make heavy demands on the language of those who learn and those who teach. To deal with the situation effectively, teachers need to have an understanding of how language operates generally, and the nature of the spoken language specifically, since so much of classroom instruction relies on teacher talk (Martin & Miller, 1999). Teachers therefore need to consider how children can be helped to use language to transform knowledge and experience into understanding across the curriculum and become active learners. This, however, cannot be done without reference to the language that students use in their communities, and the ways in which their language differs from those they are required to use to learn in school.

Language in Mathematics and Science

Language in mathematics, like in other school disciplines, constructs knowledge in specific ways, and schools attempt to teach students ways of using this language or "register" to participate effectively in mathematical ways of knowing (Halliday, 1978). Halliday defined "register" as "a set of meanings that is appropriate to a particular function of language, together with the words and structures which express these meanings" (p. 95). The variety serves a specific function and is characterized by vocabulary that is associated with a particular domain of activity, appropriate styles of meaning, and modes of argument. For example, lawyers in a courtroom would use a register associated with the practice of law. For mathematics, the "register" can be said to be characterized by the use of language in ways that are different from other disciplines, and from everyday language. For example, in baking at home, children may use or hear their parents use a measurement of "a pinch of salt," but this is not a conventional unit of measurement in school mathematics. Students may therefore come to class with the knowledge of terms used in one way, and must learn the mathematical concept called by the same name (Schleppegrell, 2007). Such vocabulary is needed to classify mathematical objects, understand mathematical ideas, and to reason mathematically. Though some teachers may explicitly teach new technical vocabulary, some crucial ones may be overlooked, and teachers may assume that students either know them already, or will pick up the meanings elsewhere in the curriculum (Lager, 2006). In a Caribbean linguistic situation, there is also a need for consideration of the overlap of words in the lexicon that may mean different things in the language systems, and thus create difficulties for learners.

Apart from vocabulary items, complex language structures in word problems in mathematics can affect students' reading comprehension and affect their ability to solve problems (Byron, 1988). Byron's study suggested that where the semantic and syntactic information in mathematical texts were close to understandings that students held, the better the chances were that they would solve the problem.

Additionally, mathematics uses multiple semiotic or meaning systems. A semiotic system, such as language, uses signs, symbols, and images to create meaning and influence behaviour by making meaningful choices in a particular context (Eggins, 2004). Just as spoken and written language do, visual modes of communication have their own "grammar," and different components work together to create meaning (Towel & Smilan, 2009). Applied to school disciplines, the use of semiotic systems requires students to make important connections among physical, pictorial, graphic, symbolic, verbal, and mental representations of mathematical and scientific ideas. Such connections are especially crucial where concepts are hierarchically ordered and the precise meanings of words need to be established (Fang & Schleppegrell, 2010). Schleppegrell (2007) demonstrated how complex grammatical patterning can be in common mathematical expressions. Some of the patterns that she identified were the following (all examples are from Schleppegrell, 2007):

- Long, dense noun phrases that express complex meaning relationships in problems that students have to solve
- The use of pre-numerative phrases that refer to abstract but quantifiable mathematical attributes of the head noun, such as "The volume of…"
- The use of classifying adjectives that precede nouns, as in phrases such as "rectangular prism"
- The presence of quantifiers that come after the noun: "prism with sides 8, 10, 12 cm…"

Teachers can easily underestimate the level of difficulty such grammatical patterns and structures pose for student comprehension.

Lager's (2006) study of middle school students' challenges in learning algebra also demonstrated the kinds of implicit mathematics language reading interactions that can make it difficult for students to understand written curricula. This was not only limited to interactions during instruction, but included challenges to their performance on assessment tasks. Based on his research, Lager concluded that it is difficult for English language learners to engage fully with mathematics content if they do not possess a strong command of both common everyday language and the specialized mathematical language.

As it does in mathematics, language plays an important role in the acquisition of science knowledge and concepts. Students use language to interpret and create ways of representing science activity and knowledge in subject-specific ways (Carolan, Prain, & Waldrip, 2008). This includes science vocabulary, since many words such as "force," "work," "energy," and "stress" that are used in everyday speech have a different, precise meaning in school science. Apart from learning science concepts, Waldrip and Prain (2006) showed that students must also understand and conceptually link different modes of representation. Such representations include verbal, graphic, and numerical forms, which are often linked to produce multi-modal representations in science texts. The process would be even more difficult if learners have to comprehend in a language that is not their first language, since research evidence suggests that limited proficiency in English constrains students' science achievement when instruction and assessment are conducted exclusively or predominantly in English (Lee, 2005).

A related consideration is the extent to which culture and traditions in students' communities influence the ways in which they interpret signs and symbols, leading to misconceptions in school disciplines. For example, Lee (2001) examined the relationship between culture and language in science education, and concluded that cultural and linguistic diversity challenge conventional notions of science content, learning, teaching, and assessment. This is demonstrated in the work of Caribbean researchers such as George (1995) and Herbert (2003, 2008). George's initial study explored the differences between the traditional practices and beliefs of rural villagers and the principles of conventional science. She showed how some concepts may have meanings that are unique to the two different settings: community and school. Building on this research, Herbert (2008) devised a curriculum to help students to "cross borders" between traditional and conventional ways of knowing, and to enable them to have greater access to school science. Both researchers agreed that science teachers should be sensitized to the benefits of adopting a cross-cultural approach to teaching science that takes the prior knowledge and out-of-school experiences of their learners into account. There is international literature to support this position (Aikenhead, 1996; Costa, 1995; Jegede, 1997). The relevance of this issue to the current study lies in the recognition that the language challenges in school disciplines cannot be considered in isolation, but must be viewed in the context of the connection between language and culture, and possible differences in experiences and world views of community and school.

Limitations of the Study

This investigation utilized only the examiners' reports on students' performance. It did not examine actual samples of students' written responses nor did it record the exact frequency of each difficulty. In addition, the reports focused on the written products of examinations and were not derived from observation of any other communicative language process in the course of student learning of mathematics and science. The use of actual students' scripts and classroom observation across disciplines would certainly provide primary data and allow different perspectives on this critical issue. Also, the question papers for the mathematics and science examinations were not included in the data.

Theoretical Framework

The theoretical framework used in the study is Halliday's systemic-functional linguistic theory, which explains language use and variation in terms of the diversity in structures and processes in the social system, and as a reflection of communicative choices made by users to serve different functions (Halliday, 1978). The theory further seeks to explain how the structure of a text works to provide unity through the use of patterns and cohesive devices. Systemic-functional linguistics is therefore useful for analysing language interactions in social contexts, in school, home, and community. Most activities that human beings engage in involve language use, and in this process a variety of texts are produced. For example, the occasion of a wedding generates diverse texts through the use of different modes, beginning with the written invitation, speeches by different officials, the signing of the register, and perhaps a slide show or presentation. Texts are thus produced in contexts using different modes.

Eggins (2004, p. 3) summarized the four main theoretical claims that systemic-functional linguistics makes about language. The first is that language use is functional; that is, it serves a specific purpose. The second claim highlights the semantic property of language in that it is used to create meaning. Thirdly, the social and cultural context in which language is used influences the meaning that is created. The final claim is that the entire process of language use in a specific context is a semiotic one; that is, language users choose the means by which meaning is created, and the modes they select to communicate can vary from oral speech, to written text, to icons and pictures.

As indicated previously, Halliday (1978) used the term *register* to refer to a variety of language that is appropriate to particular social situations. Registers link texts (oral, written, or visual) to their context. *Text* is produced in the course of an event that occurs in a specific social *context*. This context is framed by the social activity taking place, which Halliday calls the *field*, while the *mode* is the rhetorical channel through which communication takes place. Consistent exposure to conventions of language use leads users to associate texts to particular contexts.

In classrooms, students who attempt to communicate using the register of a school discipline must consider the form and the appropriateness of their linguistic choices, given the requirements of content areas for the creation and interpretation of texts. Thus, when mathematicians or scientists use terms and structures in discipline-specific ways, they are using registers and creating meaning with other mathematicians and scientists in their community through the use of meaningful linguistic choices.

In order to focus the investigation, two main questions were addressed:

1. *What language issues were highlighted in the 2010-2011 reports of examiners of mathematics and science subjects offered for the Caribbean Secondary Education Certificate (CSEC)?*
2. *What recommendations did examiners make to address the language issues highlighted?*

The next section of the paper provides the research context and explains the method adopted.

Caribbean Examinations Council Assessment of Student Performance in Mathematics and Science

The Caribbean Secondary Education Certificate (CSEC) examination is a regional one for students who have completed five years of secondary schooling. It is administered by the regional examining body, the Caribbean Examinations Council (CXC), with all subjects offered during the months of May/June and a limited number of subjects offered in January. The Chief Examiner for each subject usually reviews the performance of students and compiles a report, which is circulated to schools. The reports are available to the public from CXC's website and they provide quantitative and qualitative analyses, and detailed assessment of responses to questions on the examination papers. These reports vary in focus and details across subject disciplines. However, they usually link to the relevant CXC syllabus, which is part of the curriculum of secondary schools in the region. Reports highlight the perceived strengths and weaknesses of students' responses, compare their performance with that of students examined in previous sittings, and offer recommendations for teachers. While the examiners' comments primarily address students' knowledge, skills, and understanding of subject area content, some observations connect to other areas that can be described as cross-curricular. Language is one such area, given the fact that students must read and interpret questions in the final examinations, and must respond to such questions in writing, or in a language mode that is conventional for that subject.

Data Analysis

To answer the research questions, a qualitative content analysis was conducted of 2010 and 2011 CXC examiners' reports for mathematics (CXC, 2010e, 2011e) and five science subjects–biology (CXC, 2010a, 2011a), chemistry (CXC, 2010b, 2011b), physics (CXC, 2010f, 2011f), integrated science (CXC, 2010d, 2011d), and human and social biology (CXC, 2010c, 2011c). These 12 reports constituted the data set for this study.

Content analysis seeks to identify, describe, and analyse the content of documents. Graneheim and Lundman (2004) surveyed literature on content analysis and proposed definitions of key concepts related to qualitative content analysis. These include *manifest and latent content*; *unit of analysis*; *meaning unit*; *condensing*; *abstracting*; *content area*; *code*; *category*; and *theme*. These terms are used as defined in Graneheim and Lundman, who distinguished between the *manifest* and *latent* content of texts; the first referring to the visible and obvious, while the second labels interpretation of the content at a higher level of abstraction. The initial examination of the *manifest content* of the reports revealed that recurring language issues were mentioned and that recommendations were made to address them. The next stage involved a process of data *condensation*. Each report was read several times to obtain an overall sense of the content, then any reference to language was extracted and brought together to form one text, which was considered a *unit of analysis*. *Meaning units* were derived from this text. A *meaning unit* was taken to be the "constellation of words or statements that relate to the same central meaning" (Graneheim & Lundman, 2004, p. 106). For example, the 2010 Biology report noted that "spelling of common biological terms continues to be atrocious. Even when the biological term is used in the question, candidates will introduce their own spelling of the term" (CXC, 2010a, p. 3). This section of the report was identified as a *meaning unit* because of the direct reference to spelling, a convention of writing in a language. This was condensed to "atrocious spelling of common biological terms and own spelling introduced." This was later coded as "incorrect spelling." All such units were condensed, abstracted, and coded. The codes served to label the meaning units. Using an iterative process, the codes were sorted into categories based on similarities and differences, and then themes were derived based on the underlying meaning of the categories. The next section presents the findings of the analysis in the main categories.

Understanding and Using Subject-Related Terminology in Examinations

Subject terminology is perhaps the most visible language component that marks school disciplines as *registers* or varieties of languages. It was therefore not surprising that this was the largest category of language challenges highlighted by examiners. All reports indicated that candidates in the examinations had difficulties with subject-related vocabulary. This was evident both in students' lack of understanding of examiners' use of terms in questions, and in students' inappropriate vocabulary. Examiners referred to challenges exhibited in defining concepts: "Candidates often indicate that they 'know' the material, but cannot recall correctly the names of structures, definitions and processes" (CXC, 2010a, p. 6). Examiners also found that "while many candidates discussed each [term], most of them were not clear about the meaning of the terms [such as] social, ethical…. As such, they spoke of ethnicity rather than ethical; and they discussed socialization of plants" (CXC, 2011a, p. 8). Similar difficulties with definition of concepts were highlighted in other disciplines. In 2010, the HSB examiner noted that, "Part (c) (i) presented the most difficulty as candidates were unable to give the meaning of the term 'antagonistic muscles'" (CXC, 2010c, p. 4). Here, the context of the use of the adjective *antagonistic* is significant. Students had to distinguish between the meaning of the word *antagonistic* as it is used in science, in contrast to the meaning of the word in other non-scientific contexts. This might have been the source of students' difficulties.

Additionally, examiners thought that students had challenges distinguishing between terms with similar spelling or semantic associations and multiple meaning words across the subject areas:

> The lack of use of scientific terms continued to be prevalent. (CXC, 2010c, p. 2)
>
> Far too many candidates continue to confuse related concepts, terms that may sound alike or those that may have a different meaning from everyday common usage. These include concepts such as corrode and corrosive; …. In a number of instances, terms were used rather loosely, completely distorting the overall meaning of the idea being communicated. (CXC, 2011b, p. 2)

The chemistry examiner further noted that the subject being examined required a specific language to express concepts and relationships in the discipline and some students had not mastered this:

> The language of chemistry also posed problems for some candidates. Far too many candidates confused calcium hydroxide with calcium carbonate. Many showed limited appreciation for the balancing of ionic equations …. Candidates wrote terms such as 'kill' or 'destroy' when referring to the denaturing of protein molecules. (CXC, 2011b, p. 2)

This apparent confusion of scientific terms with everyday terms can be understood in the context of the use of registers in different domains or social activities. The examiner in biology referred to students' use of "non-traditional language," and in mathematics, their use of "informal language." In addition, it was found that "the answers provided were often vague, lacking in the scientific terminology required at this level. Words like 'soaked up', 'absorbed' were loosely used…" (CXC, 2011a, p. 10).

The examiners' complaints suggest that after years of instruction in mathematics and science, some students had not acquired the appropriate terminology to communicate in these disciplines. The registers of school disciplines are different from the registers that students understand and use in their everyday lives. However, they appeared unable to distinguish between the use of academic language and everyday language. Though there is overlap in vocabulary terms, some are specific to domains of use or events in which they serve specific communicative events in schools or community.

As the literature suggests, the complex nature of texts in mathematics and science also has the potential to challenge student comprehension, and although the actual questions on the examination papers were not included in the data for this study, the examiners usually summarized the questions in order to identify the content knowledge that was targeted. Sometimes, versions of expected responses were given. In some instances, this provided evidence of the kind of complexity of grammatical patterns and structures indicated in Schleppegrell (2007). For example, students had to negotiate long, dense noun phrases such as the one that appeared in the 2011 mathematics examination, when they were asked to “determine the intercept of the graph of a linear function…” (CXC, 2011e, p. 6). Students also had to read and interpret text with both quantifiers and qualifiers placed after the noun:

> Clockwise rotation of 90 degrees about 0,0. (CXC, 2011e, p. 10)
>
> Solve a pair of equations in two variables when one is linear and the other non-linear. (CXC, 2011e, p. 8)

Complex grammatical patterns and structures were not only evident in mathematics. The chemistry report reflected the use of classifying adjectives that precede nouns in phrases: “differences between oxidizing and reducing agents” (CXC, 2011b, p. 3). Other challenges would have arisen when students had to interpret language used in a metaphorical way: “repay the oxygen debt” (CXC, 2010a, p. 6).

However, difficulty in defining or using the correct labels for concepts and processes in mathematics and science is only partly attributable to a lack of comprehension or use of vocabulary. It also relates to the psychological process of concept formation and learning processes in school science and mathematics.

Data Representation in the Disciplines

The second most common area of language challenges that examiners identified related to students’ attempts at data representation. Candidates in all examinations experienced difficulty in interpretation and construction of subject-appropriate modes of representing data to communicate meaning in the disciplines. These included difficulty constructing tables, diagrams, and drawings to represent concepts and ideas:

> A few candidates still confuse the direction of flow of the arrows in a food chain. (CXC, 2010a, p. 7)
>
> In general, diagrams were poorly drawn, which could be due to insufficient practice at drawing pieces of chemical apparatus. (CXC, 2010b, p. 6)

The examiner in physics expressed particular concern about the difficulties students experienced with the use of formulas, and so did the chemistry examiner in his evaluation of students' writing of formulas, symbols, and balanced equations:

> Part (b) presented problems with transposing the formulas. (CXC, 2011f, p. 2)
>
> This skill [writing and balancing equations] seems to be on the decline once more. Far too many incorrectly written formulae were presented in the scripts. (CXC, 2011b, p. 3)
>
> Many candidates were unable to correctly interpret the data presented in the table and the graph. (CXC, 2011c, p. 2)

Most examiners also identified the construction of visual representations as a problematic area. In mathematics, the examiner observed that "the construction of angles posed a problem for many candidates. They had more success in constructing 60° than 90°. A small number of candidates also had problems labelling their diagram" (CXC, 2010e, p. 7).

Occasionally, students used a format in one discipline that was considered more appropriate for another discipline, and examiners commented on this:

> It should be emphasized to candidates that the title format *name of independent variable* vs. *name of dependent variable*, for instance, *time* vs. *distance* is not acceptable in Biology, although it may be used in the other areas of science. (CXC, 2011a, p. 3)

The reports varied in the level of emphasis placed on the challenges students faced when they attempted to communicate with semiotic tools such as graphic representations. For example, the reports in physics and mathematics stressed difficulties with the use of symbolic notation and transposing data more than the reports in the other subject areas:

> In Part (b), a large number of candidates were unable to successfully use symbols to express a phrase as an algebraic expression. Further, they did not know when to use brackets and incorrectly wrote $7x + y$ instead of $7(x+y)$ in Part (b) (i). (CXC, 2010e, p. 4)

In these instances, the examiners evaluated students' competence in using signs and symbols to convey thoughts and ideas. This reinforces the view of school disciplines as different registers, and the fact that students need to be taught the differences in conventions among them.

Each discipline represents information in ways that are similar in some respects, but quite specific in others. Mathematics and science use representations in oral and written forms of language, visual or graphic representations, and symbolic notations in the form of formulas and equations. These are all language tools used to convey meaning, which students are expected to master.

Writing in the Content Areas

Several aspects of writing in the content areas emerged as issues of concern. Except for physics and mathematics, reports noted challenges in the spelling of basic subject-related terms, with comments such as, "too many candidates incorrectly spelt common biological terms" (CXC, 2010a, p. 6). In addition, adhering to conventional features of written texts associated with the disciplines was sometimes problematic. For example, reports for biology and physics noted that some students had difficulty describing methods of experiments, aim, statements, and conclusion in the expected form:

> Although candidates seemed knowledgeable of the content of the Aim statement, a large number of them were unable to offer a well-written one. An acceptable Aim includes a verb, the manipulated variable, observations to be made and the subject of the experiment. (CXC, 2011a, p. 8)
>
> Part (b), the description of the experiment, proved challenging for many students. In Parts (c) and (d), the observation and conclusion were satisfactorily produced by some candidates only. (CXC, 2011f, p. 6)

These comments evaluate students' ability to use the conventional features of the texts that are expected in written communication in science and mathematics. Such features are textual aspects of reports on experiments, including format and internal structure. In chemistry, some students experienced difficulty using the appropriate format for stating chemical tests. Similarly, the mathematics report commented on students' inability to "write in mathematical form" (CXC, 2011e, p. 4).

Difficulties with language use featured in all reports, most of which described students' writing as "vague" or "ambiguous." For example, in evaluating students' response on one question, the examiner commented that "some candidates gave broad, ambiguous answers … which were inadequate because the specific reason for the transport system was not indicated (CXC, 2010d, p. 3). In addition, students had difficulty using different genres of writing such as description, analysis, exposition, and argumentation, which are required in mathematics and science:

> In Part (b), describing the rotation proved particularly challenging for candidates. Some of them stated the centre correctly but they used informal language when describing the direction. Responses such as to the left, westward and south east were often given. It was evident that candidates did not know how to state a geometrical relationship between a triangle and its image. (CXC, 2010e, p. 9)

The examiners also referred to weak skills in grammar and mechanics, one observing that students "did not use appropriate linking words to compare" (CXC, 2011a, p. 8). Such difficulties with language resulted in little or no elaboration of answers, the inclusion of irrelevant information in students' responses, and, consequently, low scores on the examination.

To some extent, the writing competence that is critiqued in the reports refers to general writing skills expected across the curriculum. For example, the ability to use comparative terms is required in all subject areas and, when writing, students need to show a command of grammar. However, when writing reports on experiments, specific formats are required, and students cannot write as though they are reporting on an accident or event.

Reading and Interpreting Skills

The final major category identified in all subjects, except physics and mathematics, related to students' ability to read and interpret the questions on the examination papers. Based on students' responses, examiners sometimes concluded that students had misinterpreted the questions they were asked. Invariably, examiners judged this to be a consequence of students' inability to distinguish among key verbs of interrogation in the examination questions such as *state*, *explain*, *describe*; or students' lack of content vocabulary. The following comment in the report for human and social biology was typical, stating that it "seemed that candidates were not reading the questions carefully and, therefore, provided answers that were in no way related to the questions" (CXC, 2010c, p. 2).

Two issues arise here in relation to the examiners' comments. The first relates to reading in the content areas. When students are taught mathematics and science, their skills in reading the texts associated with the disciplines must be developed. They cannot approach the reading of a science text as they would read a literary text such as a poem. The same is true when they have to interpret the meaning of parts of a text in mathematics, such as a word problem in which the structure of phrases and their relationship to each other are critical in determining the selection of procedures to solve the problem. The process might require them to represent information given in one mode, in another mode. Put another way, the syntax of a word problem is not the same as the syntax of a line of poetry, and students need to be helped to negotiate the meanings created in the text structures they encounter in the disciplines.

The second issue relates to the extent to which students are taught strategies to interpret and respond to examination questions. The fact that students appeared unable to provide the details signalled by key verbs does not mean that they would do so if they knew the meaning of words such as *state*, *define*, and *explain*. They must be taught how to analyse the text structure of the question and arrive at an accurate interpretation of its meaning, in order to respond with appropriate content knowledge.

Examiners' Recommendations to Increase Levels of Achievement

The examiners offered several recommendations, which covered pedagogical approaches, strategies, and activities. This section addresses only those recommendations that are relevant to the language issues identified above.

Most examiners urged teachers to adopt more student-centred approaches, which would allow increased oral and written engagement of learners, and provide opportunities for students to acquire appropriate subject terminology:

> Students should have opportunities to express their ideas and to communicate effectively, orally and in writing, in the classroom. These experiences are necessary to develop mathematical vocabulary and proficiency in communication, not only in mathematics but in their daily experiences. (CXC, 2010e, p. 9)

The examiner for chemistry (CXC, 2011b, p. 2) similarly suggested that teachers facilitate student conversation on subject-related concepts; while the physics report (CXC, 2011f, p. 5) called for a review of teaching emphasis to include more discussion on the relationship between concepts. The integrated science (CXC, 2011d, p. 7) and human and social biology (CXC, 2010d, p. 6) reports recommended an emphasis on the use of scientific vocabulary, and opportunities for students to differentiate concepts and to improve their knowledge of conventional text features.

The mathematics report also stressed the importance of teachers recognizing the role of language in teaching mathematics concepts, and the need to consistently use subject terminology and conventions such as the use of brackets: "Teachers should also pay close attention to mathematical vocabulary so that students are familiar with basic terminology such as solve, simplify and factorize" (CXC, 2010e, p. 5). In order to address the challenge of distinguishing terms, the examiner further suggested that "in teaching approximations, a clear distinction must be made between significant figures, decimal places and standard form" (CXC, 2010e, p. 3). This was supported in the report for integrated science: "Students need more practice in distinguishing between related and sometimes unrelated concepts and should be guided in expressing differences in terms of parallel points to improve completeness of responses" (CXC, 2010d, p. 10).

With respect to the challenges of data representation, the reports recommended that students be exposed to many opportunities to develop skills in communicating through visual representations. One advised that "teachers should use diagrams and graphs in teaching. Students need to be taught how to analyze and interpret graphs" (CXC, 2010c, p. 3). Other reports directed teachers to increase opportunities for practice, with the mathematics reports strongly recommending that students be instructed in the interpretation and use of graphic representation:

> Teachers should teach students to verify that the information recorded in their Venn diagram accurately represents the given data. (CXC, 2010e, p. 6)
>
> Teachers need to emphasize the role of language in teaching functional notation. In particular, students need to understand the meaning of f(x) and gf(x). (CXC, 2010e, p. 7)

The reports contained few recommendations aimed at improving writing in mathematics and science. However the integrated science report commented on:

> the need for proper grammar, sentence construction and spelling. Marks are more accessible when answers are communicated effectively. Teachers can incorporate these elements as part of their evaluation of students' work. Occasional or regular spelling quizzes or games with scientific terms may also help. (CXC, 2010d, p. 10)

Although most reports identified difficulties for students in reading and understanding the examination questions, few recommendations addressed this language concern. The report in integrated science, though, suggested that candidates "need to be encouraged to read questions clearly, paying attention to key words that should guide responses" (CXC, 2011d, p. 7).

The examiners frequently recommended increased opportunities for students to practise areas where they appeared to experience the greatest challenges. However, mastery of subject registers would be enhanced through the development of all the language modes, and requires more opportunities for students to speak, read, write, and visually represent their ideas to develop their thinking and acquire concepts in mathematics and science. The paucity of recommendations addressing writing and reading in the disciplines could be due to an emphasis on visual representations and subject terminology in mathematics and science, and a lack of prominence of reading and writing in the content areas. The consequences of this are addressed in the next section.

Discussion

This section discusses three main themes in relation to the language issues that emerged in the study in relation to classroom pedagogy. These are, firstly, the development of student proficiency in the registers of mathematics and science; secondly, the significance of multiple modes in interpreting and creating meaning in school disciplines; and, thirdly, language differences as reflections of cultural differences. The challenges that students experienced with examinations can best be understood within the larger context of these issues.

Although the reports were based on written responses, examiners made inferences about a wide range of students' communicative skills in the disciplines. Thus, in addition to an evaluation of students' writing skills, spelling, and vocabulary, the examiners pronounced on students' ability to read, interpret, and translate knowledge into visual and graphic representations to communicate meaning. Examiners also concluded that many students showed a limited ability to use textual features and cues in the language, format, and structure of questions to produce conventionally acceptable responses. At times, they noted improvement in some aspects of students' language performance; however, most observations emphasized limited competence in using the language conventions of mathematics and science.

Some of the recommendations made by examiners are in line with best practices in the literature on language and literacy in the content areas. For example, some advocated the use of more student-centred approaches and more encouragement of student discussion to deepen their understanding of concepts, thus providing students with more opportunities to develop the ability to use subject registers.

The recommendations in the reports reflected the limitations of the examiners' perspectives and purpose. Consequently, they did not address many of the critical socio-linguistic issues pertinent to education and student learning in the Caribbean context, although they serve as a timely stimulus for deeper inquiry into the role of language in student learning across the curriculum, and the way their achievement is measured.

Implications for Pedagogy

From a systemic-functional perspective, students experienced challenges using the registers of mathematics and science on examinations. Aspects of the registers include subject-specific vocabulary, associated grammatical forms and structures, and all other prescribed ways of communicating in the disciplines, including the use of language for reasoning and argumentation. A categorization of the language issues into different components of language separates the language from the content. However, as Shanahan and Shanahan (2008) point out, language and literacy are embedded within disciplines and are connected to specific learning situations. Thus, if students are to develop ways of thinking, speaking, reading, writing, and representing used by mathematicians and scientists, educators would need to immerse them in the discourse of the disciplines. In this way, students can assume the roles and participate meaningfully in the community of the subject disciplines.

Although reading and writing challenges did not feature as significantly in examiners' reports, students must read textbooks and other texts that contain linguistically and conceptually dense content (Schleppegrell, 2001). Norris and Phillips (2002) argued that reading is not merely a functional tool but a constitutive part of disciplines. Successful teaching of science and mathematics, therefore, cannot be accomplished without consideration of language and literacy teaching, since language processes are intrinsically linked to the nature and fabric of these disciplines. It is therefore unreasonable for content area teachers to expect language teachers to effectively instruct their students in the language of mathematics and science in the absence of the critical knowledge necessary for language teachers to do so effectively.

The same can be said of writing in content areas. A major genre, expository writing, is privileged in the sciences, and students are required to report, hypothesize, argue, and use language in conventional ways.

According to Worth, Winokur, and Crissman (2009), "writing in science is not only for communicating with others; it also is a tool for learning that supports scientists and students alike in clarifying thinking, synthesizing ideas, and coming to conclusions" (p. 49). If students are to write convincingly as mathematicians and scientists, and display their understanding of these subjects on standardized tests, they must be highly engaged in activities that promote their writing skills. Performance on writing tasks should demonstrate conceptual understanding, and such understanding is facilitated by extensive talk in the classroom. Teachers and learners must therefore connect reading and speaking to writing, especially if writing is the primary mode in which learners are assessed. Indeed, the integration of the modes of language has proven to be the most effective approach to language instruction, rather than one that isolates and segments the different skills. This would be most effectively done through meaningful and authentic learning experiences that cater to the linguistic and cognitive development of all students in an inclusive environment.

Another crucial consideration in teaching mathematics and science is the fact that students must learn to understand and use different semiotic codes to translate their knowledge into multiple modes of representations. With reference to mathematics, Altieri (2010) stressed that along with developing word knowledge, students need to learn to visually represent mathematical information and use representations to enhance their literacy skills, while strengthening their mathematical knowledge (p. 132). This position is supported by Schleppegrell (2007), who argued that students must not only understand terminology, but must also manipulate all other linguistic elements to understand how the registers construct knowledge in the disciplines, including the graphic symbols and notations that are pervasive in mathematics and science. As the CSEC examiners' reports highlighted, students had particular difficulties creating, reading, and reasoning with visual representations such as diagrams, models, and graphs. Such activities are ways of making meaning, and are "among the fundamental elements of scientific learning" (Wu & Krajcik, 2006, p. 853). Mathematics and science education must therefore also facilitate the development of this competence along with all other features of the language of the subject, since students must transact such features when they read and write, when they think and talk, and, ultimately, when they are assessed in examinations.

Teacher classroom pedagogy must also address linguistic and cultural diversity in classrooms, in order to make the link between students' everyday language use and the academic language of school science and mathematics. Subtle and abstract features, such as differences in vocabulary and terms denoting relationships among ideas, make learning science difficult for all learners, particularly those who are not being instructed in their first language or dialect (Gagnon & Abell, 2009). If Caribbean students are to be given better chances of success in mathematics and science, educators must address the need to make the kind of academic language privileged in schools more accessible to them. The greater the distance between the nature and the patterns of discourse at home and at school, the more demanding the process of learning would be for students. Some of the reports referred to weak conceptualization or concept formation exhibited in students' responses; all of them offered examples of "misconceptions" that students reportedly brought to school science and mathematics, and suggested possible consequences for students' performance on CSEC examinations. As educators, therefore, we need to identify those areas of differences between the knowledge that children bring to school and the school knowledge that we expect them to learn, and on which we assess and evaluate them. Many of the differences between home and school are cultural, and are often expressed in the language of the students. The difficulties that students experience when learning school disciplines can possibly be linked to the distance between their social and cultural frames of reference and those valued by the schools they attend (George, 1995; Gorgorió & Planas, 2001; Herbert, 2003, 2008).

Conclusion

Even though this study was based on the limited perspective of examiners' assessment of students' language use on CSEC examinations, it is evident that there is need for greater investigation of classroom discourse in content areas to assess the extent to which language competence is a factor in students' achievement across the curriculum. Linguistic analysis of textbooks, learning materials, and examination questions would provide educators with critical knowledge of the way texts work to construct knowledge in school disciplines. Access to classrooms at all levels—primary, secondary, and tertiary—would enable educators to gain insights necessary to create appropriate curricula to cater to linguistic and cultural diversity, and to develop the potential of all our students. This is also imperative if we wish to improve teacher pedagogy and make learning more accessible for all students, especially in the Caribbean region where the language of instruction differs from the vernacular of the majority of students.

References

Aikenhead, G. S. (1996). Science education: Border crossing into the subculture of science. *Studies in Science Education, 27*, 1–52.

Altieri, J. L. (2010). *Literacy + Maths = Creative connections in the elementary school classroom.* Newark, DE: International Reading Association.

Bielenberg, B., & Wong Fillmore, L. (2004/2005). The English they need for the test. *Educational Leadership, 62*(4), 45–49.

Byron, M. K. (1988). *An investigation of the effect of language variables on problem solving in mathematics at the Standard three level*. Unpublished master's thesis, The University of the West Indies, St. Augustine.

Caribbean Examinations Council (2010a). *Report on candidates' work in the Secondary Education Certificate examination, May/June 2010: Biology, General Proficiency examination*. Retrieved from www.cxc.org

Caribbean Examinations Council (2011a). *Report on candidates' work in the Secondary Education Certificate examination, May/June 2011: Biology, General Proficiency examination*. Retrieved from www.cxc.org

Caribbean Examinations Council (2010b). *Report on candidates' work in the Secondary Education Certificate examination, May/June 2010: Chemistry, General Proficiency examination*. Retrieved from www.cxc.org

Caribbean Examinations Council (2011b). *Report on candidates' work in the Secondary Education Certificate examination, May/June 2011: Chemistry, General Proficiency examination*. Retrieved from www.cxc.org

Caribbean Examinations Council (2010c). *Report on candidates' work in the Secondary Education Certificate examination, May/June 2010: Human and Social Biology, General Proficiency examination*. Retrieved from www.cxc.org

Caribbean Examinations Council (2011c). *Report on candidates' work in the Secondary Education Certificate examination, May/June 2011: Human and Social Biology, General Proficiency examination*. Retrieved from www.cxc.org

Caribbean Examinations Council (2010d). *Report on candidates' work in the Secondary Education Certificate examination, May/June 2010: Integrated Science General Proficiency examination*. Retrieved from www.cxc.org

Caribbean Examinations Council (2011d). *Report on candidates' work in the Secondary Education Certificate examination, May/June 2011: Integrated Science General Proficiency examination*. Retrieved from www.cxc.org

Caribbean Examinations Council (2010e). *Report on candidates' work in the Secondary Education Certificate examination, May/June 2010: Mathematics General Proficiency examination*. Retrieved from www.cxc.org

Caribbean Examinations Council (2011e). *Report on candidates' work in the Secondary Education Certificate examination, May/June 2011: Mathematics General Proficiency examination*. Retrieved from www.cxc.org

Caribbean Examinations Council (2010f). *Report on candidates' work in the Secondary Education Certificate examination, May/June 2010: Physics General Proficiency examination*. Retrieved from www.cxc.org

Caribbean Examinations Council (2011f). *Report on candidates' work in the Secondary Education Certificate examination, May/June 2011: Physics General Proficiency examination*. Retrieved from www.cxc.org

Carolan, J., Prain, V., & Waldrip, B. (2008). Using representations for teaching and learning in science. *Teaching Science*, *91*(1), 18–23.

Carrington, L. D. (1990). *The linguistic situation in Trinidad and Tobago: Implications for classroom practice*. Paper presented at the conference on "The parent, the Child and Literacy" of the Committee for International Literacy Year of Trinidad and Tobago.

Costa, V. B. (1995). When science is "another world": Relationships between worlds of family, friends, school, and science. *Science Education*, *79*(3), 313–333.

Craig, D. (2006). *Teaching language & literacy to Caribbean students: From vernacular to Standard English*. Kingston, Jamaica: Ian Randle.

Eggins, S. (2004). *An introduction to systemic functional linguistics* (2nd ed.). London, UK: Continuum.

Fang, Z. (2005). Scientific literacy: A systemic functional linguistics perspective. *Science Education*, *89*, 335–347.

Fang, Z., & Schleppegrell, M. (2010). Disciplinary literacies across content areas: Supporting secondary reading through functional language analysis. *Journal of Adolescent and Adult Literacy*, *53*(7), 587–597.

Gagnon, M. J., & Abell, S. K. (2009). ELLs and the language of school science. *Science and Children*. *46*(5), 50–51.

George, J. (1995). *An analysis of traditional practices and beliefs in a Trinidadian village to assess the implications for science education*. Unpublished doctoral dissertation, The University of the West Indies, St. Augustine.

Gorgorió, N., & Planas, N. (2001). Teaching mathematics in multilingual classrooms. *Educational Studies in Mathematics*, *46*, 87–113.

Graneheim, U. H., & Lundman, B. (2004). Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. *Nurse Education Today*, *24*(2), 105–112.

Great Britain. Committee of Enquiry into Reading and the Use of English. (1975). *A language for life: Report of the Committee of Enquiry Appointed by the Secretary of State for Education and Science under the Chairmanship of Sir Alan Bullock* [The Bullock Report]. London, UK: HMSO.

Halliday, M. A. K. (1978). *Language as social semiotic*. London, UK: Edward Arnold.

Herbert, S. M. (2003). *Exploring a bridge-building strategy of comparing conventional science and traditional ways of knowing at the lower secondary science level.* Unpublished doctoral dissertation, The University of the West Indies, St. Augustine.

Herbert, S. M. (2008). Collateral learning in science: Students' responses to a cross-cultural unit of work. *International Journal of Science Education, 30*(7), 979–993.

Janzen, J. (2008). Teaching English language learners in the content areas. *Review of Educational Research, 78*(4), 1010–1038.

Jegede, O. (1997). School science and the development of scientific culture: A review of contemporary science education. *International Journal of Science Education, 19*(1), 1–20.

Lager, C. (2006). Types of mathematics–language reading interactions that unnecessarily hinder algebra learning and assessment. *Reading Psychology*, *27*(2-3), 165–204.

Lee, O. (2001). Culture and language in science education: What do we know and what do we need to know? *Journal of Research in Science Teaching*, *38*(5), 499–501.

Lee, O. (2005). Science education with English language learners: Synthesis and research agenda. *Review of Educational Research*, *75*(4), 491–530.

Martin, D., & Miller, C. (1999). *Language and the curriculum: Practitioner research in planning differentiation*. London, UK: David Fulton Publishers.

Norris, S. P., & Phillips, L. M. (2002). How literacy in its fundamental sense is central to scientific literacy. *Science Education*, *87*, 224–240.

Robertson, I. (1999). Educational linguistics for the Caribbean: Some considerations. *Caribbean Journal of Education*, *21*(1&2), 75–86.

Schleppegrell, M. J. (2001). Linguistic features of the language of schooling. *Linguistics and Education*, *12*(4), 431–459.

Schleppegrell, M. J. (2007). The linguistic challenges of mathematics teaching and learning: A research review. *Reading & Writing Quarterly*, *23*(2), 139–159.

Shanahan, T., & Shanahan, C. (2008). Teaching disciplinary literacy to adolescents: Rethinking content area literacy. *Harvard Educational Review*, *78*(1), 40–59.

Simmons-McDonald, H. (2004). Trends in teaching standard varieties to creole and vernacular speakers. *Annual Review of Applied Linguistics*, *24*, 187–208.

Towell, J., & Smilan, C. (2009). Teaching literacy through the visual arts in a multicultural world. *Journal of Reading Education*, *35*(1), 12–20.

Valdés, G. (2004). Between support and marginalization: The development of academic language in linguistic minority children. *International Journal of Bilingual Education and Bilingualism*, *7*(2-3), 102–132.

Waldrip, B., & Prain, V. (2006). Changing representations to learn primary science concepts. *Teaching Science*, *52*(4), 17–21.

Worth, K., Winokur, J., Crissman, S., & Heller-Winokur, M. (2009). *The essentials of science and literacy: A guide for teachers*. Portsmouth, NH: Heinemann.

Wu, H., & Krajcik, J. S. (2006). Exploring middle school students' use of inscriptions in project-based science classrooms. Advance online publication: doi:10.1002/sce.20154

Zwiers, J. (2005). The third language of academic English. *Educational Leadership*, *62*(4), 60–63.

Zwiers, J. (2007). Teacher practices and perspectives for developing academic language. *International Journal of Applied Linguistics, 17*(1), 93–116.