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Language Barriers in Statistics Education: Some Findings From Fiji

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Abstract. Despite the fact that language plays a crucial role in mathematics education, not much research has been carried out in documenting the problems of learning statistics in a second language. This paper reports on findings from a larger qualitative study that investigated high school students' understanding of statistical ideas. Data were gathered from individual interviews. The interviews were audio recorded and complemented by written notes. Two major themes that evolved from the analysis of data were the confusion among registers and the interpretation of the tasks. Moreover, students lacked verbal skills to explain their thinking and interpreted the tasks in ways not intended by myself. The findings are compared and contrasted with relevant literature. The paper ends with some suggestions for practice and further inquiry.
Keywords: English language learners; high school students; implications; language barriers; mathematical language; socio-cultural perspective.

Introduction

Imagine a teacher running her fingers across the pages of the textbook and telling her students, "When numbers or objects are chosen at random they are chosen freely without any rule or any obvious bias." The whole class listens in silence, but one of the shy students is thinking, "I thought it was something that was rare like the possibility of an earthquake."

A common view about mathematics is that it is a 'universal language' and is 'culture free' (Barwell, 2012; Bishop, 2002; Borgioli, 2008; Brown, Cady, & Taylor, 2009; Hoffert, 2009; Meaney, 2006). It uses a variety of symbols that are common across cultures and therefore easily accessible to language learners. From this perspective, mathematics learners anywhere in the world can access mathematical concepts using any language (Barwell, 2012; Bishop, 2002). However, as the text above illustrates, the language of statistics can sometimes be challenging for students (Bay-Williams & Herrera, 2007; Boero, Douek, & Ferrari, 2008; Borgioli, 2008; Campbell, Adams, & Davis, 2007; Lavy & Mashiach-Eizenberg, 2009). Many statistical words are unusual, some terms such as 'random' and 'normal' have a range of interpretations in everyday communication, and some have more than one meaning in mathematics and statistics (Kaplan, Fisher, & Rogness, 2009; Lesser & Winsor, 2009; Rubenstein & Thompson, 2002; Watson, 2006; Winsor, 2007).

According to a number of authors (Goldenberg, 2008; Halliday, 1978; Moschkovich, 2005), mathematics is strongly connected with language and culture. To be able to do well in mathematics, students must be proficient in the language of instruction and use language effectively in diverse contexts (Borgioli, 2008; Kotsopoulos, 2007; Morgan, Craig, & Wagner, 2014; Nacarato & Grando, 2014; Xi & Yeping, 2008). This situation may present some unique challenges for students as they must simultaneously learn ordinary English and mathematical English, and be able to differentiate between the types of English (Abedi & Lord, 2001; Adler, 1998; Bay-Williams & Herrera, 2007; Kaplan et al., 2009; Moschkovich, 2005; Winsor, 2007). Students must be able to move between everyday and academic ways of communicating ideas and relate these expressions to mathematical symbols and text (Goldenberg, 2008; Kotsopoulos, 2007; Morgan et al., 2014; Salehmohamed & Rowland, 2014). Students in an English medium classroom may undergo more processing than native English speakers (Bay-Williams & Herrera, 2007; Bose & Choudhury, 2010; Clarkson, 2007; Latu, 2005; Meaney, 2006; Nacarato, & Grando, 2014; Salehmohamed & Rowland, 2014). These students can miss out on mathematical learning because they may be spending too much time trying to understand the problem. Furthermore, to be able to perform competently, students must understand the highly technical language used specifically in mathematics (Bay-Williams & Herrera, 2007; Brown, Cady, & Taylor, 2009; Goldenberg, 2008; Xi & Yeping, 2008). This language is not used in everyday English, and therefore is less likely to be familiar or understood by English language learners.

The technical language and vocabulary mathematics has is not only essential for students to be able to understand and access the mathematics they are learning now, but has a significant influence on their future mathematical development and careers (Borgioli, 2008; Hoffert, 2009; Morgan et al., 2014; Neville-Barton & Barton, 2005; Xi & Yeping, 2008). Teachers need to be aware of issues surrounding mathematical language acquisition and develop pedagogical strategies to address students' difficulties in making sense of mathematical language (Bay-Williams & Herrera, 2007; Campbell et al., 2007; Salehmohamed & Rowland, 2014).

The vital role that language plays in mathematics education is evident in a number of studies (Barwell, 2012; Bose & Choudhury, 2010; Goldenberg, 2008; Halliday, 1978; Pimm, 1987; Planas & Civil, 2013; Salehmohamed & Rowland, 2014). However, according to Lesser, Wagler, Esquinca and Valenzuela (2013, p. 7) "there have been a few research studies about language issues in statistics education but these did not involve students learning in a second language". The conclusions are consistent with the conclusions reached by Kaplan et al. (2009) and Lavy and Mashiach-Eizenberg (2009). It is important to gain insights into how English second language students learn statistics and probability (Kazima, 2007; Lesser & Winsor, 2009). Moreover, probability context is "regarded as the biggest challenge for teachers since it has previously belonged only in the high school curriculum (15-17 years old)" (Nacarato & Grando, 2014, p. 13). In addition, most of the studies in statistics have been done in western countries with elementary students rather than secondary students. Like

Shaughnessy (2007), Sharma (2012, p. 33) noticed "a lack of research in statistics education outside of western countries". Given the lack of research on English language students learning statistics, Sharma (1997) study addressed these gaps in literature. It provided an awareness of how other countries and cultures teach statistical concepts.

This paper has four sections. The first section reviews mathematics and statistics education research literature to discuss the challenges faced by English Language Learners. The next section reports on data gathered from a larger qualitative study that investigated high school students' ideas about statistics. It discusses examples from a Fijian study to explain the impact of language issues in statistics education. The findings are compared and contrasted with relevant literature. The final section provides directions for instruction and future studies.

Problems faced by English Language Learners in Mathematics

Language plays an important role in any learning area in the classroom. It is a tool that can develop student understanding and helps them communicate their thinking to others. Language also provides a medium by which teachers can assess student learning (Bay-Williams & Herrera, 2007; Bose & Choudhury, 2010; Kaplan et al. 2009; Mady & Garbati, 2014; Rubenstein & Thompson, 2002). Indeed there is a growing demand on students' linguistic skills in mathematics lessons (Bay-Williams & Herrera, 2007; Cobb & McClain, 2004; National Council of Teachers of English, 2008). Pupils at all levels are not only expected to listen, talk and to read, but also to write about their work using mathematical language (Franke, Kazemi & Battey, 2007; NCTM, 2000). However, research shows that communicating mathematically poses many challenges for students due to interference from everyday language and within the mathematical register (Barwell, 2012; Bay-Williams & Herrera, 2007; Boero, Douek, & Ferrari, 2008; Borgioli, 2008; Cobb & McClain, 2004; Ferrari, 2004; Kotsopoulos, 2007; Rubenstein & Thompson, 2002). Cruz (2009, p. 1) argues that "one of the goals of mathematics instruction for bilingual students should be to support the participation of all students, regardless of their proficiency in English, in discussions about mathematical ideas poses many challenges for students". Some of the challenges of language learning and mathematical understanding with particular reference to English language learners is explored below.

Language Syntax and Translation

Language is a vehicle through which students learn and communicate mathematical concepts (Barwell, 2012; Boero et al., 2008; Kaplan et al., 2009; Moschkovich, 2005). However, English is a complex language with a complex syntax (sentence structure) and semantic properties (process of making meaning from the language). Sometimes, the structure of natural English is at odds with the conventions of mathematical language structures. Students need to be able to make an appropriate translation from the words of the problem into the symbolic representation of the solution. Latu (2005) claims that difficulties arise when the mother tongue does not have the vocabulary to express the idea being studied. The same points were made by Fasi (1999) and Sharma (1997) in their studies with Tongan and Fijian-Indian students respectively. Some students in Sharma's study translated the term "sample" into Pasifika Hindi equivalence.

Mathematical Register

According to a number of authors (Barwell, 2012; Boero et al., 2008; Bose & Choudhury, 2010; Goldenberg, 2008) multiple registers are used in mathematics classrooms. For a student to succeed in a mathematics classroom, they not only need to be familiar with and competent in their ordinary English register, so they can communicate with their classmates, but must also have fluency in what can be multiple mathematical registers (Barwell, 2012; Boero et al., 2008; Halliday, 1978; Setai & Adler, 2001). The mastery of the mathematical registers, and the strong ability to switch between them, requires strong linguistic and metalinguistic skills. This is necessary for students to be able to cope with more advanced mathematics (Bay-Williams & Herrera, 2007; Boero et al., 2008; Kaplan et al., 2009; Meaney, 2006; Moschkovich, 2005).

For a student from an English speaking background, mathematical registers can pose a significant challenge, as a new form of language must be learned and mastered (Bay-Williams & Herrera, 2007; Meaney, 2006). Not only must an English language learner try to learn in English whilst concurrently learning to speak English, they must also be working within the English mathematical registers without yet having mastery of ordinary English. Furthermore, it is common for a lot of processing to occur so an English language learner can work within English and their home language (Moschkovich, 2005; Parvanehnezhad & Clarkson, 2008; Setai & Adler, 2001). They must be able to understand the mathematical register, translate it into ordinary English, then translate that into their own language, before translating it into one of the mathematical registers used in their home language, before going through the process again in reverse to enable the student to express their thinking or answer in the appropriate English mathematical register (Lager, 2006). Therefore, even if an English language learner is competent in using the ordinary English register, the use of the mathematical register provides extra difficulties for English language learners.

Reading Mathematics

The language of mathematics is expressed in mathematical words, graphic representations and symbols (Kenney, 2005). Reading mathematical texts provides the learner with an extra challenge over reading English (Latu, 2005). The learner must simultaneously comprehend and process in both English language and the discipline language (mathematics) (Kester-Phillips, Bardsley, Bach, & Gibb-Brown, 2009).

Redundancy is one characteristic of ordinary English that has a significant influence on how students (mis-) read mathematical English. Ordinary English has a high degree of redundancy; consequently students learn to skim read, sampling key words to get the key point, e.g. when reading a novel. In comparison, mathematical English is concise, each word has purpose with little redundancy, and a large amount of information is contained in each sentence (Padula, Lam, & Schmidtke, 2001). Students who transfer their reading skills from ordinary English to mathematical English texts may be disadvantaged by a tendency to overlook key information. Cultures with less redundant natural languages are more likely to pay attention to every word and therefore understand better some forms of mathematical English despite this being their second language (Mady & Garbati, 2014; Padula et al., 2001).

Code Switching

Code switching involves the movement between languages in a single speech act and may involve switching a word, a phrase, a sentence or several sentences (Adler, 1998; Bose & Choudhury, 2010; Salehmohamed & Rowland, 2014; Setati & Adler, 2001). English language learners may code switch for various reasons, including to seek clarification and to provide an explanation (Bose & Choudhury, 2010; Moschkovich, 2005). Code switching promotes both student-student and student-teacher interactions in classrooms involving English language learners (Salehmohamed & Rowland, 2014; Setati & Adler, 2001).

In the mathematics classroom, English language learners often employ code switching to clarify their understanding and as a way to express their arguments and ideas (Bose & Choudhury, 2010; Clarkson, 2007; Moschkovich, 2005; Parvanehnezhad & Clarkson, 2008; Salehmohamed & Rowland, 2014). Moreover, in mathematics code switching not only occurs between languages but also between registers. This can add an extra layer of challenge to the English language learner, as they may find themselves working between a multitude of registers in both English and their home language (Bose & Choudhury, 2010; Lager, 2006). In a study of Australian Vietnamese learning mathematics, in Australia, Clarkson (2007) found that some of these students switched between their languages, when solving mathematics problems, individually, because solving problems in their first language "gave them more confidence" (p. 211). Sometimes these students switched their languages because they found the problem difficult to solve in English. This linguistic complexity English language learners face further demonstrates the need for mathematics teachers to have the tools and training to effectively work with English language learners.

The Study

The study (Sharma, 1997) took place in Fiji. As mentioned in Sharma (2014, p. 107) "it was designed to explore what ideas form five (Year-11) students have about statistics and probability, and how they construct these ideas. Twenty nine students aged 14 to 16 years of which 19 were girls and 10 were boys participated in the study". Data was collected using individual interviews. Students could use both English or vernacular to explain their thinking.

Tasks

As stated in Sharma (2012, p. 36) "the advertisement regarding the sex of a baby (Item 1) explored students' understanding of the bi-directional relationship between theoretical and experimental probability in an everyday life context".

Item 1: Advertisement involving sex of a baby

> "Expecting a baby? Wondering whether to buy pink or blue?
> I can GUARANTEE to predict the sex of your baby correctly.
> Just send $20 and a sample of your recent handwriting.
> Money-back guarantee if wrong!
> Write to…..
> What is your opinion about this advertisement?"
> Sharma (2012, p. 36)

Understanding that a sample from a population can be used to make estimates of the characteristics of the entire population is key to statistical inference. Item 2, buying a car (Sharma, 2003) was used to explore students' understanding of sample size and sampling methods within a meaningful context.

Item 2: Buying a car

> "Mr Singh wants to buy a new car, either a Honda or a Toyota. He wants whichever car will break down the least. First he read in *Consumer Reports* that for 400 cars of each type, the Toyota had more break-downs than the Honda. Then he talked to three friends. Two were Toyota owners, who had no major break-downs. The other friend used to own a Honda but it had lots of break-downs, so he sold it. He said he would never buy another Honda. Which car should Mr Singh buy? "(Sharma, 2003, p. 3)

Results and Discussion

This section discusses student responses to the two items mentioned above. The main focus is on the language challenges faced by these students. Extracts from individual interviews are used to explain student thinking.

As mentioned in Sharma (2006, p. 48) "one student explained that Item 1 was really to do with a doctor charging a $20 consulting fee to inform the parents of the sex of their unborn baby". Even when asked to explain how those involved in putting the advertisement could benefit, the student could not articulate on the relationship between theoretical and experimental probability.

Three students thought that the advertisement was placed to make money. When asked to explain their reasoning, "students talked about businesses putting advertisements to sell their products. There was no evidence of students integrating theoretical and experimental views of probability"(Sharma, 2014).

It appears that for these English language learners working in different contexts and registers posed challenges, students were not able to shift between informal and formal ways of expressing their thinking. The findings resonate with the conclusions of (Bishton, 2009; Boero et al., 2008). For the students to succeed in the problem they needed to not only be familiar with both ordinary English and mathematical registers, but they also needed strong ability to switch between them in order to cope with different interpretations of probability (Parvanehnezhad & Clarkson, 2008; Padula et al., 2001). Additionally, not having the necessary technical, mathematical vocabulary may have hindered students' mathematical communication.

To buy a car based on a report of 800 cases (Item 2) represents the statistically appropriate response because it represents the population more reliably. According to Sharma (1996, p. 5) "nine students did not use sample size information on the car problem (Item 2), they based their responses on their cultural beliefs and experiences". Rather than referring to 800 cases in a consumer report, three students in this study said that Mr Singh could buy either car because the *life* of a car depends on how one keeps it (Sharma, 1996). They did not apply the idea that a larger sample will produce more accurate estimates of population characteristics. For example, one student explained:

> "He should buy any of the cars Honda or Toyota; it depends on him how he keeps and uses the car … Ah … Because it depends

on the person, how he follows instructions then uses it. My father used to own a car and he kept it for ten years. He sold it but it is still going and it hasn't had any major breakdowns." (Sharma, 1996, p. 6)

As stated in Sharma (2003, p. 4) four students based their thinking on their everyday experiences with consumer reports. Students thought that Mr Singh should take advice from a consumer report because they were the right people to consult or they felt that Mr Singh should not take advice from the consumer reports because consumer people often give misleading information.

Two students thought that Mr Singh should buy a Toyota. They drew upon information given in the consumer report as reflected in the following transcript;

"S; Mr Singh should buy Toyota.
I: Why do you think Mr Singh should buy Toyota?
S: Consumer people did the survey with 400 cars. They used a big sample.
I: But here it says … Toyota had more break-downs.
S: Sorry, Madame did not read the question properly. He should buy Honda … Toyota more break-downs."

The student quote above reinforces to us that students can struggle with thinking of the sample size in relation to the population, rather than in relation to the representativeness of the sample. It appears that everyday reading strategies of skimming and using the context or knowledge of the world to support comprehension are insufficient for reading statistical English. As a result, students constructed responses based on these unintended strategies.

The above findings concur with the findings of Padula et al. (2001) and Kester-Phillips et al. (2009). The authors stated that reading mathematical texts provides the learner with an extra challenge over reading English "because they have to simultaneously comprehend and process in both the language of English and the language of mathematics."

When asked to define the word sample, five students based their ideas on previous everyday experiences. They thought that a sample is any small quantity, or an example of something. For instance, a student explained,

"Eh … sample. Sample is like … in the body you take a small amount of blood to test whether a person has some disease or not. If a person wants to give blood to other person, they take out a sample and test in the lab."

When asked whether he thought a blood sample is different from a sample that is selected for research, he said,

"In the maths text book taking a sample means taking small amount. If you are doing a research like the one you asked me in the last interview, so you ask each and every student."

The particular problem here is that the two meanings are not far apart; the differences are quite subtle. The word sample has a wide general interpretation, being met in such contexts as a sample survey, free samples of consumer goods, and samples of blood and urine in medical investigations.

A small number of students used their prior school experiences in constructing a meaning for range. The students used an algebraic context and thought of the range as the set of second elements in an ordered pair. They appeared to relate their relations and functions knowledge to this statistics question.

When asked to find the range from a data set (nine weights recorded in grams), two students said, "that the range was the second element in the data set. This is evident in the following interchange" (Sharma, p. 2003, p. 5):

I: What is the range for this data set?
S: 6.0
I: Why do you think so?
S: There are two numbers. First is 6.3 and second is 6.0 and the first number is domain, the second number is the range.

In the supporting documents, special names are given to the set of first elements used in a relation and to the set of second elements. The domain is the set of first elements, and the range is the set of second elements. It seems that the above student tried to use her previous knowledge about relations and functions to find the statistical range.

The findings resonate with the findings of a number of authors (Barwell, 2012; Boero et al., 2008; Bose & Choudhury, 2010; Goldenberg, 2008). These researchers claim that for students to succeed in a mathematics classroom, they must have fluency in what can be multiple mathematical registers. The mastery of the mathematical and statistical registers, and the ability to switch between them, requires strong linguistic and metalinguistic skills.

The vocabulary and syntactical structure used in statistics can present unique challenges to all learners, due to the frequent use of familiar English words and phrases that are assigned different meanings (Kostopolos, 2007). This again is something that all learners need to learn to understand and work with, but gives added challenge to English language learners as they must simultaneously learn and work within both ordinary and mathematical and statistical English (Winsor, 2007).

According to a number of researchers (Bose & Choudhury, 2010; Clarkson, 2007; Moschkovich, 2005; Parvanehnezhad & Clarkson, 2008; Salehmohamed & Rowland, 2014), English language learners often employ code switching to clarify their understanding and as a way to express their arguments and ideas. None of the students in my study used this strategy although they were told during the individual interviews that they could explain their thinking using their home language (Hindi) or English language. One reason for this discrepancy could be the "political role of language and the complexity of the context in which mathematics is taught and learned"(Planas, 2012, p. 337) in Fiji. Students are not allowed to use their first language in their mathematics classes as teachers may think that fluency in English has an impact on students' access to higher education and qualified employment. Hence, any behavior contrary to the classroom norm may have been seen as a sign of disrespect to the teacher. Indeed the socio-cultural context can have an impact on students' mathematics learning.

Reflections

When planning a unit in statistics, it is vital for teachers to be aware of the prior knowledge and linguistic ability of their students. Once this information has been collected, teachers could build on this understanding. Teachers could use questions such as Item 2 as a starter for discussion of sample size, method and potential bias. It is likely to generate stories from students' family experiences of buying cars, for example, asking a friend.

In statistics, students need language and statistical skills to relate their thinking to the real life context and to communicate their ideas both verbally and in writing. However, teachers may not have the skills to help students develop communication skills and sound statistical arguments due to a lack of opportunities to develop their own statistical skills. This has implications for mathematics teacher educators.

As well as statistical and mathematical knowledge, contextual and statistical language and English literacy knowledge and skills are important for making sense of statistical tasks. Students need to have reading, comprehension and communication skills if they are to achieve statistical literacy. The integration of these skills can occur in everyday life contexts although a careful choosing of tasks to accommodate reading abilities is required. Text comprehension support may be important for helping English learners interpret meaning from the often unfamiliar, out-of-school contexts and writing styles different to that found in text books.

Although the range can help provide a more complete picture of a data set, it has received very little research attention. The findings of this study add to the research literature. Difficulties may also be caused by students not differentiating between the meaning of statistics range and function range. It is evident that students do not properly understand the meaning of the term range even though they can calculate it using "highest minus lowest".

According to a number of authors (Shaughnessy, 2007; Watson, 2006), context plays a crucial role in the development of statistical thinking. However, providing students with an unfamiliar context can make their cognitive loads more difficult. A child's cognitive load increases when they are exposed to unfamiliar context whilst also grappling with an unfamiliar language (Goldenberg, 2008). This has implications in an assessment context, as it further works to advantage students from English speaking backgrounds who belong to the dominant culture over English language learners, therefore undermining the validity of the assessment.

In Sharma study, audiotapes were used to record interview data. However, this approach did not capture student facial expressions and gestures. In future research, video recordings could help address these shortcomings.

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