Multilingual Contexts: A New Positioning for STEM Teaching/Learning

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Introduction

Multiple cultures and languages are represented in most classrooms worldwide. Hence the majority of teachers may now expect to work with at least some pupils from ethnic, linguistic, and/or cultural groups distinct from their own. Cultural, linguistic, political, and social issues in learning have until recently been seen as distant to and have had little impact on the teaching and learning of STEM. But the problems of "others" that are "different" from "us" are now a reality (Babaci-Wilhite 2016; Markic and Abels 2016). If STEM education is to become an equitable practice, there is a continuing need for research that takes seriously an understanding of the complexity of the teaching and learning in multilingual situations and the possible benefits these may have.

Research into the teaching and learning of STEM in multilingual situations is normally closely linked to the phenomena of worldwide refugee migration that many recipient societies see as a problem (Australia and Germany as two examples among many) rather than as an opportunity as Atweh and Clarkson (2001) have argued. But this is only one context that gives rise to multilingual classrooms. Other contexts include Papua New Guinea where one of the official languages, English in a land of 820 languages, is deemed to be the language of teaching, although few students understand English when entering school, and many beginning teachers are still learning the language (Clarkson 2016). In the USA the long-term multiple-generation Latino populace often has to learn in English. Hence the learning/teaching is more complicated than supposed in much of the research literature when a monolingual context is normally assumed. There is a clear need for research that understands the complexity of the teaching and learning of STEM in multilingual

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situations and an exploration of the possibilities this may have for more equitable societies. A new positioning for STEM teaching/learning is needed.

In this chapter we review some assumptions often made in research. We then explore some different language contexts that give rise to diversity. We first look at the diversity that exists within the teaching language and how this can impact on different students. We then turn our attention to language diversity that arises because of the different languages that may be present within a classroom. Finally we turn our attention to researching STEM in the midst of such diversity.

Some Assumptions and Inherent Complexity

The narrow focus of much STEM research stems from related assumptions of a "monolingual" context, students belonging to the dominant culture, and that they possess the social habitus of the middle class (Clarkson et al. 2001). Thus it is often assumed that mathematics and science can be taught in the absence of a common language because STEM subjects are "universal" and independent of language. For those who make this assumption, a STEM classroom is not the best place to learn the language and the norms of the school. It is taken for granted that students have already a mastery of the language of instruction and its subtleties, and this is somehow automatically linked by the students to the discourses of different subjects taught in the school. It is also a common assumption that the students know the "norms" of the school. But such is just not the case for many students, particularly those from migrant communities. Compounding this context, it is particularly difficult for children from a non-Western background, migrating to a Western or Westernized country, to learn Western science and mathematics when these are understood as part of Western culture. Further, these curricula are embedded in the wider school curriculum, and are intended for monolingual, middle-class students, belonging to the dominant social group. Often neglected is the reciprocity of this dynamic: Learning is influenced by language and culture is accepted, but language and culture also influence what is taught and what is researched, and indeed the research methods used are not always understood (Chellougui et al. 2015).

In fact we know STEM teaching/learning is a process where cognitive, affective, emotional, social, cultural, and linguistic factors are deeply intertwined (Bishop 1988; Lave 1988; Lee 2005). Further, the multiple links among these factors make the teaching of STEM a complex task even in a monolingual context, let alone in multilingual/multicultural contexts. In a classroom, neither the teacher nor the researcher may now assume that they are part of, or with, a homogenous group. Indeed there should be recognition by teacher and researcher that there is a great heterogeneity among the several multilingual and/or multicultural situations that can, and probably are, present in any one classroom. The complexity of the research contexts requires the use of multilayered theoretical perspectives and a deep sensitivity for different cultures present.

One advance that goes beyond the above stereotypical assumptions interestingly focuses on achievement and assessment. For a long period, most of the research concerning ethnic, cultural, or linguistic minorities and their learning of STEM subjects focused on the achievement of those groups. It is only recently that researchers' interests have turned to the understanding of how and why it is for many of these students that they normally obtain low achievement scores and why it is that there are very interesting exceptions for a particular small group of such students who gain above average scores in STEM (Clarkson 2007; Cummins 2000). This new direction for research has not been at the expense of a focus on achievement per se. The societal need for high achievement in STEM is normally present when there is an emphasis on schooling, and hence achievement outcomes cannot be neglected by education research. The new direction is more of opening up, another parallel line of investigation, with the belief that both are interrelated. However, there is also an understanding with this new direction that "achievement" should no longer be looked upon as the sole arbiter of whether students are "succeeding" or a particular program is "performing well."

So gradually the notion of "achievement" as the ultimate measure of quality in all things is coming under challenge, although whether this change can be brought about in the understanding of society in general is more problematic. One interesting example comes from work with small groups in classrooms. In the search for an understanding of the STEM learning of individuals belonging to groups that are culturally different to the dominant one, the idea of "participation" seems to be crucial. Participation refers to both participation in verbal conversation and in the broader discourse that takes place in the small group, within the classroom, as well as participation in the wider school culture (Clarkson 1992). All seem to be crucial. Participation is an essential process for inclusion. It has to be mediated at least in part by the teacher and has to take into account both the students' backgrounds and foregrounds. The formal STEM education of an individual requires his/her participation in an institutional network of practice where empowerment, recognition, and dialogue are tools to face conflict in a positive way. Conflict should be understood not only as cognitive conflict but also as cultural, social, and linguistic conflict. Within this broader sense, it must be seen also as a tool for learning. Indeed it may turn out to be the critical strategy for learning. Once this type of thinking is entered into, achievement seems to be a very gross measurement for a conglomerate of interconnected processes that function when a student is learning.

Diverse Contexts

As noted above, it is a given that linguistic diversity exists in most classrooms, in most schools, throughout the world. But there are a variety of linguistic contexts of multilingual STEM classrooms that are generated by different societal determinants. Such situations include classrooms where the language of instruction is

different from the first language of the students: For example, the teaching of recently arrived immigrant students. At least in some places, for example, the southern states of USA, there are complete Latino classes of students who speak the same language, although it is a non-English language, but in a school system where English is designated as the language of instruction (Cuevas et al. 1995).

However the situation can be more complicated than this. In some European countries, the new influx of migrants mean that schools are admitting students who come from a number of different language groups, and they sit with students who speak the language of instruction as their first language: For example, in Germany, many classes have a majority of Turkish-speaking students in various regions but who share classes with mono German-speaking students (Markic 2013). In the Catalan region of Spain, it is even more complicated. Catalan is the language of instruction, although Spanish is also an important language in use. Clearly local students speak both. But there are now migrant students attending these schools who speak neither language as their home language (Espinet et al. 2015). In some other countries such as Australia, there is yet again a different variation. There is a continuing flow of new migrants from different language groups being added to older migrant families who speak other languages. For example, many schools that still have first- or second-generation migrant families who came from southern European countries and still speak Greek, Italian, Croatian, etc. in their homes are being joined by students from Vietnam, India, and Cambodia, but the teaching language for all is English (Wotley 2001). Recently the authors were working in a school that has 50% Chaldean students (very recent arrivals), about 30% Vietnamese (both first- and second-generation migrants), and an assortment of other groups including some Somali students who attended school for the first time at this school although they were aged 10 or 11.

A further scenario is when the teaching of STEM may be in a language which is not the first language of the teacher or students. In Papua New Guinea, this happens often where the teaching language is English, but students and teachers may well speak multiple non-English languages in their homes (Clarkson 2016; Muke and Clarkson 2011). And yet another situation was found in Malay schools until recently. The policy from 2003 was for mathematics and science to be taught in English, but all other subjects were still taught in the language common to both teacher and students, Bahasa Malay (Clarkson and Indris 2006; Heng and Tan 2006). Interestingly that policy was changed abruptly in 2011 to revert to the use of Bahasa Malay for all subjects including science and mathematics (Lim and Presmeg 2011).

How communication and learning take place when the languages spoken are not shared, how the fluency of the language of instruction is related to the mastery of the broader notion of scientific discourse, and how using a particular language is linked to different ways of learning are all questions that need further exploration. But the quite different possible contexts – only some of which are listed above – in which such questions arise, need to be taken seriously in our research.

Diversity Within the Same Language

The impacts of other social factors such as social class also impact classrooms. Even within monolingual classrooms, this creates diversity. The communication patterns of the middle class are dominant within most classrooms, in Australia at least. During the authors' many decades of working in schools, it is noticeable that most teachers are drawn from this sector of society. Even if the teacher is from a lower class, they enter the teaching profession as a way of progressing "up" away from the lower class, and hence utilization of the middle-class patterns of communication for such teachers is accepted as the norm. But for students from the lower class, this can be a barrier for their ease of communication. Hence knowing when to ask questions, of whom it is appropriate to ask questions, and how to respond to questions in todays' STEM classrooms are important for quality learning. So even though the language of teaching may well be an official language of the society and may be shared as the home language of both teacher and most students, this classroom context can be described as multilingual and can impact on students' performance and their sense of belonging in the STEM classroom.

For example, in the Australian context, students from the western suburbs of Melbourne, by and large a lower socioeconomic status area, tend to speak fast, run words together, truncate words, and use an inordinate amount of slang terms. Although all of these characteristics may well be noted by non-Australian speakers of English as partly what denotes "Australian English," the extent of all these characteristics is much more noticeable in schools in the west of Melbourne. The authors have noted young beginning teachers completing their school practice as part of their preservice degree, trying to understand the "English" these western suburban students are talking. Clearly this "English" is not spoken in the homes the young teachers grew up in.

Another "within a language" diversity is the specific STEM language embedded in the official teaching language. This crucial variation is probably the most studied aspect of this complicated question (Ryan and Childs 2013) and at times seems to be the only consideration given to issues of language and STEM. As implied in the argument presented here, that is far too limiting a context to understand the messy language complexity of most STEM classrooms. But nevertheless "STEM languages" are a critical aspect of this complexity.

Within an official teaching language, there is the obvious science vocabulary, more or less exclusive to one or more of the subjects that make up STEM. Clearly students need to master these. You will not get far in chemistry without understanding "pH," "acids and bases," and so on. It is more complicated with other words. For example, a common logical connective "or" changes meaning slightly when shifting from ordinary, everyday English to mathematical and scientific language, and hence vocabulary whose meaning is context specific, can make life complicated for students. There are also shifts between written and verbal language. Common verbal Australian English heard from students such as "gotta" or "yer" is rarely written down. Some researchers and/or teachers might say such language is not proper

English, and yet it is the verbal language of many students. On the other hand in STEM written vocabulary, words like "explain" or "therefore" can be found, but they are much less frequent in STEM verbal language.

It is just not vocabulary that students have to come to understand in the context of STEM learning. To some extent, grammar and other aspects of the language also change. In English there is more use of logical connectives in STEM than in other subjects (Gardner 1975; Wellington and Osborne 2001). Often diagrams are incorporated into text, not just as beautifying elements, but as important fundamental aspects of the text without which students will not understand what is being communicated (Clarkson 1981, 1994). The incorporation of many symbols and the truncating of sentences are also elements of the written STEM language quite different to everyday language and can be confusing (Thomas 1986). Again in English, "words" that sound the same in verbal language but can have different spellings (sine, sign, sin) can also be a cause of difficulty. Although some or all of these aspects of language seem to occur in languages other than English, it would be interesting to know whether they cause similar problems for understanding science or whether other characteristics of specific languages cause or mitigate confusion and any promotion of or lack of understanding.

STEM Languages Across Languages

More research concerning the interactions between STEM languages embedded in different languages spoken by students in the same classroom is needed. All languages have embedded within them specific language that deals with this area of the culture. Some STEM languages are more elaborated than others depending on how a culture has met the needs it has faced. Hence, Tok Pisin, a pervasive lingua franca in Papua New Guinea, has measurement language that can be used for wholes and halves but has not been elaborated for further fractions.

Across languages, there may be analogous vocabulary, but symbolism may well differ. For example, "." (a "full stop" in ordinary "Australian English" but a "period" in "US English") is a decimal point used to separate the whole number part of a number from the decimal part; hence 100.98 would be written. In Australia the decimal point is normally placed on the line of writing, but can be used above the line. In Greece and Malta, this decimal marker must be on the line. In Hong Kong and Singapore, it is used above the line. In Chile and Italy, "." is used to separate thousands and hundreds, but in Australia a gap is left to show this, and in a number of countries such as Greece and Holland a "," is used. Actually in Australia "." can also be used to notate a product. So for migrant students, a statement such as "3.4 + 4 = …" may well have different meanings for students who might be sitting in the same classroom in Australia (some of these uses of symbols may have changed in the intervening years since Thomas 1986).

Teachers'/Students' Research Questions

In developing important research questions, one avenue that should perhaps be taken far more seriously is what teachers are saying. The changing and complex role teachers are asked to live out in STEM classrooms has already been noted. What teachers have to contend with in their day-to-day teaching experiences may not readily match the theoretical thinking and rhetoric expounded on at various research conferences and in research journals. This could lead to a gap between accepted theoretical knowledge and teacher knowledge. Such a gap can give rise to potential dilemmas, but if problematized these in turn can lead to insightful questions. To this end, we need good practical descriptions of teaching within multicultural classrooms which may be best generated by teachers. This would give researchers the classroom context as seen by teachers in order to inform the research questions developed perhaps by teachers in consultation with researchers. In other words, the culture of the practice of teaching should be a rich resource for research questions and may well lead to possible ways forward in our theorization as well as in our attempts to help generate more insightful practice. It is probable in this dialogue that the researchers' perspective with its wide-ranging resources and knowledge of theory may well give a general frame for such teacher-generated questions. Hence a dialogue between the two is needed, as both teachers and researchers stand in the overlap of their domains.

Students do not always behave as we anticipate. This is particularly so when it comes to language. They use their language abilities as they wish in order to communicate among other things their understandings, confusions, delights, and annoyances, at a specific point in time with each other and the teacher. They do this in various ways including gestures and using their language(s). Students live their lives without recourse to knowledge of the way researchers have interpreted other students' behaviors in the past. Barwell et al. (2015) have critiqued the way researchers have formalized switching codes and how this can inform future research. They suggest, although many insights have been gained, that one needs to remember that this, as all research, is an interpretation of reality. Barwell (2016) goes further with such a critique and wonders whether if we could really view the context as a student sees it, and with all the nuances and possibilities they see, we might well choose to ask different research questions than those we ask at present. Clearly we cannot see the world as a student sees it. But attempting to may well foreground different aspects of the language context of learning in multilingual situations that never occur to us and hence in turn suggest research questions that would be well worth pursuing.

Framing Research More Broadly

The recognition of complexity, sketched out above, when producing insightful research questions may well prove to be important. However there are other approaches that might also prove to be useful, such as the mapping out of different

types of broad contexts within which research questions focused on multilingual STEM classrooms could sit. Two such sets of contexts are noted here. The first is the complexity of language linked to STEM education. This gives rise to at least four practical issues:

- Different "levels" of language (families of languages, distance between languages)
- Different language contexts (indigenous, multilingual, immigrants)
- Contexts within language (speaking, listening, writing, reading) as well as the immediate context (conversational compared with academic)
- Content realities (cultural, social, political)

There are also at least four theoretical issues that seem to be relevant and important, although there are clearly more:

- The structural relation between language and STEM
- The registers and discourses relating to STEM
- The interactions in STEM classrooms
- The different theoretical tools and approaches (e.g., linguistic approach, Vygotsky's social/cultural approach, education didactic approach)

The interplay between such broad descriptors as these may well be a framework for generating useful research questions.

Conclusion and Implications

This chapter has underlined the fact that many classrooms in which STEM is taught are multilingual. With the recognition that STEM, and more clearly what and how STEM is taught, is influenced by culture, language, and the social milieu of the classroom, school, and the wider society, deeper and complex issues for research immediately become the foreground. There are implications with such recognition for some traditional markers of what makes a successful student and/or program. For example, assessment may no longer be considered the only marker of success. However, an analysis of these issues shows that there are differing contexts that may be important in such research. The complexity that comes with the recognition that multilingualism is the norm for most students engaging with STEM suggests that this must become a normal aspect of our research and indeed becomes a fundamental that must be foregrounded for preparing teachers to teach STEM.

In this chapter different contexts and situations that arise with language have been briefly explored, but the same can be also undertaken for culture and other influences. There was no attempt here at deeply analyzing the implications of such complexity. The crucial aim of this chapter is to draw attention to such complexity and argue that it is undoubtedly important. Hence our research needs to accommodate this complexity, as suggested above, even though this undoubtedly will make out research more complex and messy. Likewise, we need to ensure that teachers

become aware of the complexity that language issues give rise to in teaching STEM (Martin et al. 2016) and engage with strategies designed to cater for such diversity (Markic 2016).

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