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Irish and Breton are both Celtic languages but unity has vanished resulting in deep linguistic differences. But the common heritage is still at hand when one considers the lexicon, grammatical peculiarities and number. The concept of the structure of a language impacting on thought processes is referred to as the linguistic-relativity hypothesis, which proposes that the vocabulary and phraseology of a particular language influences the thinking and perception of speakers of this language, and that each language will have a different cognitive system. This paper examines the Irish and Breton languages in their bilingual context, their linguistic characteristics and impact on mathematics learning in comparison to English and French, while identifying future research requirements.

Keywords: bilingual contexts, Irish-English, Breton-French, linguistic differences.

INTRODUCTION

Irish and Breton are both Celtic languages, spoken in the western ends of Europe, namely in Ireland and in the western half of Brittany (France). The Celtic languages are divided into two branches: the *gaelic* one (the native languages of Ireland, Scotland and the Isle of Man) and the *brythonic* one (comprising Welsh, Cornish and Breton). Accordingly, these languages might have once been the same language or at least two dialects of the same language. Nevertheless, centuries have passed by and unity has vanished, resulting in deep linguistic differences. However, the common heritage is still at hand when one considers the lexicon (roughly 5 000 shared words, those expressing very old notions such as a house: *teach/ti*; weather: *aimsir/amzer*; good: *maith/mat,* etc.) and grammatical peculiarities (mutations of initial consonants to distinguish word gender; mutations in syntactical context; 'declined' prepositions; word order, etc.). Numbers are also a domain where a very old continuity can be traced, as will be shown in this paper. These two languages are spoken in a bilingual context, involving either a Germanic language: English, or a Romance one: French. This is the first investigation of its nature into the Irish and Breton languages and given the rise in Irish-and Breton-medium education it is timely and can contribute to the development of policy in this area. This paper presents a preliminary study and is building on two previous research studies in these contexts (Ní Ríordáin, 2013; Poisard *et al.,* 2014), with the aim of identifying future comparative studies. We focus here on languages features and the potential of language as a resource for teaching (Adler, 2001), while examining fundamental questions about relationships between mathematics and language (Barton, 2008). Taking into account that language reflects the way we see the world and that mathematics is a modelisation of the world, our

questions are: What are the features of languages that may be of importance for mathematics teaching and learning? How can language be a potential resource for teaching? How to identify mathematical particularities in linguistic expression?

LANGUAGE CONTEXTS

The history of Irish and Breton is marred by stories of decline and persecution. However, both languages have experienced parallel revivals at various times. Since the 90's on, there is more and more concern in both populations to revitalize their languages and avoid complete extinction (Le Pipec, 2013). Strategies have been and are being designed at state or near-state level to revitalize them, primarily by supporting them as medium of education. Table 1 provides a summary of the number of students learning through the medium of Breton and Irish.

	Type of schools	Number of primary and secondary students	Total of students
Breton-medium education	Bilingual public schools	6 662	15 338
	Bilingual catholic schools	4 971	
	Diwan schools	3 705	
Irish-medium education	Maintenance heritage language	15 546	56 974
	Immersion	41 428	

Table 1: A comparison between Irish and Breton educational contexts

Breton schools are part of the centralised educational system of France and the teaching of Breton is optional. There are over 15,000 pupils learning through the medium of Breton (with an average growth of 4 to 5% per year), ranging from pre-school to secondary level (OPLB, 2014). There are three types of Breton-medium schools that pupils can attend, distinguishable by two ways of utilising the languages. The 'bilingual schools' (Public or Catholic) devote the same amount of time to each language. On the other hand, *Diwan* schools claim to be 'immersive' schools since Breton is only in use during the first four years of schooling. French is then introduced by the age of 7 to 8 and takes up to half of school time by age 11. Irish-medium education is the norm for those growing up in the Gaeltacht regions in Ireland (maintenance heritage language education). The rise in popularity of primary (Gaelscoileanna) and second level (Gaelcholáistí) immersion education (Irish-medium education outside of Gaeltacht regions) is significant and has seen an increase in excess of 60% over the past decade. Currently, approximately 8% of the primary level population and 4% of the second level population are learning through

the medium of Irish (Gaelscoileanna Teo., 2014). In Ireland, there is an adequate supply of suitably qualified teachers at the primary level due to incentives and a strong history of native speakers pursuing a career in primary teaching. However, at second level education there is a shortage of suitably qualified teachers to deliver the specific subject areas of mathematics, science and foreign languages through the medium of Irish (Ó Gradaigh, 2014). Similar problems arise in Brittany. However, at primary level a shortage of skilled speakers willing to become teachers can be observed. Moreover, no *specific* qualification is required for teaching through the medium of Irish/Breton at primary or second level education, although some specific teacher education programmes exist. Accordingly, teachers in Irish- and Breton-medium schools may not have high standard of Irish/Breton themselves, nor have an understanding of the complexities of teaching and learning mathematics in a bilingual context. Therefore, it is not surprising that teachers report difficulty in supporting the language development element of mathematics teaching and learning and a lack of suitable resources and textbooks to support their work (Poisard *et al*., 2014).

THEORETICAL FRAMEWORK

Bilingual education research shows that using two or more languages to learn and teach is not a simple addition of languages that enable someone to use one language or another (Cummins, 1984). Indeed, linguistic competencies and learning strategies are involved simultaneously and bi-/multilingualism is seen as a "language-sensitive approach of content" (Bernaus *et al.*, 2012). Bilingualism is a particular form of multilingualism. The concept of the structure of a language impacting on thought processes is referred to as the linguistic-relativity hypothesis (Sapir, 1949; Whorf, 1956). The basic premise of this hypothesis is that the vocabulary and phraseology of a particular language influences the thinking and perception of speakers of this language, and that conceptions not encoded in their language will not be available to them. Hence, they are proposing that each language will have a different cognitive system and that this cognitive system will influence the speaker's perception of concepts (Whorf, 1956). Whorf emphasises also that we act according to how we describe things, and accordingly different languages may classify experience in different ways. Therefore, in theory, an Irish speaker/learner should have a different cognitive system to that of an English speaker/learner, influence our actions and accordingly may influence mathematical understanding. For example, Miura et al. (1994, p.410) contend that 'numerical language characteristics *(East-Asian languages)* may have a significant effect on cognitive representation of number'. However, other researchers have questioned argued for the difficulty in applying the linguistic-relativity hypothesis and the difficulty in testing such claims in relation to mathematical thinking (Towse & Saxton, 1997). We acknowledge that this may be too strong of a way of viewing the influence of language on the mathematical thinking and less severe forms of this hypothesis have been proposed. We support the premise that language may not shape and determine our entire mathematical thinking, but that it may influence it to a certain degree and facilitates our thinking and

perception (Sternberg, 2003). Moreover, we are acutely aware of the importance of other factors such as exposure to mathematics, teaching strategies employed and culture as influencing attainment in mathematics, not just language (Towse & Saxton, 1997). For example, some research shows the positive effect of teaching and learning mathematics in bilingual and multilingual classrooms. In particular, Adler (2001) considers linguistic plurality as a possible resource for mathematics teaching. Three types of resources are distinguished: material, cultural (including language) and human resources. Adler's work is set in the post-apartheid context in South Africa where multilingual classrooms and lack of material resources are common. She shows how linguistic diversity can gradually constitute a resource for mathematics teachers. At primary level, Setati (2005) explored the language practices in primary multilingual mathematics classroom in South Africa where the complex relationships between English language and home language and mathematics education is confirmed. In Australia, Edmonds-Wathen (2015) studied the grammar and conceptualisation of motion in Iwaidja, an indigenous language. She discusses how understanding grammatical features to express spatial concepts in Iwaidja can help teachers of Indigenous students. Moschkovich's (2002) research demonstrates that language can be a resource if a teacher's focus is not only on acquiring mathematical vocabulary, but also on constructing multiple meanings across registers and on developing participation in mathematical practices. This is possible only if teachers are aware of cultural and mathematical needs to teach mathematics (Adler, 2001).

The example of New Zealand is also of interest to us (Barton, Fairhall & Trinick, 1998). In the 1980's mathematical vocabulary was developed in Maori. Several general principles were adopted in making vocabulary decisions and "metaphors were a common method of vocabulary development in both formal and informal settings. […] An example was the development of *rere* and *arawhata* as early translations of *continuous* and *discrete* as applied to statistical data, the methaphor being that of a flowing stream or one proceeding in a sequence of waterfalls." (Barton, Fairhall & Trinick, 1998, p.5). In the Welsh context, Jones (1993) concluded that there are benefits to studying mathematics in a minority language due to it being developed relatively recently as a language of learning and accordingly the terminology established tends to avoid linguistic complexity and employs a more self-explanatory mode. Furthermore, Dowker (2005) found an advantage for students learning through the medium of Welsh, in comparison to English, in terms of how numbers and arithmetical relationships are expressed in Welsh. Our work in the Breton context (Poisard *et al.*, 2014) shows that the particularities of the Breton language can be a resource for the teaching of mathematics, for example in the teaching of geometrical concepts and oral numeration. Teachers in this study also identified a lack of suitable resources as a significant issue. In particular, many of the material resources used in class are a direct translation from French to Breton, with no consideration of linguistic and cultural specificities. Mathematical and linguistic competencies are interrelated and these competencies need to be jointly developed by students and teachers. Research in the Irish context demonstrates that students with

high ability in both languages (Irish and English) perform better mathematically (Ní Ríordáin & O' Donoghue, 2009) and that a significant relationship exists between their performance on English mathematical word problems and their Irish language proficiency at the primary to second level education transition (Ní Ríordáin, 2011). A comparison of the English and Irish languages demonstrates that there are differences between the two languages in relation syntax, semantics and access to meaning. However, what is difficult to conclude, without further investigation, is whether differences between the languages have a differential impact upon cognitive processing (Ní Ríordáin, 2013). In this paper we discuss such questions in Irish and Breton mathematical vocabulary and the structure of the languages, while demonstrating how bilingual students' languages can be a resource for them in mathematics learning. As in Barton (2008), we examine fundamental questions about relationships between mathematics and language.

LANGUAGES: A RESOURCE TO TEACH MATHEMATICS

Some linguistic peculiarities of Breton and Irish may influence the teaching of mathematics. The facilitating aspects and combinations of key features of Breton and Irish are presented here, and where appropriate comparisons are made with English and French. The findings presented here are hypothesis and further investigation (class observations, interviews, questionnaires, etc.) would be helpful to give some more precise conclusions of the influence of the use of these languages on bilingual learners of mathematics. We will not discuss dialects in this section, but Breton and Irish codification as united languages leave much space for dialect variation. In many places, it may happen that the language of books differs from oral use. General features of the languages (sentence length, topic prominence, mutations) are presented initially, followed by a focus on mathematical aspects (transparent lexicons, oral numerations and numbers). The six aspects we develop here are linked to our previous individual research (Ní Ríordáin, 2013; Poisard *et al.,* 2014) and demonstrate commonalities between both languages.

Sentence length: Short sentences are generally more common in Breton and Irish than in French and English, which demands less concentration for pupils and short-time memory is devoted to side-information. Shorter sentences lend to an easier understanding of mathematical text and are a desirable feature (Austin & Howson 1979). English and French readers may have a greater cognitive processing load, and this suggests a difference in mathematical processing.

Topic prominence: Breton and Irish are strongly oriented topic-prominence languages, in comparison to French and English. In Irish, the first word is usually the verb, while in Breton, it may be any word (rarely the verb). Indeed, in Breton, words expressing new information should come first in a sentence, no matter of their grammatical status or function. In problem solving, this gives pupils clues about relevant mathematic information, emphasised by their position in texts (Galligan

2001) in comparison to English and French. Topic prominence may alter the complexity of semantic structures and have an effect on mathematical processing.

Mutations: They are an important feature of Celtic languages, either to indicate word gender or in syntactical constructions. As an example, in Breton after the word *tri* (three), any *p-* standing at the beginning of a word goes to *f-*. When combined with *poent* (point), *three points* is thus expressed as *tri foent*. The permanence of words through surface changes may help to understand the permanence of mathematical relations. Although mutations would cause difficulties for pupils with good language skills, recognising mutated words (especially when there are many of them) may be problematic for those insufficiently familiar with the language. Such mutations are not evident in English and French.

Transparent lexicon: A large part of the mathematical vocabulary is coined out of autochthonous word-roots. The meanings of many words have become easier to understand. For example, to say *parallel* in Breton is *kenstur* (same direction) and in Irish is *comhthreomhar* (equal directionality). Many of the Breton/Irish words describe concepts/objects as opposed to just labelling them. Given that the more easily and quickly the meaning of words is activated, the simpler it is to process mathematical text. It may help to retrieve all the words associated with the concept thus enhancing the total cognitive structure (Galligan, 2001). However, Celtic-made vocabulary has been criticised for various reasons: some words might have been coined too quickly by *amateur* linguists; often these words are not encountered outside of the classroom; in some cases, they were promoted not in an effort to facilitate understanding, but to wash brains of a foreign language; concern lies with if pupils must leave and should adapt to a dominant-language school. This is why an international mathematical lexicon has also been developed in Breton (Kergoat, 2012). Instead of *kenstur*, the teaching authority now recommends to express *parallel* a s *parallelenn*. Further investigation is needed in terms of student learning and accessing meaning in more common languages/lexicon of English/French.

Oral numerations and counting: In this area Guitel (1975) gives an historical view of written numeration. One of the particularities of Celtic languages is the use of vigesimal system (base 20) to say numbers. Some groupings by 20 are evident in French also. In old Irish, we find traces of 20 groupings in all tens: 30, 40, 50, 60, 70, 80, and 90. For example 90 is *ceithre fhichead a deich* (four-twenty and ten, 4×20+10). We find traces in French for 80 (quatre-vingts four-twenty, 4×20+10) and 90 (quatre-vingt-dix, four-twenty-and-ten, 4×20+10) where it is literally the same expression as old Irish. Breton refers also to 20 for 40, 60, 70, 80, and 90. Indeed 40 is *daou-ugent* (two-twenty, 2·20), 60 is *tri-ugent* (three-twenty, 3·20)… 90 is *dek ha pevar-ugen*t (ten-and-four-twenty, 10+4·20), etc. In Breton the word order is not the same: +10 is mentioned before and not after as in French and English. We have the equality (the model) 90=4×20+10= 10+4×20 that is shown in a comparison of languages. If we make a link with topic prominence (above), we could argue that old Irish emphasises the grouping by 20 (coming first) and Breton the addition on this

grouping (+10 coming first). These characteristics are clearly different from the numerations/counting systems of English and French (base 10). We think that the comparison of number names could be a rich resource for teaching oral numeration, written numeration and the associated mathematical meaning. Oral numerations have been studied concerning other contexts. For example, number words in "other" languages is explored by Chronaki et al. (2015) in the Greek context to experiment a mathematical learning activity with young children, and shows that the creation of a culturally responsive context.

Word order to say numbers: In Breton, *32 pupils* is said *daou skoliad ha tregont* (two pupil and thirty, 2 pupil and 30). The common name expressed by the number is in-between tens and units. One can notice that the name is here in singular form (*skoliad*) and not plural (*skolidi*). Indeed plurality is not attached to nouns but it is expressed by the adjunction of a number. For large numbers, the word order refers also to this rule. For example, 32 000 pupils (*daou vil skoliad ha tregont, 2* thousand pupil and 30 (thousands not mentioned), coming from 2 000+30 000) and 3 020 pupils is (*tri mil ugent skoliad*, 3 thousand 20 pupil, 3 000+20). Irish is similar to Breton when using ordinal numbers in that the common name is positioned in-between tens and units. For example, 53 pens is *trí pheann is caoga* (three pens and fifty, 3 pens and 50). Large numbers generally preserve this order also. This can be seen as a difficulty for students, but we also argue that this is a good opportunity to work on number sense and the place of each digit in a number. In Irish, different words are used for counting people: two, three, four etc. is expressed by *beirt, triúr, ceathrar*, to signify that the numbers relates specifically to counting people. The comparison between the languages is a good resource to understand the grouping by three of large numbers.

DISCUSSION AND CONCLUSION

This paper explored specific aspects of language concerned with mathematics teaching and learning in relation to the bilingual contexts of Irish-English and Breton-French. But why does this matter? The importance of language for the teaching, learning, understanding and communication of mathematics cannot be ignored. Features of the Irish and Breton languages presented in this paper demonstrate the importance of investigating languages and their potential impact on mathematical learning. For example, some Breton and Irish words assist in conveying meaning and/or permit the concept to be formed more readily. Similarly the sentence structure allows access to key information. Some promising insights are emerging, suggesting that students who learn through the medium of Irish or Breton may experience advantages in terms of mathematical learning. Further investigation is needed into how a particular language and its syntactical structure may impact on mathematical activity and reasoning (Morgan, Tang & Sfard, 2011).

When investigating the Irish and Breton languages we are cognisant of the fact that that we are investigating bilingual learners (Irish-English, Breton-French). Clearly the

intricate relationship between mathematics learning and a student's language is highly complex. This is further complicated when working with bilingual learners. Moreover, we need to consider mathematics as a discourse and that this is not a singular or homogenous discourse (Adler, 2001). Accordingly, mathematical learners use multiple resources and languages from their experiences (both in and outside of the learning context) and we need to be cognisant of multiple registers co-existing in the learning environment. Bilingual learners should not be viewed in a deficit mode, but rather view their language(s) as a resource for learning mathematics. However, as demonstrated in this research paper, this area is under-researched and under-theorised. Research practices/findings generated from participants from a dominant group (e.g. monolingual speakers) assumes these to be the norm for all learners. We endorse a call for more research in relation to the specific role of bilingual learners' different languages when engaged in mathematical learning (Barwell, Barton & Setati, 2007). There has been a focus more on the social, rather than cognitive functions of code switching (Ní Ríordáin, 2013). The authors of this paper purpose that there is a need for a coherent and integrated framework to investigate whether differences in languages, and their use, by bilingual mathematical learners, have a differential impact upon cognitive mathematical processing. The authors also stress the importance of recognising and integrating the social aspect of learning into the framework and seeing language as a resource for the teaching and learning of mathematics.

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