Adults Learning Mathematics

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Objectives

Adults Learning Mathematics (ALM) – An International Research Forum has been established since 1994 (See www.alm-online.net), with an annual conference and newsletters for members. ALM is an international research forum that brings together researchers and practitioners in adult mathematics/numeracy teaching and learning in order to promote the learning of mathematics by adults. Since 2000, ALM has been a Company Limited by Guarantee (No.3901346) and a National and Overseas Worldwide Charity under English and Welsh Law (No.1079462). Through the annual ALM conference proceedings and the work of individual members, an enormous contribution has been made to making available research and theories in a field which remains under-researched and under-theorized. In 2005, ALM launched an international journal dedicated to advancing the field of adult mathematics teaching and learning.

Adults Learning Mathematics – An International Journal is an international refereed journal that aims to provide a forum for the online publication of high quality research on the teaching and learning, knowledge and uses of numeracy/mathematics to adults at all levels in a variety of educational sectors. Submitted papers should normally be of interest to an international readership. Contributions focus on issues in the following areas:

· Research and theoretical perspectives in the area of adults learning mathematics/numeracy;
· Debate on special issues in the area of adults learning mathematics/numeracy; and
· Practice: critical analysis of course materials and tasks, policy developments in curriculum and assessment, or data from large-scale tests, nationally and internationally.

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Adults Learning Mathematics – An International Journal

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Editorial
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The issue of “context” is often discussed in educational circles, and especially in mathematics education. It is addressed in terms such as “street mathematics” or “school mathematics” (Nunes, Schliemann & Carraher, 1993), however context encompasses much more than the locational dimension implied in these terms. It includes associated practices (See Lave, 1988 who extensively described arithmetic practices in everyday situations) or psychological aspects, such as the motivation to earn money or doing well in a test (See Saxe, 1991; Nunes et al., 1993 and others). The notion of context therefore provides a reference point for informing solutions to prevailing problems in mathematics education, such as developing adequate adult numeracy assessment tools – a challenge for many countries. Within the context of mathematics teaching and learning in general, and in adult numeracy in particular, the issue of context is relevant, not only to determining whether adults are numerate, but it helps to inform knowledge focused on how adults utilize mathematics in everyday life. Or, as Wedge put it: “To know or not to know – mathematics, [that] is a question of context” (Wedge, 1999, p. 205).

The theme of the 21st annual ALM conference in Bern, Switzerland, “Adults learning mathematics – inside and outside the classroom” was driven by this idea of two different contexts, with two different set of expectations for how adults acquire and display their knowledge of mathematics. While this important theme emphasized the idea that the learning of mathematics can occur these two contexts, namely (1) inside of the classroom and (2) outside of the classroom, the situation is not as simple as the theme might lead us to believe. The contributions of this edition of the ALMIJ shed some light on why this is the case: On one hand, the contributions illustrate some of the places where students learn mathematics other than classrooms (e.g., their home, workshops but also mathematics learning support centres) – meaning that outside the classroom is a very heterogeneous concept. On the other hand, they show that learning in these places does not happen in isolation, but that there are various complex mechanisms, processes and factors linking them.
A few examples of these complex processes, which are described in various articles in this document, include the tutor who explicitly moves between real life and educational contexts (See Brooks, this edition), or the factors that motivate students to visit a mathematics support centre (See Fitzmaurice, Mac an Bhaird, Ní Fhloinn & O’Sullivan, this edition). While some of the articles highlight specific aspects of the classroom such as how students perceive a class (Larsen, this edition) or how learning is influenced by socio-cultural values (Dalby, this edition), others describe more general issues such as bi- and multilingual adult learners of mathematics (Ní Riordáin, Coben & Miller-Reilly, this edition).

In the first paper, Ní Riordáin and her colleagues address a fundamental issue, relevant in any learning context, namely that of the role that language plays in the learning of mathematics. The authors present a broad literature review drawing on a multitude of linguistic and other resources that highlights language as a tool for interaction. They argue that mathematical language uses a “register” distinct from any natural language – a reality that presents some linguistic challenges for all students who learn mathematics in a language other than their first. The age of technology has brought together people of various cultural and linguistic backgrounds, and many of these people often come together as students in mathematics classrooms. As such, it has become more important to learn about the relationship between language and mathematics and we hope that the authors’ call for more research in relation to multilingual adult learning falls on open ears.

While the first paper is a literature review, the remaining four papers are empirical studies that present a variety of contexts in which mathematics is taught and learned, and how the link between the classroom and the real world can be made. Brooks’ (this edition) contribution, which presents two teachers and their classes from adult and community settings in the UK, addresses the latter and focuses on how teachers support the learners’ transfer of mathematical knowledge. More specifically, the author develops a continuum of six categories between the education context (abstract) and the real life context (situated) and uses those categories to analyse teachers’ actions in the classroom. Brooks’ continuum provides a useful tool for the observation of teacher practices and their development, as it presents an opportunity for systematic and structured analysis and could therefore also be useful for peer observation.

Like Brooks, Dalby (this edition) also looks at the role of the teacher, though from a different perspective. Dalby’s paper focuses on socio-cultural aspects of two learning settings, namely vocational learning situations and mathematics classes in the UK. By describing and contrasting one session from each of these two contexts, Dalby identifies variations in the expectations between teachers and learners, and highlights significant differences in the social structures (i.e., vocational learning and mathematics classes). She argues that by adjusting the traditional mathematics classroom culture and by providing “bridges” to the students’ vocational experiences, their learning experience could become more relevant to them. Dalby provides a rich description from the perspective of the students, and by doing so she captures a unique perspective in a way which enables readers to understand teaching and learning from students’ point of view.

In line with the previous paper, Larsen (this edition) in her presentation of a flipped adult mathematics upgrading classroom also describes the experiences from the students’ perspective. Larsen presents three prototypical students and her vivid portrayal of their behaviour throughout the semester brings the flipped classroom alive to anyone who has never experienced this setting before. By focusing on variables such as student autonomy, their goal orientation and class attendance, Larsen identifies what she calls a “bifurcation” in the students’ behaviour during the second part of the term (i.e., complete engagement or a more self-paced approach). She concludes (by confirming previous research results) that in this setting, autonomy is essential to student engagement. Moreover, the flexibility in

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1 In linguistics, a “register” refers to the body of terminology unique to a respective area of inquiry (e.g., the medical field has its own body of unique terminologies; the legal field has its own body of unique terminologies).
implementation which a flipped classroom approach allows for diverse student experiences might be particularly suited to the specific needs of adult learners because it has the potential to prevent early drop-outs.

While these three empirically-based articles are more in line with the classic qualitative approach (i.e., small scale case studies that examine participants’ perceptions), the last article (Fitzmaurice, et al., this edition) uses quantitative data drawn from a large scale student evaluation of Mathematics Learning Support in Ireland. That article focuses on a comparison between the responses of the adult learners in this population and those of traditional students. In this effort, the authors not only aimed to pinpoint motivational factors for adult learners to seek support, but they also identified reasons why some of these adults choose not to do so. When compared to traditional learners, the findings show that adult learners were more likely to seek support, and they were very positive about their experience with the support offered in the learning centres.

The five articles in this edition illustrate the diversity of inquiries that constitute adults learning mathematics. They present vivid illustrations of the various contexts in which adults learn mathematics and describe associated expectations, behaviours, and perceptions from both teachers and learners. Furthermore, the articles address several topics, such as the concept of the flipped classroom or bi- and multilingual learners of mathematics, which, as is shown by the authors, have received increased attention from mainstream research in the past years, though barely addressed within the context of adult education. We hope that, as a whole, the articles pique the readers’ interest in considering context as an important framework for understanding the teaching and learning of adult mathematics. We also hope that in reading the articles, readers increase their understanding of the complexities associated with teaching and learning mathematics within an adult learning context.

References

What Do We Know about Mathematics Teaching and Learning of Multilingual Adults and Why Does it Matter?

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Abstract
The significant role of language in mathematics teaching and learning is not a new phenomenon. Given the growth of cultural and economic migration, the increasing international focus on education for economic development and the widespread use of English as a language for learning, we have become acutely aware of the importance of language in adults’ mathematics learning. While investigation has been undertaken in relation to the role of language in the learning and teaching of mathematics at primary and second level, little research has been done on multilingual (including bilingual) adults’ learning of mathematics and the ways in which teaching might support such learning. In this paper we investigate the role of language in the mathematics and numeracy education of bi/multilingual adults with a focus on the mathematics register and discourse; we address the relationship between language(s) and learning; we provide a review of available literature specific to adult learners; and discuss implications for adult mathematics education.

Keywords: language, adult mathematics education, numeracy, bilingual/multilingual learners

Introduction
This paper is the latest in a series of papers for which the impetus was an international comparative study of adult numeracy education, focusing initially on the UK and New Zealand. That endeavour has so far resulted in a series of papers presented at successive international conferences of Adults Learning Mathematics – A Research Forum (ALM), starting at ALM17 in Oslo, Norway. At ALM20 in Newport, South Wales, we investigated language policy and adult numeracy education in Wales and New Zealand, focusing on the Māori language in New Zealand and the Welsh language in Wales (Coben & Miller-Reilly, 2014). In our ALM20 paper we noted that while much has been written about the relationship between language and literacy, the relationship between language and numeracy - especially adult numeracy - has been less explored, in particular from a policy perspective, despite evidence of the importance of language for learning. Accordingly, in that paper we sought to discuss the role of language in the learning and teaching of mathematics, with a focus on the mathematics register and discourse. In this paper we provide a review of available literature specific to adult learners, and discuss implications for adult mathematics education.
shed light on the policy context in which adult numeracy education is set in Wales and New Zealand with respect to those languages, viewed from a critical linguistic human rights perspective.

The need for further examination of the specific role of language in adult mathematics education is thus an important consideration emerging from our previous research. Language and communication are essential elements of teaching and learning mathematics, as is evident from research carried out in bi/multilingual settings (Gorgorió & Planas, 2001). Language facilitates the transmission of (mathematical) knowledge, values and beliefs, as well as cultural practices. Language is also the channel of communication within a mathematics classroom as language provides the tool for teacher-student and student-student interaction. Accordingly, we decided to examine the role of language in teaching and learning mathematics with and to adults. In this paper we are collaborating with Máire Ní Ríordáin, who has explored the role of language in mathematics learning with respect to Gaeilge, the Irish language (Ní Riordáin, 2013; Ní Riordáin & O'Donoghue, 2007, 2008; Ní Riordáin & O’Donoghue, 2009, 2011). Our theoretical investigation focuses on the following main question: What is the role of language in the mathematics and numeracy education of bi/multilingual adults? This main question is broken down into the following sub-questions which are addressed in turn in the following sections:

- What can we learn from research on language and multilingualism?
- How should we understand the relationship between language and mathematics?
- What is meant by the ‘mathematics register’ and why is it important?
- What factors impede and promote mathematics learning in an additional language?
- What do we know about mathematics/numeracy education, language and adult learning?
- What are the implications for adult mathematics education in bi/multilingual settings?

Before answering these questions we wish to make clear that we recognise that there are differences between bilingualism and multilingualism, with their respective consequences for mathematics teaching and learning, and we use both terms in this paper as well as the composite term ‘bi/multilingualism’ when we mean to indicate that these can be considered together. Similarly, terms such as ESL (English as a Second Language), ELF (English as a Lingua Franca), EAL (English as an Additional Language) and English as a Second or Other Language (ESOL) are used throughout this paper. We are aware that there are differences between these contexts for bilingual and multilingual learners and that more than one language may be involved (e.g., Breton as well as French in France, multiple languages in South Africa). However, this paper is presenting a theoretical perspective and is drawing on available literature published in English viewed through the lens of adult mathematics and numeracy education. We aim to be as comprehensive as possible within the scope of this paper because we want to contribute to opening up this important area for further research and development. We believe that to limit our investigation to either bilingualism or multilingualism, or to one context over another, might result in not presenting appropriate available research to help guide future research developments.

**What can we learn from research on language and multilingualism?**

There is growing recognition that language (and bilingualism/multilingualism) plays a key role in mathematics teaching and learning. Given the increase in international migration, the changing status of minority/indigenous groups and the dominance of English as a language for learning and teaching mathematics, many students face a transition to learning mathematics through the medium of another language (Barwell, Barton & Setati, 2007). Much diverse research has been undertaken on the effect of bilingualism/multilingualism on
mathematics education, but it is beyond the scope of this paper to address all aspects. However, research on language and multilingualism from a range of perspectives has been reviewed by Canagarajah and Wurr (2011). They highlight the burgeoning research on English as a Lingua Franca (ELF) in which ELF is a locally achieved practice adopting negotiation strategies to achieve intelligibility and constructing intersubjective norms that are sufficient to achieve their communicative objectives. They point to an emerging synthesis in the research literature which treats:

- Competence as an adaptive response of finding equilibrium between one’s resources and the factors in the context (participants, objectives, situational details), rather than a cognitive mastery of rational control;
- Cognition as working in context, in situ, distributed across diverse participants and social actors;
- Proficiency as not applying mental rules to situations, but aligning one’s resources to situational demands, and shaping the environment to match the language resources one brings.

(Canagarajah & Wurr, 2011, p. 11)

We take this synthesis as the starting point of our exploration of language and multilingualism in relation to adult mathematics education. It chimes with our professional and academic experience in that it situates the language user (in our case, the adult learner of mathematics) as actively seeking to adapt and align their language use with the demands of the context. We draw on Grosjean’s (1999) concept of bilingualism as a continuum of modes, with bilingual individuals using their languages independently and together depending on the context and purpose. We think this may shed light on some of the factors that promote and impede the mathematics learning of bilingual and multilingual adults. In particular, we are concerned with how bi/multilingual adult learners may use their languages when engaged in mathematical discourse and the process of learning, and how these language(s) may provide a set of linguistic resources for social and cognitive purposes, as described by Zahner and Moschkovich (2011). If competence is “an adaptive response of finding equilibrium between one’s resources and the factors in the context (participants, objectives, situational details)” as Canagarajah and Wurr (2011, p. 11) propose, then adult mathematics and numeracy educators need to accommodate this in their teaching and learners need to know this is an effective strategy, albeit with some pitfalls for the unwary, rather than ‘wrong’. Accordingly, it is of importance to examine the role of language in teaching and learning mathematics.

**How should we understand the relationship between language and mathematics?**

Given the significant role of language for the teaching and learning of mathematics, the language through which we initially learn mathematics will provide the mathematical foundations to be built upon and developed within that language (Gorgorió & Planas, 2001). A significant body of research exists supporting the view that different linguistic characteristics may impact on cognitive processing. Influential psychologists and educationalists, including Vygotsky and Bruner, have investigated the nature and relationship between language and thought. The primary concern to emerge from this research is whether language follows thought, thus making language a means for expressing our thoughts, or whether language determines and is a prerequisite for our thoughts (Brodie, 1989). The relationship between language and thought is extremely complex and conflicting views exist in the literature. However, the general consensus in cognitive science is to presume that thinking is occurring in some language (Sierpinska, 1994). Vygotsky was one of the earliest theorists to begin researching the area of learning and its association with language. He concluded that language is inextricably linked with thought – “the concept does not attain to individual and independent life until it had found a distinct linguistic embodiment”
Although a thought comes to life in external speech, in inner speech energy is focused on words to facilitate the generation of a thought. If this is the case, it raises an important question—does the nature of the language used affect the nature of the thought processes themselves? The transition from thought to language is complex as thought has its own structure. It is not an automatic process and thought only comes into being through meaning and fulfills itself in words. Thought is mediated both externally by signs and internally by word meanings (Vygotsky, 1962). Bruner (1975) emphasizes that it is the use of language as an instrument of thinking that is of importance, as well as its affect on cognitive processing. Therefore, thought is intimately linked with language and ultimately conforms to it.

Mathematical language is considered as a distinct ‘register’ within a natural language. Therefore, the mathematics register in Irish will be different from the mathematics register in English, with each language possessing distinct ways and structures for expressing mathematical meaning and concepts. Of concern here is what the consequences of differences in languages are for adult mathematics learners. For example, do the (mathematical) thinking processes of those learning mathematics through the medium of Irish differ from those learning mathematics through the medium of English? How are languages utilised in and impact on developments in mathematical discourses in adult education? 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). 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 & Sternberg, 2012). It follows from interpretation of this theory that the language through which we speak/learn facilitates our thinking and perception. When working with bilingual/multilingual learners, we need to be acutely aware of their languages and how these languages may impact on their mathematical thinking and learning as language is necessary to facilitate mental representation and manipulation of written mathematical text (Sierpinska, 1994).

‘Understanding can be thought of as an actual or a potential mental experience’ (Sierpinska, 1994, p. 1). Sierpinska defines these mental experiences as ‘acts of understanding’ as distinct from ‘an understanding’, which is the potential to experience an act of understanding. These acts of understanding occur at a particular time and are short in duration. In education, understanding is often correlated with cognitive activity over a longer period of time. In this ‘process of understanding’, ‘acts of understanding’ represent the important steps while the attained ‘understandings’ represent the supports for further development (Sierpinska, 1994). For many, understanding is often associated with meaning and/or understanding why (e.g., Piaget, 1978). Understanding can be described in relation to meaning, while meaning can be described in terms of understanding, thus heightening the confusion surrounding the topic. In order to be consistent in explaining the association between meaning and understanding, we consider that ‘the object of understanding is the same as the object of meaning: it is the sign broadly understood’ (Sierpinska, 1994, p. 23). Therefore, the concept/thought forms the basis
of our understanding, while what we seek to understand are the signs that embody these concepts/thoughts. Because language and thought are interrelated (Bruner, 1975; Vygotsky, 1962) and thought is engaged in our understanding, then language is involved in developing our mathematical understanding. Understanding unveils a meaning: learners move from what the text states to grasping what the text is articulating (Sierpinska, 1994).

In 1979 Cummins refined his Threshold Hypothesis and this led to the development of his Developmental Interdependence Hypothesis, which had a more in-depth focus on the relationship between a student’s two (or more) languages. The Interdependence Hypothesis proposed that the level of proficiency and use already achieved by a student in their first language would have an influence on the development of the student’s proficiency and use of their second language. Cummins (1980) also addresses the importance of recognising that both languages interact and are stored together internally (Common Underlying Proficiency). Therefore, the impact of the first (and second, third, etc.) language of learning for mathematics is significant and needs examination when investigating bilingual/multilingual students. In particular, investigation is needed into how a particular language and its syntactical structure may impact on mathematical activity and reasoning (Morgan, Tang & Sfard, 2011). Galligan’s (2001) extensive literature review in relation to differences between English and Chinese is the most significant review to be undertaken in relation to mathematics. She found that considerable differences exist in orthography, syntax, semantics and phonetics between the Chinese and English languages and that these differences may impact on the processing of mathematical text. However, few other studies specifically exist in relation to a comparison of languages and impact on mathematics learning (Cai, 1998). In particular, there is a dearth of quality research in the relationship of adult numeracy teaching and learning and language, and it is to this issue that we turn next.

Moreover, we see mathematics as a discourse and a type of communication (Sfard, 2012). Discourse is more than just language. Our usage is close to that of Gee’s Discourse, which he distinguishes with an upper-case D, while discourse (with a lower-case d) refers to language-in-use (Gee, 1990). As defined by Gee (1996, p. 131):

A Discourse is a socially accepted association among ways of using language, other symbolic expressions, and ‘artifacts,’ of thinking, feeling, believing, valuing and acting that can be used to identify oneself as a member of a socially meaningful group or ‘social network,’ or to signal (that one is playing) a socially meaningful role.

By employing this definition, Discourses are more than verbal and written language and the use of technical language; Discourses also involve communities, points of view, beliefs and values, and pieces of work. Moschkovich (2012, p. 95) utilises the phrase ‘mathematics Discourse practices’ to draw attention to the fact that Discourses are embedded in sociocultural practices. The following description is provided:

On the one hand, mathematical Discourse practices are social, cultural and discursive because they arise from communities and mark membership in different Discourse communities. On the other hand, they are also cognitive, because they involve thinking, signs, tools and meanings. Mathematical Discourses are embedded in sociocultural practices. Words, utterances or texts have different meanings, functions and goals depending on the practices in which they are embedded. Mathematical Discourses occur in the context of practices and practices are tied to communities. Mathematical Discourse practices are constituted by actions, meanings for utterances, foci of attention and goals: these actions, meanings, foci and goals are embedded in practices.’ (Moschkovich, 2012, p. 95)

Therefore, mathematical Discourse practices involve multi-semiotic systems (e.g. speech, writing, gestures, images, etc.) and thus are of importance when analysing mathematical teaching and learning in relation to bi/multilingual adults. Accordingly, we stress 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).

What is meant by the ‘mathematics register’ and why is it important?

We consider mathematical language as a distinct ‘register’ within a natural language, e.g., Gaeilge or English or French, which is described as “a set of meanings that is appropriate to a particular function of language, together with the words and structures which express these meanings” (Halliday, 1975, p. 65). One aspect of the mathematics register consists of the special vocabulary used in mathematics (Gibbs & Orton, 1994); it is the language specific to a particular situation type (Lemke, 1989). However, the mathematics register is more than just vocabulary and technical terms. It also contains words, phrases and methods of arguing within a given situation, conveyed through the use of natural language (Pimm, 1987). The grammar and vocabulary of the specialist language are not a matter of style but rather methods for expressing very diverse things (Ellerton & Wallace, 2004). Therefore, each language will have its own distinct mathematics register, encompassing ways in which mathematical meaning is expressed in that language. As is evident, the complex ‘register’ of mathematics is similar to a language per se and requires learning skills similar to those used in learning a language. This adds another dimension to mathematics learning and reinforces the view that the content of mathematics is not taught without language. The process of learning mathematics inevitably involves the mastery of the mathematics register (Setati, 2005). This allows students to communicate their mathematical findings in a suitable manner; “without this fluency, students are restricted in the ways that they can develop or redefine their mathematical understandings” (Meaney, 2005, p. 129). Developing a learner’s mathematical register provides them with analytical, descriptive and problem solving skills within a language and a structure through which they can explain a wide range of experiences. Once the register is mastered, learners will have the ability to listen, question and discuss, together with an ability to read, record and participate in mathematics. However, when working with adult bilingual/multilingual learners we need to be cognisant of each language having its own distinct mathematics register and ways of communicating mathematics. Similarly, registers exist in many disciplines (e.g., science, technology) but likewise ordinary/everyday English language can be classified as a register. The mathematics and ordinary language registers can interfere, often in subtle ways, in a learning environment. Thus learners need to recognise each of these registers so as to identify which is being used at any given time (Sierpinska, 1994) and this is a challenge many bi/multilingual learners encounter. We need to be aware of how different languages and registers, and use of multiple languages and registers, may help support the development of mathematical knowledge (Ní Ríordáin, 2013).

What factors impede and promote mathematics learning in an additional language?

It follows from the foregoing discussion of the mathematics register that mathematics is far from ‘language free’ and its particular vocabulary, syntax and discourse can cause problems for students learning it in a second language (Barton & Neville-Barton, 2003). Similarly, the concepts presented here are not limited to second language learners – these language features can impact on monolingual learners of mathematics. However, while many students who learn mathematics in their mother-tongue (e.g. Gaeilge) have difficulty in acquiring the mathematics register, this is heightened for those who must learn it in a second language (e.g., English). Learners have to cope with the new mathematics register, as well as the new language in which the mathematics is being taught (Setati & Adler, 2000). Some of the language features that may impede mathematical learning are discussed in the following sections. We propose that knowledge of such language factors can be utilised by teachers of bilingual/multilingual adult mathematics learners in order to promote and support mathematics learning.
A key issue that causes significant problems for second language learners (as well as monolingual learners) is the number of ‘borrowed’ words from everyday English (Pimm, 1987). These words tend to be ambiguous due to having one meaning in the mathematics register, while having another meaning in everyday use (Yushau & Bokhari, 2005). Examples of such words include average, degree, even, odd, operation, etc. The non-mathematical meanings of these terms can influence mathematical understanding, as well as being a source of confusion. Also, Rudner (1978) found that language features such as conditions (if, when); comparatives (greater than, the most); negatives (not, without); inferential (should, could); low information pronouns (it, something) can be sources of difficulty and hinder students’ interpretation and understanding of mathematical word problems. Similarly, the use of specialist terms can lead to misinterpretation of mathematical tasks. Students tend to only encounter these terms within the mathematics classroom (for example, ‘quadrilateral’, ‘parallelogram’ and ‘hypotenuse’) and they are unlikely to be reinforced outside of it (Pimm, 1987). If second language learners do not acquire their correct meaning then this can lead to difficulties within the mathematics context. Second language learners have a tendency to translate new mathematical terms/vocabulary into their mother-tongue. There may be no equivalent translation and/or the translation may be done incorrectly, thus resulting in further confusion and misinterpretation (Graham, 1988). However, what is also worth considering is that specialist terms in some languages actually facilitate access to meaning and accordingly could be incorporated into teaching and supporting mathematics development for bilingual/multilingual adult learners. Such examples include the development of terms in Māori (Barton, Fairhall & Trinick, 1998), Chinese (Galligan, 2001) and terminology in the Irish language where, for example, velocity is ‘treoluas’ which when directly translated is ‘direction speed’ (Ní Ríordáin, 2013).

Context is also a key issue: ‘Words can change their meaning depending on their context within the mathematics lesson’ (Gibbs & Orton, 1994, p. 98). In terms of language analysis, this is known as semantics – establishing the meaning in language, or the relationship and representation between signs and symbols. Due to the multiple meanings that various words can have, the context is vital in determining the correct interpretation. This is very much connected to the use of specialist terms in mathematics and multiple meanings of words (as discussed in the previous paragraph). This is by no means limited to the English language. For example, in Chinese context is essential as the language has relatively little grammar (Galligan, 2001). Findings from a review of literature found that children experience more difficulties with the semantic structure of word problems than with other contributing factors such as the vocabulary and symbolism of mathematics and standard arithmetic (Ellerton & Clarkson, 1996). Working within a bi/multilingual mathematics learning context would require attention being given to context and semantics and impact on mathematics learning. Finally, symbolism is one of the most distinctive features of mathematics, for example >, <, /, Σ. It is crucial for the construction and development of mathematics. Unfortunately “symbolism can accordingly cause considerable difficulties to those whose mother language has different structures” (Austin & Howson, 1979, p. 176). One of the requirements for mathematical learning is that students can interpret the mathematical text and convert it to an appropriate symbolic representation, and perform mathematical operations with these symbols (Brodie, 1989). Thus if students cannot understand the text (due to the language medium) they will be unable to convert it to the appropriate mathematical construction needed to solve the problem. Symbols provide structure, allow manipulation, and provide for reflection on the task completed.
What do we know about mathematics/numeracy education, language and adult learning?

While research has been done on language and mathematics learning, this has tended to focus on children’s rather than adults’ learning (e.g. Barwell, Leung, Morgan, & Street, 2002; Chval, Pinnow, & Thomas, 2015; Cuevas, 1984). A literature review by Benseman, Sutton and Lander (2005a) in New Zealand designed to provide a “critical evaluation” of the available research evidence on effective practices in literacy, numeracy and language (LNL) teaching and educational programme provision found “a dearth of specific research relating to this area in New Zealand and the situation is only marginally better overseas” and they were not able to identify any research that met the criteria for their review with regard to “factors associated with progress in numeracy” (Benseman et al., 2005a, p. 5). Earlier, Coben stated in the first major literature review of research in, and relevant to, adult numeracy:

The research domain of adult numeracy is fast-developing but still under-researched and under-theorised. It may be understood in relation to mathematics education, as well as to adult literacy and language, and to lifelong learning generally.

(Coben et al., 2003, p. 117)

Similarly, a review of the literature in adult numeracy conducted in the U.S.A. found, in common with the findings of earlier reviews (Coben et al., 2003; Tout & Schmitt, 2002), that “very few research studies have used Adult Basic Education students to study the effects of adult numeracy instruction, and the research that does exist is neither theory-driven nor guided by any systematic approach” (Condelli et al., 2006, p. 23).

In the years following these reviews, the National Research and Development Centre for Adult Literacy and Numeracy (NRDC) in England undertook a series of ‘effective practice’ studies, including a study of effective practice in adult numeracy (Coben et al., 2007). The summary of findings for that study highlighted the diversity of adult numeracy learners and education, including the fact that many learners were bi/multilingual:

The heterogeneous nature of adult numeracy teaching, the range of learners and the number of variables amongst teachers and learners, make it difficult to identify effective practices and factors that can be generalised with confidence across the whole sector. […] There were particular difficulties for adults with lower ability levels, and with reading or language difficulties (two in every five learners in the sample spoke English as an additional language).

(Coben et al., 2007, p. 10)

Also, over the period from 1998 to 2007, the Longitudinal Study of Adult Learning (LSAL) investigated the development of ‘literacy’ (subsuming ‘numeracy’ into ‘literacy’) in adult life of a target population of about 1000 high school dropouts. At the start of the study, participants were aged 18-44, proficient but not necessarily native English speakers, and residents of Portland, Oregon, USA. Perhaps because the participants were all proficient English speakers, language issues do not feature in the findings, that: literacy development varies and continues to develop in adult life after leaving school; age has an effect on literacy growth; literacy measures are correlated; life history events have effects on literacy development; participation in programmes and self-study have patterns of effect on literacy development; and there are strong effects of programme participation on adults’ subsequent perceptions of improved literacy (Reder, 2012). Also, long-term effects on proficiency bear out the predictions of practice engagement theory (Reder, 1994; Sheehan-Holt & Smith, 2000) in that engagement in literacy practices leads to growth in literacy proficiency and literacy development in adulthood affects employment and earnings (Reder, 2012). The NRDC ‘Effective Practice in Adult Numeracy’ study and LSAL have to an extent filled the gap identified by Coben et al. in 2003 and Benseman et al. in 2005a, but still much remains to be done before we can say that understanding of instructional impacts on adults learning numeracy/mathematics and language is sufficiently strong to support clear guidance on teaching and learning.
Research is also limited on the impact of workplace numeracy programmes, and on workplace ESOL (English for Speakers of Other Languages) and ESL (English as a Second Language) programmes. For example, Barker writes with regard to workplace literacy: “Empirical studies on the impact of workplace literacy programmes are not common, indeed the whole area of evaluation of training is underdeveloped” (Barker, 2001, p. 28). Gray (2006, p. 45) states that “information on outcomes from workplace ESL instruction is also lacking. The research studies that do exist are generally case studies or qualitative research.” A review by the American Institutes for Research (AIR) which focused on ESL students in Adult Basic Education also found very few studies with Adult Basic Education and ESL students which demonstrated a statistically significant impact of instruction (Condelli, Wrigley & Yoon, 2008). As was the case also for Benseman, Sutton and Lander’s literature review (Benseman et al., 2005a), the scope of the criteria used to select studies was extended. Condelli, Wrigley and Koon found that over the last 30 years there had been extensive international research into second language, as distinct from (first language) literacy, teaching and learning, but this was not the case in the numeracy field. A search for research about numeracy for ESL students by an AIR team in 2006 revealed none: “There exists no research base at all on how numeracy is taught in ESL classes, let alone studies that examine instructional approaches and their impact on these learners” (Condelli et al., 2006, p. 34).

In the first major review of adult numeracy only a few studies were found that addressed research on numeracy and ESL students and it was concluded that “Very little is known about learning and teaching adult numeracy with adults who speak languages other than English; research is needed in this area” (Coben et al., 2003, p. 118). This conclusion is echoed by AIR researchers, who suggested five areas for further research in order to move the field of Adult Basic Education forward. The fifth area suggested by the AIR researchers for further research is relevant to this paper, namely, to “examine (instruction for) ESL learners and students with learning disabilities” since these areas are “completely neglected” (Condelli et al., 2006, p. 61). The review goes on to state:

We found no research on how to provide instruction to these learners, on how they learn, or on how to address the challenges these learners face in learning mathematics. Research needs to pay particular attention to instruction for adult ESL learners, who make up over 40 percent of students in adult literacy programmes.

(Condelli et al., 2006, p. 62)

Benseman, Sutton and Lander (Benseman et al., 2005a) found that various factors appear likely to enhance learner gain in literacy, numeracy and language. These include appropriately skilled teachers able to identify learners’ strengths and weaknesses in speaking, reading, writing and numeracy and undertaking deliberate, explicit and sustained acts of teaching, clearly focused on learners’ diagnosed needs, using a curriculum linked to learners’ lived experience. Programmes of over 100 hours of tuition are recommended, allowing for high levels of participation, using a range of clearly structured teaching methods. They recommend ongoing assessment, taking account of the variation in learners’ skills and a focus on efforts to retain learners, including pro-active management of the positive and negative forces that help and hinder persistence as well as family-focused programmes with a clear focus on literacy and numeracy development. They also contend that ESOL programmes may need to be longer and should be structured to maximise oral communication, discussion and group work based on real-world situations, texts and tasks. Computers and multi-media technology can provide useful support, with bi-lingual teaching to explain concepts and learning tasks.

The authors note that an “emphasis on individualized teaching and learning may not support the needs of adult ESOL learners” for talking and interaction and such an individualised approach may be more common in adult numeracy classrooms than in other areas of education (Benseman et al., 2005a, p. 78). In addition, they state that: “the use of everyday, culturally-specific situations to contextualise maths problems may act as a barrier to attainment for ESOL learners in numeracy classes, when they don’t have either sufficient
language knowledge or contextual experience” (Benseman et al., 2005a, p. 78). Such cautionary notes are necessary, since, as Ciancone (1996) acknowledges, some educators working with adult learners may not be experienced with the teaching and learning of mathematics in a contextualised manner and linked with literacy. Marr’s (2000) work demonstrates “that aspects of language acquisition will develop when supplemented with conceptual tasks and activities that focus on the written and oral use of mathematical understandings” (Coben et al., 2003, p. 113). Numeracy taught in this way might benefit all adult students as they learn the mathematics register, and might particularly help students learning English as an additional language in the numeracy classroom. A kit designed to develop the adult numeracy skills of literacy and mathematics trained teachers in Australia using a participatory workshop approach includes a chapter on ‘Language and Maths’ which includes theoretical and background information and provides guidelines for integrating literacy and numeracy with adult learners (but not ESOL learners) in the classroom (Marr & Helme, 1991).

In particular, studies focused on the teaching of mathematics/numeracy to multilingual adult learners are limited. The aim of an observational study of 15 literacy, numeracy and language teachers (Benseman, Sutton & Lander, 2005b, p. 92) was to gain an overview of how teachers teach literacy, numeracy and language in New Zealand. In the event, little numeracy teaching was observed in this study. These teachers came from tertiary institutions, community organisations, workplaces and private training establishments. The authors of the review comment on the diversity of the sector and the challenges of teaching adults literacy, numeracy and language. They conclude that teachers’ commitment, empathy and support for their learners stem from the teachers’ strong belief in the value of their programmes and their intrinsic interest in their work. The range of teaching methods observed was limited (both generic and literacy, numeracy and language-related). The authors note that generic teaching and classroom management skills play a significant role in literacy, numeracy and language teaching and the teachers appeared to use the same teaching strategies for ESOL as for others for whom English was a first language.

Ciancone gives guidelines for teaching numeracy in an ESL literacy programme, drawing on a range of sources (Ciancone & Jay, 1991; Kallenbach, 1994; Leonelli & Schwendeman, 1994; Lucas, Dondertman & Ciancone, 1991). He recommends: encouraging learners to look for patterns rather than just finding the right answer; pointing out to them that there may be many ways to solve the same problem; encouraging peer-group collaboration: he argues that the best way to clarify one’s own understanding of a concept is to explain it to someone else. He also recommends encouraging learners to write journals about their mathematics learning and their feelings about learning mathematics, because using the language of mathematics reinforces both the mathematical concepts taught and the learner’s proficiency in English. He notes that although numeracy is an everyday coping skill, mathematical concepts can be quite abstract and advocates using more concrete and visual explanations to facilitate understanding of the abstract concept. He advocates that each numeracy lesson should provide a balance between skill building and functional needs. For example, a lesson might begin with a problem (e.g. a mistake on a pay check) that provides a context for learning new skills (such as subtracting decimals), or it might start with a skill (e.g. adding decimals) followed by practical applications (such as adding sales tax to a fast food bill). He argues that mathematics should be included in literacy instruction from the beginning and that even learners who have almost no proficiency in English need to learn numbers for such basic activities as shopping and riding the bus (Ciancone, 1996, p. 4).

Finally, consideration must be given to EAL adults in post-compulsory mathematics education (e.g. undergraduate). Barton, Chan, King, Neville-Barton and Sneddon (2005), investigating the issue surrounding the learning of mathematics at university by students who have English as an Additional Language (EAL students), showed that the problems experienced by these students are not experienced by students whose first language is English (L1 students). EAL students struggle with their learning of mathematics in English at
undergraduate level much more than has been appreciated. The effect is masked at Year 1 undergraduate level because of the better mathematical prior knowledge of EAL students and the relatively low language requirements at this level. However, the effect in the third year is much greater. This study of third-year undergraduate students confirms for the first time that specific features of mathematical discourse cause difficulty for EAL students. Discourse density and logical structure are particularly confirmed as critical in this study, although comprehending mathematical discourse as a whole is also found to be much more complex than anticipated. In addition, these EAL students are unaware of their difficulties. These authors suggest that Departments of Mathematics need to acknowledge and address this issue in realistic ways.

What are the implications for adult mathematics education in bi/multilingual settings?

As we have seen, the literature specifically dealing with adult mathematics education in bi/multilingual settings is sparse. The considerably greater body of research on children’s mathematics learning in relation to language, and on language learning more generally, may give some indications of ways forward. For example, Winslow concludes that

The view of mathematics as characterized by a specific linguistic register, including an analysis of the nature and functions of this mathematical register, enabled me to provide several arguments for mathematics teaching in an ambitious sense which emphasises communicative abilities developed thereby, and to formulate the arguments in a way which indicate the position of mathematics among other forms of communication in which human knowledge (and school subjects) appear. In particular, I have stressed the importance of general fluency in the mathematical register for global, noise-free human interaction, for participation in human society and for popular engagement in the dialogue between humanity and nature. I have pointed out the contours of possible need for a complete revision of mathematics teaching, both in the choice of emphasis and in its temporal placement within the educational system.

(Winslow, 1998, p. 23)

Winslow’s ‘linguistic approach to the justification problem in mathematics education’ chimes with the findings of Schleppegrell’s (2007) review of research, which suggests that focusing on the features of the language through which mathematics is constructed can be a strategy for engaging students and supporting their learning. Schleppegrell stresses that “focus on meaning, not form, is key to all discussion about mathematics concepts” (Schleppegrell, 2007, p. 151). However, she points out that exposure to the mathematics register through teacher’s talk or textbook, or interaction with peers, will not in itself lead to learners developing the mathematics register. She cites research by Adams (2003) who suggests that teachers can help students to move from everyday language into the mathematics register by helping students recognize and use technical language rather than informal language when they are defining and explaining concepts; by working to develop connections between the everyday meanings of words and their mathematical meanings, especially for ambiguous terms, homonyms, and similar-sounding words; and by explicitly evaluating students’ ability to use technical language appropriately. There is a tension between the formal register of academic mathematics and the ‘everyday’ or ‘functional’ focus of many adult numeracy programmes. Evidence-based ways forward have been proposed by various researchers. For example, contributors to an edited collection exploring the mathematics education of Latinos/as present research that grounds mathematics instruction with and for these learners in the resources to be found in culture and language. Language (e.g., bilingualism) is thus not framed as an obstacle to learning, but as a resource for mathematical reasoning and learning, in and out of school (Téllez, Moschovkovich & Civil, 2011). Prediger, Clarkson and Bose (2012) also propose a way forward for teaching in multilingual contexts. They do this through purposefully relating multilingual registers. They explore the overlap between the three
different strong ideas related to different language registers and discourses: code switching, transitions between informal and academic (mathematical) forms of language within a given language, and transitions between different mathematical representations. They argue that integrating these ideas has the potential to enhance language-sensitive teaching strategies in multilingual classrooms that aim for conceptual understanding: an insight that might be fruitful for adult educators. Schleppegrell argues for more active engagement with the mathematics register and concludes that:

We have seen that features of the mathematics register can be identified and analysed by students to see how meaning is made in mathematics. Teachers can support the development of the multi-semiotic mathematics register through oral language that moves from the everyday to the technical mode. Students can be encouraged to produce extended discourse in mathematics classrooms, engage in discussion about the language through which word problems are constructed, and practice the writing of mathematics concepts in authentic ways. Teachers can become aware of the linguistic issues in learning and teaching mathematics and can develop tools for talking about language in ways that enable them to engage productively with students in constructing mathematics knowledge. Further research by applied linguists and mathematics educators can explore the linguistic challenges of mathematics learning in its multi-semiotic complexity to provide more support for teachers who want to engage struggling learners.

(Schleppegrell, 2007, pp. 156-157)

We conclude that there is a clear need to develop specific recommendations in relation to multilingual adult learners of mathematics in order to address their specific needs and to facilitate participation in mathematical discourse.

Summary – why does it matter?

This paper explored aspects of practice concerned with mathematics teaching and learning in relation to multilingual adults. But why does this matter? The importance of language for the teaching, learning, understanding and communication of mathematics cannot be ignored. Educational objectives require students to understand mathematical concepts and to possess an ability to express their understanding of these concepts in written format (Gerber, Engelbrecht, Harding & Rogan, 2005). However, the function of language does not lie solely in the representation of mathematical knowledge. Language is required for and engaged in bringing this knowledge into existence (Halliday & Martin, 1993). Furthermore, mathematics learners are required to possess competency both in everyday language and mathematics-specific language, but competency in the natural language does not necessarily contribute to competency in the mathematics specific language (Lemke, 1989). Clearly the intricate relationship between mathematics learning and a student’s language is highly complex. This is further complicated when the language of instruction/learning changes, as is the situation faced by many multilingual adult mathematics/numeracy learners. Moreover, we need to consider mathematics as a discourse (or Discourse, in Gee’s terms) and one that is not singular or homogenous (Moschkovich, 2012). Accordingly, mathematical learners use multiple resources 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. Therefore, addressing the needs of multilingual adult learners is of paramount importance. Bi/multilingual learners should not be viewed in a deficit mode. Rather, their language(s) should be viewed 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 adult learners. We endorse a call for more research in relation to multilingual adult learning, and we suggest that ALM, as an international and (to an extent) multilingual organization, is ideally placed to generate such studies and in so doing to increase understanding of the important and neglected area of the relationships between language and mathematics learning and teaching with and for adults. The need for more
research and debate, as well as language-informed and language-friendly policy, is evident. Only then can we tackle these issues through pedagogic and support measures.

References


Ni Ríordáin, Coben & Miller-Reilly: What Do We Know about Mathematics Teaching and Learning of Multilingual Adults and Why Does it Matter?


Making Maths Useful: How Two Teachers Prepare Adult Learners to Apply Their Numeracy Skills in Their Lives Outside the Classroom

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Abstract
This pilot case study of two teachers and their learner groups from Adult and Community settings, investigates how numeracy teachers, working with adult learners in discrete numeracy classes, motivate and enable learners to build on their informal skills and apply new learning to their own real-life contexts. Teachers used a range of abstract and contextualised activities to achieve this. Similarities and differences between teachers’ approaches were analysed using a Context Continuum model. Whether teachers started with real-life situations then moved to the abstract mathematics within them, or approached it the other way around seemed less important than ensuring there was movement back and/or forth between the different discourses of numeracy and mathematics.

Keywords: context continuum, numeracy, out-of-school practices

Introduction
The inherent complexities of developing an adult learner’s numeracy knowledge and skills in a way that will both enable them to pass a summative assessment in order to gain a qualification, as well as develop the motivation and ability to ‘transfer’ and use their skills and knowledge to support their own real-life problem solving, are widely debated, and relevant internationally. This research investigates whether and how numeracy teachers of adult learners enable learners to apply their skills to real-life uses, particularly in ‘discrete’ numeracy classes, i.e. those which are not vocationally or workplace-based.

Mathematics and numeracy qualifications in the Further Education (FE) & Skills sector in the UK identify the contextualised and embedded agendas within which adult numeracy teachers are working:

Functional skills are the fundamental, applied skills in English, mathematics, and information and communication technology (ICT) which help people to gain the most from life, learning and work.

(Ofqual1, 2012)

Prior to the relatively recent introduction of the Functional Mathematics curriculum, the preceding Adult Numeracy core curriculum (BSA, 2001) stated that it is deliberately context free so that numeracy teachers can relate the curriculum to their learners’ own contexts.

The stated intentions of helping people to gain the most from life, learning and work, and relating the curriculum to learners’ own contexts, raise some interesting questions; for

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1 Ofqual – the Office of Qualification and Examinations Regulation.
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example, are these intentions consistent with learners’ and teachers’ intentions and aims? Research (Coben et al., 2007; Swain, Baker, Holder, Newmarch, & Coben, 2005; Swain & Swan, 2007) suggests that many learners simply want to gain a qualification to enable them to gain access to other programmes of study or to enhance their job prospects, other learners wish to be able to help their children. In summary (Swain et al., 2005) explain that:

Students’ motivations are varied and complex but few come to study maths because they feel they lack skills in their everyday lives.

There are also difficulties associated with teaching numeracy and mathematics in a way that enables learners to apply what they learn outside the classroom, partly because of the differences between the approaches used to problem solve inside the classroom - to ultimately enable learners to gain a numeracy qualification - and the approaches we use to problem solve in real life (Ivanič, Appleby, Hodge, Tusting & Barton, 2006), further amplified if the summative assessment is not fully aligned with the intended outcomes. These approaches are sometimes respectively referred to as ‘school maths’ and ‘street maths’ (Nunes, Schliemann, and Carraher, 1993). Therefore teachers need to make choices about the extent to which they balance these different approaches or types of numeracy (Kanes, 2002), and the methods they use to aid learning.

Other considerations must be where and how numeracy is likely to be used in learners’ lives in terms of citizenship, learning, work, and life in general, and the extent to which it is possible to help learners to apply their knowledge of mathematics or numeracy to real-life scenarios, and to ‘transfer’ their skills to different situations (Lave, 1988). How successful are teachers in achieving this?

In summary, a number of underlying questions are raised:

1. What are teachers’ aims for numeracy learners?
2. What are learners’ aims? (Do their aims include learning maths in order to be able to apply it to their own real-life contexts?)
3. To what extent are teachers successful in enabling learners to apply the mathematics they learn?
4. What methods do teachers employ in order to help bridge the gap between abstract mathematics and useable numeracy?

This paper, based on a pilot case study of two numeracy teachers and their learner groups, gives a brief summary of the findings of the first two questions, but focusses mainly on questions three and four. During the data analysis stage I developed a ‘Context Continuum’ model which might be of use to teachers, teacher educators and possibly researchers in providing a means of discussing the extent to which different teaching and learning activities are embedded into real life contexts, and to discuss ways in which teachers can help learners to make links between the methods and processes of discrete mathematical concepts and applied problem-solving in real-life contexts.

Prior to outlining the study’s methodology and findings, a review of relevant literature and research is presented to provide further background to the study, as this was used to inform the collection, and to some extent, the analysis of the research data.

**Theoretical background**

In particular, this section focuses on two main areas: firstly, the different kinds of numeracy that exist, and the difficulties and contradictions that this creates in terms of learning and teaching; and secondly, consideration of the adult numeracy teacher’s role in facilitating learners to make sense of these different types of numeracy.
Different kinds of numeracy

Many research studies in the late 80’s and 90’s, for example, Lave (1988), Saxe (1988), Nunes, Schlieman and Carraher (1993), Harris (1991), and Hoyles, Noss and Pozzi (1999), investigated the numeracy practices that people used in life and in work, and examined the differences between the maths learning that takes place in work (often referred to as ‘street’ mathematics), and the maths learning that takes place in a more formal learning environment such as school (referred to as ‘school’ mathematics). Lave’s research (1988) challenged the idea that mathematics can be taught in a formal setting and then that knowledge can be transferred and applied to a vocational area or to everyday practice. Nunes, Schliemann and Carraher (1993) also suggest that the maths used in working practices is best learned within those practices, which supports the idea of ‘embedded’ learning being carried out in the vocational context rather than in the classroom. This research supports Barton’s (2006, p. 13) social practice perspective in which he questions the idea of “numeracy as itemised, transferable skills” as he suggests that numeracy processes are not easily detachable from their context. However, in the UK not all numeracy learning takes place in vocational contexts, instead, discrete numeracy classes are available to adult learners.

One aspect explored in these studies is that formal and informal techniques use different mathematical practices, for example in street maths, there is often more emphasis on mental maths and estimation, whereas in school maths learners generally expect to use specific written algorithms to apply to problems that they do not see as real life scenarios. Such differences in approaches were borne out in Jurdak and Shahin’s study (2001, as cited in FitzSimons, 2008) which explored the differences in the types and sequences of the actions of a group of five experienced plumbers and a group of five school-children in creating a cylindrical container (given a specific height and capacity) from a plane surface. The plumbers engaged with the physical resources available and used a kind of trial and error approach to refining their model whilst the students engaged mainly with cognitive tools to select the formula and calculate the unknown. Obviously these different approaches have implications for numeracy teaching and learning, particularly if the intention is for learners to be able to apply their learning to work and other real-life contexts.

Oughton’s (2009) and Dowling’s (1998) research is also consistent with these ideas. Dowling explores the difficulties presented in the linking of mathematics to real-life scenarios, in written mathematics school texts, highlighting the conflicts that result and the unrealistic scenarios that are consequently played out. He summarises:

School mathematics may incorporate domestic settings in its textbooks, but the structure of the resulting tasks will prioritize mathematical rather than domestic principles. Alternatively, domestic practices may recruit mathematical resources, but the mathematical structure will be to a greater or lesser extent subordinated to the principles of the domestic activity.

(Dowling, 1998, p. 24)

He is emphasising the important role that context plays in informing the approaches used in problem solving. In a maths classroom, a learner expects to use mathematics, whereas in a real-life problem-solving scenario, mathematics is but one factor. Oughton (2009, p. 27) supports the idea of unrealistic maths problems in classrooms, suggesting that often:

students were required to willingly suspend disbelief where the narratives of word problems did not reflect the real world.

Clearly the careful selection and design of learning materials is important, if learners are to be able to make links between what they do in the classroom and how they can use their numeracy skills outside it. Such unrealistic problems have been identified as ‘quasi’ activities in the research study.

In fact, Kanes (2002) suggests there are three different kinds of numeracy, which he terms: visible-numeracy, constructible-numeracy, and useable-numeracy. Visible-numeracy is where
mathematical language and symbols are used explicitly, usually in a learning environment; constructible-numeracy is where constructivism and social constructivism approaches enable learners to build on and transform previous knowledge adequately to problem solve; and useable-numeracy is where the specific numeracy tools and techniques used are “complex and deeply embedded in the context in which it acquires meaning” (Kanes, 2002, p. 4), for example, the workplace in which they are used. Building on the work of Noss (1998, as cited by Kanes, 2002), Kanes explains how the different kinds of numeracy might be considered to create tensions in designing a suitable curriculum, as they conflict with one another, for example concentration on visible-numeracy “oversimplifies issues relating to useable-numeracy, and this leads to numeracy becoming less “useable” than would otherwise be the case” (Kanes, 2002, p. 6). In designing a curriculum to meet the needs of all stakeholders, I propose that these tensions are at the core of curriculum planning for many teachers involved in numeracy teaching and learning.

Such challenges and tensions presented in teaching mathematics form the basis for Kelly’s (2009, 2011) research, which was based around those teaching mathematics in a vocational context and which “highlight[s] the tensions between learning relevant mathematics skills in the workplace and those in education contexts” (Kelly, 2011, p. 37). She developed a model for conceptual analysis of these tensions, and the example in Figure 1 explores the contrasting approaches used in the classroom with those used in the workplace, e.g. using centimetres and metres in the construction classroom (presumably based on curricula requirements) whilst it is customary to use millimetres in the construction workplace. Likewise, in (UK) industry it is commonly known that 60 bricks will build 1m$^2$ of wall, whereas in the classroom, this knowledge may not be used as the basis for calculations.

In seeking a conceptual model for my own research, Kelly’s model (Figure 1) provides a useful starting point. In particular, the axis denoting Context (Work Life – Education) inspired ‘The Context Continuum’ model which I developed in order to support analysis of the extent to which contexts were embedded into different teaching activities, as identified in the collected data.

![Figure 1. Kelly’s model of analysis for learning numeracy in different contexts – applied to construction (Kelly 2011, p. 41).](image)

Having considered the different types of numeracy, the numeracy teachers’ role in navigating through these is explored next.
The teacher’s role and contextualisation

Because of the different types of numeracy that exist, the numeracy used by people on a regular basis, embedded into their daily contexts, is often ‘invisible mathematics’, a term used by Diana Coben (2000, p. 55) to describe “the mathematics one can do but which one does not recognise as mathematics”. She goes on to explore the idea that the mathematics that people can do is often considered by them to be common sense rather than mathematics, which is consistent with learner ‘Selena’s’ views in Swain et al.’s research (2005). Both the invisibility of the mathematics people already use and the status of mathematics in society means that mathematics is often seen by learners and others as “unattainable”, something they “cannot do” (Coben, 2000, p. 55), and this impacts on a learner’s self-confidence and also their perception of their intelligence or their ability to learn.

For some learners, making maths less abstract can help them make meaning, i.e. understand what it is they are doing (Swain et al., 2005). Contextualisation is one of the methods of meaning-making that Johnston (1995) explored, and it is also supported by learners in Fantinato’s (2009) research, who were explicit about the fact that thinking in terms of bags of rice, beans or sugar rather than just numbers, makes things easier to learn. Conceptually difficult areas are often those which seem most abstract, for example negative numbers, which can be usefully related to credit and debt, in making sense of why, for example, ‘two negatives make a positive’.

My belief is that in contextualising mathematics, teachers can also help make the ‘invisible’ visible to learners. If teachers are successful in making the maths more visible, by relating it to learners’ life experiences, learners will no longer see maths as something they just do in a maths class, but they will see maths as a tool they can use to help them make informed choices and decisions about, for example, purchases, financial decisions and other contexts relevant to their lives. In addition learners may see that they already do some maths in their lives, therefore that they can do maths, albeit the informal ‘street’ maths. This can be used to build confidence and to help turn learners from an “I can’t” to an “I can” kind of learner, which Marr, Helme and Tout (2003) explain as a shift in identity towards someone who is more numerate. Marr, Helme and Tout’s (2003) model of numeracy competency, which was developed by a group of experienced adult literacy and numeracy practitioners in Australia, is shown in Figure 2 below:

![Figure 2. Model of holistic numeracy competence. (Marr, Helme & Tout, 2003, p. 4).](image-url)

This model suggests that confidence is central, and perhaps the biggest single contributor, to a learner becoming competent in numeracy. The (cognitive) left hand side of the model considers different types and levels of skills and knowledge, which rise in complexity from
the bottom to the top of the model, moving from abstract mathematical skills to numeracy skills applied in real-life situations, similar to Kanes’ types of numeracy. The (intrapersonal) right hand side considers the building blocks which enable learners to become increasingly independent learners (from bottom to top), starting with linking learners’ learning goals into their interests and motivations, and ending with someone able to take more control over their own learning.

Safford (2000, p. 6) identifies one of the roles of the maths teacher as being a mediator between ‘street’ maths and ‘school’ maths “to aid students in clarifying knowledge they already own, and to alter and enhance it with new knowledge acquired in our classrooms”. Building on existing, informal skills is therefore a positive way to support learners to develop the kind of maths they need in the classroom. Saxe (1988, p. 20) suggests that otherwise:

> [the] processes of transfer are often protracted ones, ones in which [learners] increasingly specialize and adjust strategies formed in one context to deal adequately with problems that emerge in another.

Instances where the teacher has built on learners’ existing, informal skills in the study have been identified as ‘Validating’.

Safford and Saxe's suggestions are consistent with FitzSimons' (2006) research where she draws on Bernstein's work in discussing the need for teachers to help learners continually cross and re-cross “the borders of vertical discourse [of abstract mathematics] and horizontal discourse [of using numeracy in real contexts]” in the teaching and learning process “in order to develop the capacity for numerate activity” (p. 36). This suggests the need to move continually back and forth between formal, abstract mathematics and informal real-life uses, in the numeracy classroom, and evidence of this was found in the study.

**Summary**

In summary, it is evident that varying contexts foster different approaches to, and priorities in the use of mathematics. In particular, the contrast between the way in which learners approach (often unrealistic) mathematics problems in the classroom, compared to the ways in which they approach the use of mathematics knowledge in real life contexts (including in the workplace), is so great that learners are often unaware of the mathematics they actually use in real life. This invisibility compounds learners’ beliefs that they cannot ‘do’ mathematics, which affects their confidence and motivation.

Therefore the role of numeracy teachers is to cross and re-cross the different discourses of mathematics and numeracy within their teaching, despite the conflicts and challenges associated with this, in order to help learners acknowledge what they already know and use, relate it to the mathematics they do in the numeracy classroom, and build on their knowledge and understanding in a way which enables learners to use their new knowledge in their real-life contexts.

Having established the complexities involved in teaching and learning mathematics for the purpose of transferring and applying mathematical knowledge and skills to real-life contexts, the aim of this research is to identify whether and how teachers can enable learners to achieve this.

**The study**

Punch (2009, p. 119) explains “the case study aims to understand the case in depth, and in its natural setting, recognising its complexity and its context”, therefore this is a very appropriate methodology to develop an understanding which included the perspectives of numeracy teachers and learners in the research. For the pilot case study two teachers were selected by purposive sampling from numeracy teachers I previously worked with in my capacity as a
numeracy teacher educator. Although the relationship between me (researcher) and the teachers introduced some bias, it also maximised the likelihood that the teachers were comfortable in allowing me access to their classrooms and their learners, and to discuss their approaches, thoughts and beliefs. The teachers were specifically chosen because I had previously seen them actively endeavour to link the mathematics taught inside the classroom with the potential uses that learners may have to apply their numeracy outside the classroom.

To maintain confidentiality and anonymity, teachers are referred to as Teacher 1 and Teacher 2, their learner groups, Group 1 and Group 2 respectively; learners who were interviewed were given pseudonyms and learning locations have been withheld. Having obtained ethics approval from Anglia Ruskin University, permission from the participants’ learning organisations, and informed consent from the two teachers and their learners, data were collected from discrete numeracy classes in two different Adult and Community Learning settings towards the end of the academic year, once relationships between teachers and learners had been established, and once learners had some experience of learning numeracy in an adult class. Learner Group 1 were on a Family Learning course, designed to help them relate the numeracy they had previously learned on an Adult Numeracy qualification-based course to their children’s key stages, and to explore ways they could support their children’s learning. Learner Group 2 was attending a general numeracy class with an Adult Numeracy qualification outcome as its primary goal.

Teacher interviews, learner group interviews, and observation of classes were used to collect data. Semi-structured interviews were held with each teacher to investigate their aims and methods. The interview sessions were audio-recorded and the recording was fully transcribed for the purpose of analysis. For each teacher, two two-hour observations of their teaching were carried out, to observe the methods teachers use to help learners make links between their numeracy learning and the use of numeracy outside the classroom. The purpose of carrying out the observations was to enable verification of what teachers said they did at the interview stage (Robson, 2011), and to capture approaches that may not have been voiced during interview. Field notes were made during the observation to record non-audio information and audio-recordings were made using a digital recorder, to minimise intrusion. Relevant parts of the audio recordings were transcribed for the purpose of analysis, and integrated with the field notes.

A short focus group interview was undertaken with willing learner participants (the invitation was open to all) from each learner group, to ascertain their perspectives. These were also audio-recorded and transcribed. As part of an established learning group, learners were used to talking as a group, and Brown (1999, p. 115, as cited in Robson, 2011, p. 295-6) suggests that a homogeneous group is beneficial in giving a sense of safety and facilitating communication, although it may lead to unquestioning similarity of views. Care was therefore taken to ask open questions, and learners were asked to be honest with me, to minimise the effect of any bias I might bring to the interview (Sim, 1998, p. 347, as cited in Robson, 2011, p. 296).

The family learning class (Group 1) was comprised of five female learners, between 20-45 years old. All were mothers of young children. Jackie and Emma (pseudonyms) were involved in the interview. The general Skills for Life Numeracy class (Group 2) was comprised of thirteen learners (including two males) between 19-75 years old, some of whom had joined the 30-week class during the year. The four learners involved in this group’s interview were given the pseudonyms Barbara (mother), Carol (mother), John (unemployed) and Maureen (retired).

A thematic coding approach was used as the basis for analysing the transcribed interviews and observation notes, to identify themes arising (Robson, 2011). The themes arising under coding ‘teachers’ aims’ and ‘learners’ motivations’ are listed in Table 1. Examples of the themes arising under ‘Learner Gains’ are identified in the Findings section below, and they
have been used as evidence to inform Table 1, i.e. whether or not teachers’ and learners’ aims have been met.

To identify the types of activities used in practice, some pre-determined codes were identified at the outset, informed by a review of the literature and prior experience, but these were amended and other codes arose during data collection and analysis, on the basis of the research findings. Corbin and Strauss (2008, p. 66) liken the process of coding data to “‘mining’ the data, digging beneath the surface to discover the hidden treasures contained within data.” This approach was essential in minimising researcher bias and in seeking to represent the data as truly as possible. Finally, the types of teaching and learning activities were categorized according to how ‘abstract’ they were, i.e., devoid of any non-mathematical context, and, at the other extreme, how ‘situated’ they were, i.e., immersed in a real-life context. Categories that sat between these two extremes were also identified during coding and analysis, e.g., I used the term ‘Quasi’ to describe the kinds of mathematical word problems which are included in mathematics and numeracy textbooks, worksheets and test/exam questions, but which commonly bear little resemblance to real life (Dowling, 1998; Oughton, 2009). The number of occurrences of different types of activities that were either observed or outlined by teachers during their interviews was used to establish the extent to which the two teachers used similar or different types of activities, and comparisons between the two teacher/groups were made. The order in which different types of activities were sequenced during classes was also analysed and compared.

Findings

Before exploring the kinds of activities and methods that teachers used, a summary of the findings that emerged from the study relating to teachers’ aims, learners’ motivations and the identified learning gains, is given below.

Teachers’ aims and learners’ motivations and learning gains

Table 1 summarises the data obtained from interviews with teachers and learners regarding their aims (in the left-hand column) and judges the evidence of their achievement (in the right hand column), by comparing the data analysed under the theme ‘Learning Gains’.

Table 1.  
Table Comparing Teachers’ and Learners’ Aims with Actual Outcomes

<table>
<thead>
<tr>
<th>Teachers’ and learners’ aims</th>
<th>Learners’ Gains – Is there evidence this has been achieved?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers’ aims</td>
<td></td>
</tr>
<tr>
<td>Change learners’ identity from “I can’t” to “I can” learners.</td>
<td>Yes, including gains in confidence.</td>
</tr>
<tr>
<td>Enable learners to pass their numeracy test</td>
<td>Unknown (not in scope).</td>
</tr>
<tr>
<td>Enable learners to apply their new maths to real life contexts</td>
<td>Yes – some already in place, some planned.</td>
</tr>
<tr>
<td>Enable learners to better support their children’s maths learning</td>
<td>Yes, and children improving their maths as a result.</td>
</tr>
<tr>
<td>To promote autonomy in learning / more independent learners</td>
<td>Unknown (not in scope).</td>
</tr>
<tr>
<td>Learners’ aims</td>
<td></td>
</tr>
<tr>
<td>To understand the maths their children are learning at school to be able to more effectively support their children’s maths learning. (See 4. above)</td>
<td>(See 4. above)</td>
</tr>
<tr>
<td>To gain a qualification (See 2. above)</td>
<td>(See 2. above)</td>
</tr>
<tr>
<td>To face up to maths demons – to do the maths that couldn’t previously do. (Links to 1. above)</td>
<td>Yes – evidence of better conceptual understanding.</td>
</tr>
</tbody>
</table>
As expected, learners’ stated aims (See Table 1) for joining a numeracy class were similar to those in other adult numeracy research studies (for example, Coben et al., 2007; Swain et al., 2005; Swain & Swan, 2007). Similarly, ‘Helping with everyday things outside the classroom’ was one of the least popular reasons identified in others’ research, and it was not stated as an aim for the case study learners.

During the group interviews, learners were asked whether they used maths before they attended their class, and if so, what kinds of things they used it for. Not unsurprisingly, their responses varied, e.g. Jackie identified she did basic budgeting but explains:

I would have veered away from things like percentages and that. If I wanted to know what something was off, I would ask my husband, rather than actually try and work it out myself.

Other responses included:

Carol: You use it without realising you’re using it, don’t you? Checking change in the shops, checking receipts.

John: I used to ask people. I never used it…I’d never try because I’d know I’d either make myself look really silly or get it completely wrong, so I just wouldn’t bother.

Maureen: I was okay with money and things like that…But anything like working out how much carpet I needed, or wallpaper and stuff like that, I would always give it, say, to my husband: ‘How much do you think we need?’

After they had each responded to this question they were asked whether, since they joined the class, they had used any of the maths they had learnt to do something outside the classroom, and if so to give some examples. Responses included:

Jackie: I don’t shy away from working out percentages now… I try and work them out now. I do still get my other half to check them….And when the children come with problems with their maths at school I feel more confident to tackle that, so they’re getting a bit more confident because they can do it as well.

Carol: Sorting out finances and things. I would have left it all to my husband, but, that’s my job now, working out things like how much my car costs to run… Since doing all this [maths class] I think how can I use it?

John: I work out the bills now. She [his wife] says to me sometimes: ‘Do you want me to work it out?’ and I say ‘no, I’ll work it out.’

Maureen: I’d measure the room and actually think about working out those calculations for myself [how many wallpaper rolls] and then maybe say to my husband: I think so-and-so, what do you think? Whereas before I’d never have done it myself.

Emma and Jackie also gave examples of how they plan to use their new maths knowledge and skills to help them with future DIY projects, such as, designing a patio or floor (Emma) and interior design (Jackie), things they identified they would not have attempted previously. In summary, a range of themes emerged from the resulting data, including: metamorphosis from an “I can’t” (do maths) to an “I can” person, gains in confidence, being confident with their new knowledge to help their children with their maths learning, their children improving their maths, better conceptual understanding and using (additional) maths in their everyday and/or working lives.

This research suggests that not only do the learners leave their course with benefits they had anticipated, but additional benefits are evident; in particular they are able to apply their new maths skills to their real life contexts. Therefore in answer to the research question: ‘To what extent are teachers successful in enabling learners to apply the maths they learn?’ it is evident that both teachers have been successful in enabling their learners to apply their maths skills, despite the complexities associated with the processes of learning and transfer.

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2 Do-It-Yourself.
Methods employed by teachers to help learners relate in-class learning to real-life uses

So how did the teachers achieve this? The methods that teachers used in their classes were analysed using a model I named ‘The Context Continuum’ (See Table 2), which I developed during the data analysis stage, from an adaptation of Kelly’s (2009, 2011) research model (Presented earlier – see Figure 1).

Table 2.
Table Explaining the Context Continuum Categories

<table>
<thead>
<tr>
<th>Category Name (Code)</th>
<th>Description of Category</th>
<th>Examples (from research data)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract (R₀)</td>
<td>Instances where the focus is on the numbers themselves, or on the underlying mathematical patterns, relationships and concepts, where the learning and teaching is devoid of any context other than mathematics.</td>
<td>Learners designing their own fraction walls. Submerging 3-D shapes in water to calculate volume and discover 1ml = 1cm³.</td>
</tr>
<tr>
<td>Quasi (R₁)</td>
<td>The kinds of mathematical word problems regularly included in maths and numeracy text-books, worksheets and summative assessment questions which are written as ‘contextualised’ questions but which commonly bear little resemblance to real life contexts.</td>
<td>Learner trying to make sense of frustum volume formula to answer worksheet problem. When using a ‘saving water’ worksheet, learners identify that the example bath is rather large.</td>
</tr>
<tr>
<td>Validating (R₂)</td>
<td>The occasions where teachers encourage and validate learners’ informal calculation methods, and where learners show that they understand that their informal methods are legitimate.</td>
<td>Teacher using whiteboards when doing mental maths, to encourage learners to use and identify informal methods they use. Learner 1 used traditional method of multiplication and got the wrong answer. Teacher asked how else they could calculate it. Learner 2 used informal chunking method (and got right answer).</td>
</tr>
<tr>
<td>Making Links (R₃)</td>
<td>Instances where learners and/or teachers discuss and identify links between mathematics or numeracy and its real life uses. This includes discussion of mathematical terminology, identifying specific mathematical meanings compared with general meanings.</td>
<td>Teacher sharing news items with learners, e.g. doctors and new ratios of doctors to patients. Learners thinking in pounds (£) to make sense of decimal numbers.</td>
</tr>
<tr>
<td>Re-creation (R₄)</td>
<td>Teachers’ attempts to re-create real life contexts within the educational setting. Often involves using real artefacts. Possibly context may not be directly relevant to learners’ lives.</td>
<td>Learners working out the volume of compost needed to fill some real plant pots. Using external surroundings to find examples of tessellation and angles.</td>
</tr>
<tr>
<td>Situated (Code R₅)</td>
<td>Closest to Real Life. Where learners and teachers provide/use examples of their actual uses of mathematics within a real life context.</td>
<td>A learner being able to check her payslip (presented to her in hours and decimals, rather than in hours and minutes). Learners reducing recipe when making playdoh.</td>
</tr>
</tbody>
</table>
Figure 3. The Context Continuum.
Kelly (2009, 2011) focused on workplace learning and compared education contexts with workplace contexts along one continuum (horizontal), and approaches to numeracy teaching along the other (vertical axis), from discrete concepts to problem solving. Because the methods teachers use to link classroom teaching to real-life uses form the basis of this case study, I focussed solely on the horizontal (contexts) axis, developing it to fit numeracy teaching that used ‘real life’ in general, rather than specifically a workplace context. Hence ‘Real Life’ context replaced ‘Work Life’ context. Based on the themes arising from the data, I divided the continuum into six subsections, hence ‘The Context Continuum’ (Table 2). Because my study was based in an educational context it also seemed more logical to start with the Education (mathematical) Context on the left. Codes were used to classify and sort the data, with ‘R’ representing ‘Real’, R5 being as Real Life as possible and R0 being devoid of any Real Life links. To illustrate, alongside their descriptions, examples (from the data) for each category in The Context Continuum is given in Figure 3.

For analysis, the specific examples (‘occurrences’) of numeracy teaching/learning methods identified throughout the data, i.e. in teacher and learner group interviews and class observations, were listed in a table and then the occurrences were sorted according to the six categories outlined in The Context Continuum. Although essentially a qualitative study, some quantitative analysis provided a useful means of identifying similarities and differences in teachers’ methods.

The pie charts in Figure 4 below show that the number of occurrences of all but two of the different categories were similar across both teacher/groups, with ‘Making Links’ and ‘Abstract’ being the most prevalent for each teacher/group. This identifies that the instances of teachers and/or learners discussing and making links between real-life contexts and the mathematics they are exploring in the classroom form the highest occurrences of methods captured. Also focus on the abstract, including the development of conceptual mathematical ideas, forms a high proportion of the methods identified.

However, the next most-occurring category differed. A higher number of ‘Quasi’ methods (in orange) was listed in teacher/group 2 (20%) compared with teacher/group 1 (3%). A possible explanation is that in teacher/group 2 learners were working towards a national test as part of their intended course outcome, therefore focus on ‘Quasi’ methods such as practise test questions and typical word problems could be seen as conducive to supporting success in learners’ test results. This contrasts with teacher/group 1 who were undertaking a short course for which there was no qualification outcome, and therefore ‘Quasi’ methods were likely to be less relevant in this situation.

In contrast, ‘Situated’ methods (in purple) made up a higher proportion of methods in teacher/group 1 (17%) compared with teacher/group 2 (4%). A possible explanation for this is...
that as a smaller, family learning group, all with young children, Group 1 were likely to have more common interests than the general Skills for Life group. These factors are likely to have made it easier to situate the learning in relevant real life contexts. Of course, it is also possible that these differences might be linked to teachers’ naturally different styles.

Finally, aspects of the data were preserved in linked sequences within the analysis tables (matching sequences of activities either observed or discussed in interviews), so that the sequences of different classroom activities could be analysed for any patterns emerging. These sequences are presented visually in Figures 5a and 5b below.

**Figure 5a. Sequences of activities: teacher/group 1.**

**Figure 5b. Sequences of activities: teacher/group 2.**

Analysis of the sequences of classroom activities shows that in general teacher/group 1 tended to move from the right hand side of The Context Continuum (Real Life context) (Figure 5a) to the left hand side of The Context Continuum (Education (mathematical)
context). In contrast, teacher/group 2 generally tends to move from left to right along The Context Continuum, i.e. from an Education (mathematical) context towards a Real Life context. The differences in direction are consistent with the differences in methods identified. For teacher/group 2, focus on the quasi-mathematical word problems, which are prevalent in adult numeracy test questions, is a key focus, therefore it perhaps makes sense to start with the more abstract and move towards more real life contexts. In contrast, for teacher/group 1, opportunities to focus on the class’s situated, real life uses of mathematics provided a more important focus, hence starting on the right-hand side of the continuum and moving left perhaps makes more sense.

Data from the teacher interviews suggest there may be other contributing factors. For example, Teacher 1 had less positive experiences of maths learning at school, so from first-hand experience she is aware of how a lack of understanding and feelings of failure can have a long and lasting effect on people. A focus on the individual, or the personal as the starting point for her teaching would therefore make sense. In fact Teacher 1 explained that she “always start[s] with what they know” and that she avoids ‘contrived’ contexts that are likely to be meaningless to some learners. In contrast, generally Teacher 2 seemed able to make her own sense of the maths she was taught, whether or not it was related to a context. Consequently she did not appear to have any real barriers to learning mathematics herself. Teacher 2 explains how in dealing with a group of learners with diverse interests and experiences, she tries to give multiple examples, to do things that people are familiar with in some way, to hopefully enable them to make their own links. Therefore the data suggest that teachers’ personal experiences, as well as learners’ contexts and course aims, may influence their approaches to teaching.

Discussion, implications and conclusions

The findings identified that both teachers in this study enabled learners to apply their new numeracy knowledge and skills to real life contexts, in addition to a range of other aims. These findings are relevant to other numeracy teachers including those in different contexts (e.g. vocational teachers) as well as those in different countries, where the drive for qualification outcomes sits alongside educators’ aims of making the learning useful beyond the qualification outcome.

In particular, this paper set out to answer the following questions:

- To what extent are teachers successful in enabling learners to apply the mathematics they learn?
- What methods do teachers employ in order to help bridge the gap between abstract mathematics and useable numeracy?

Whilst unsurprisingly (Coben, 2000; Swain et al., 2005), applying numeracy in real-life contexts was not an aspiration for learners on joining their course, nonetheless teachers’ methods increased learners’ knowledge, understanding and confidence and also their awareness of, and their ability and motivation to use their mathematics knowledge to support activities and problem solving in their own lives.

The way both teachers achieved this was primarily by focussing on developing the underpinning conceptual understanding of learners as well as focussing on linking these abstract procedures and concepts to real life applications relevant to learners. The differences in approaches, where Teacher 1 placed emphasis on situating the mathematics in learners’ real life contexts and Teacher 2 placed emphasis on using quasi (contextualised but perhaps unrealistic) examples, could be explained by different course outcomes, learners’ contexts, as well as teachers’ own experiences of learning mathematics in shaping their beliefs and approaches to numeracy teaching. Both teachers used all six approaches identified on the Context Continuum. Further research would be needed to establish whether the course
outcomes, learners’ contexts, or teachers’ natural approaches were more influential in guiding their course planning, and to what extent these approaches could be adapted or developed.

The different sequences of activities suggest that it does not necessarily matter which direction the order of learning activities occur, i.e. starting with real life situations and moving to the abstract mathematics within them or the other way around, but that either way, learners can gain the confidence and skills to use the maths they have learned in class for uses outside the classroom. Therefore it seems that, along with developing conceptual understanding, the important factor in the teachers’ success is the movement back and/or forth between the difference discourses of mathematics and numeracy (as discussed by FitzSimons, 2006), embedded in discussions with learners which make explicit the links between formal and informal uses of mathematics.

Both classes were discrete numeracy classes in that the learning focused on numeracy rather than being embedded in a vocational or workplace context. As a result learners had a wide range of backgrounds and experiences, and this sometimes made it difficult for teachers to identify contexts which were truly relevant to all learners. This perhaps explained why Teacher 1 was able to use more situated learning activities, as her learners were all mothers of young children, so they at least had this in common, and learning could be situated in the context of mother-educators supporting the development of their children’s numeracy learning. Teacher 2’s solution to the diversity was to offer a range of different contexts on a regular basis. Both strategies seemed to work, which suggests that a vocational or workplace context is not essential and that discrete numeracy classes can also support development of numerate skills and attitudes, as long as the teachers have the skills, commitment and drive to make their classes useful to learners beyond any qualification outcome.

The Context Continuum model was useful in classifying the different types of activities used in these discrete numeracy classes so that teachers’ approaches and their similarities and differences could be explored and communicated. In using the model again I would consider additionally capturing and analysing the length of time spent on different types of activities. This was not appropriate in the pilot study as, in addition to observation data, the analysis considered interview data, i.e. it included discussions about un-recorded sessions and activities carried out on previous occasions with the same groups. I hope that the model, along with the findings, will be of use to other numeracy teachers or numeracy teacher-educators, and researchers, to support analysis and development of adult numeracy teaching practice. The continuum could also be adapted to be of use to practitioners and researchers of other subjects (e.g. literacy).

References


Connecting Mathematics Teaching with Vocational Learning

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Abstract
For many vocational students in England, mathematics is now a compulsory part of their programme, yet the inclusion of an academic subject within a vocational course presents challenges. In this paper, an analysis of a series of case studies of vocational student groups in Further Education colleges in England shows how contrasting practices in ‘functional mathematics’ and vocational classes reinforce perceptions that mathematics is an isolated and irrelevant subject. Some mathematics teachers made contextual connections by embedding mathematical problems in vocationally-related scenarios but distinctive socio-cultural features of vocational learning situations were often absent from mathematics classes. Addressing this disconnection requires a pedagogical approach and classroom culture that links mathematics learning with vocational values. The findings suggest that adopting mathematics classroom practices that reflect the surrounding vocational culture creates greater coherence for students and has positive effects on their engagement with mathematics learning.

Keywords: mathematics, functional mathematics, vocational education

Background to the study
The separation of vocational and academic pathways in post-16 education is a result of long-standing divisions that remain unresolved within the English education system (Young, 1998). Entry to the academic pathway is largely controlled by success in GCSE examinations at age 16 and those with low GCSE grade profiles often transfer to vocational pathways in separate institutions such as Further Education colleges. The divisions between the academic and vocational pathways are not only institutional but there are distinct differences in the curricula, qualification types and forms of knowledge associated with each strand. Students have constrained choices in post-16 education within a highly-stratified system (Pring et al., 2009) that tends to prioritise the academic over the vocational.

Within vocational education, both the mathematical skill levels of students and the qualifications undertaken have attracted criticism (Wolf, 2011). Historically, many low-attaining 16-year-olds have taken no further mathematics qualification by age 18 (DfE, 2014). Recent policy changes, however, now require these students to work towards re-sitting the GCSE mathematics examination until they achieve a grade C. When coupled with the recent extension of compulsory education to age 18 years in England, this means that many more students on vocational pathways now learn mathematics as a compulsory part of their study...
programme. This GCSE mathematics curriculum is traditional and academic in nature and so does not sit easily with their vocational learning.

The research reported herein was conducted prior to these national policy changes, with students who were taking a Functional Mathematics qualification rather than re-sitting the GCSE examination. Functional Mathematics focuses on problem solving and applications in ‘real life’ scenarios and, for most students in the study, the subject was compulsory due to college policies, although it was not a government requirement at the time. This paper examines the contrasts between mathematics teaching and vocational learning that emerged from a wider study of the students’ learning experiences of mathematics and was primarily concerned with students aged 16-18 years. Before examining the research findings, some of the relevant historical academic-vocational tensions are discussed.

Divisions of knowledge, curriculum and pedagogy

The institutional divisions within the English education system can be traced back to the separate establishment of schools, work-related training and adult education. These educational traditions have continued without a coherent overarching policy for education as a whole (Maclure, 1991; Young, 1998). The academic and vocational education traditions that have grown from these roots have different purposes, curricula and qualifications but also reflect longstanding societal hierarchies (Hyland, 1999). The “links between the stratification of knowledge in the curriculum and patterns of social inequality and distribution of power in the wider society” (Young & Spours, 1998, p. 51) are evidenced in the privileging of academic over vocational pathways.

Low-achieving students often undertake vocational qualifications after the age of 16 although these qualifications are seldom considered in schools (Hodgson & Spours, 2008) where the focus remains on academic GCSEs, both prior to age 16 and after the parting of the academic-vocational ways. Vocational training in Further Education colleges has the twin goals of developing practical competencies and acquiring relevant technical knowledge in order to prepare individuals for employment. In contrast, academic qualifications in post-16 pathways prepare students for higher education and GCSE mathematics continues to act as a highly-valued ‘gate-keeper’. Despite some attempts to bridge the divide by increasing the academic rigour of vocational qualifications or bringing vocational education into schools, these initiatives have historically had limited success (Hyland, 1999).

The teaching of academic and vocational subjects draws upon contrasting traditions (Lucas, 2004). For vocational education one of the major influences has been the close association with the apprenticeship model of learning, in which the teacher, as an occupational expert, demonstrates skills for students to replicate until they achieve competence in a ‘community of practice’ (Lave & Wenger, 1991; Wenger, 1999). Teachers may take a range of roles within vocational workshops and classrooms but practical activity is particularly important in a learning process that is essentially social and collective (Unwin, 2009); the emphasis is on developing competency within a community rather than acquiring knowledge (Hyland, 1999).

The academic strand within Further Education reflects a more classical, liberal approach to education in contrast to the practical usefulness valued by vocational areas. Robson (2006) argues that pedagogy needs to reflect the disciplinary context but this causes an uneasy relationship when a subject such as mathematics is taught as part of a vocational programme. Learning mathematics for vocational purposes focuses activity on a particular context and practical need but this utilitarian view (Ernest, 2004) is in tension with the broader appreciation of mathematics and abstract knowledge valued in academic pathways.

Vocational departments in Further Education colleges associate strongly with their particular occupational values (Robson, 1998). The tendency for students to adopt these values (Colley, James, Diment, & Tedder, 2003) suggests that students primarily focus on their vocational goals, resulting in perceptions that subjects with no clear vocational purpose are peripheral.
Such values are key components of departmental culture but are also important influences in the teaching of mathematics (Bishop, 2001; FitzSimons, 1999). Against this background of historical traditions, our interest here is in the differences between students’ experiences of mathematics and vocational learning, including the pedagogies and values enacted in these lessons.

**Research questions and methods**

The research questions of interest in this paper are:

- In what ways are students’ experiences of learning in vocational sessions and Functional Mathematics classrooms related?
- How does this affect their learning of mathematics?

To answer these questions we compare teaching and learning approaches in mathematics and vocational sessions, using lesson observation data from a wider study of vocational students’ experience of functional mathematics in Further Education.

The research involved a series of nested case studies within vocational areas in three Further Education colleges, from which cross-case and within-case comparisons could be made. Seventeen different student groups were involved from the vocational areas of Construction, Hair and Beauty, and Public Services and each student group formed a separate case study. The research was exploratory as well as explanatory and used multiple methods, both qualitative and quantitative, to provide triangulation between sources and methods. Drawing on ideas involved in grounded theory, an iterative process of analysis was used that involved the coding of qualitative data and constant comparison to identify emerging themes.

In addition to the lesson observations of the same student groups in Functional Mathematics and vocational sessions, data was obtained from student focus group discussions, interviews with Functional Mathematics teachers, interviews with vocational teachers, staff questionnaires and individual student card-sorting activities. In the card-sorting activities students either ranked statements, or placed statements on a Likert scale, to describe their experiences of school and college. In the following section we present some of the relevant results from these activities as background before examining the lesson observation data.

**Research findings**

When students ranked statements about their reasons for coming to college, the dominant reasons that emerged from the analysis were ‘I was interested in the course’ and ‘I wanted to improve my education’. Focus group discussions provided further evidence that most students were interested in their vocational courses and valued the opportunity to choose the direction of their education, even though these choices were somewhat constrained by their GCSE profiles.

Secondly, students placed statements regarding their experiences of college on a Likert scale and discussed these in focus groups. Most students depicted college in positive terms (See Table 1 in Appendix I) referring to features such as being treated in a more adult manner, experiencing greater freedom, having more agency and taking more responsibility for their own learning. These results suggest that values relating to adulthood and employment were important to students and welcomed their presence in the college culture. In contrast, many students referred to their experiences of mathematics in school in negative terms (Table 2). Focus group discussions provided further evidence that most students approached college with a view that mathematics was a remote and irrelevant academic subject, one associated with previous failure and disaffection.
Within this context, where many students were positive about their general experience of college but showed an initial negative disposition towards mathematics, we compare their experiences in vocational and mathematics sessions. The differences will be set out using two short summaries of observed sessions. These exemplify the high contrast between vocational sessions and the traditional features of mathematics lessons that were evident in many of the seventeen case studies. After summarising the key features, the approaches used by some functional mathematics teachers to connect the two learning situations will be considered.

Observation A: Beauty Therapy students in the training salon

The students were giving facial treatments to clients. This involved individual skin consultations and one-to-one practical work. One student, Nina, was demonstrating the treatments on a “doll” (artificial head) to students who had missed the previous session. Nina explained the stages of the facial and how each had to be completed properly but within a timescale of about 30 minutes since extra time would lose money for the business. Another student, Gemma, was acting as the salon manager: replenishing products, keeping records of the treatment times and generally making sure the salon was running smoothly. Quiet, relaxing music was playing as each student worked individually on their client. Several times during the session the students were reminded by the teacher to talk solely to their client and not chat to other students. All the students were wearing clean uniforms and seemed to have taken considerable care over their personal appearance. Students were expected to maintain their own uniforms, have their hair tied back and keep jewelry to a minimum. Apart from moderating the atmosphere, the vocational teacher watched and advised, acting as a guide and source of further information when necessary.

Observation B: Functional mathematics with Public Services students

The session took place away from the Public Services vocational area. Space was tight and although the students could all be seated at tables there was little room for the teacher, David, to move between them. This had an impact on the lesson since it was difficult for him to check work, give feedback and support individual students. After a formal teacher-centred introduction and some worked examples on the board, the main activity was to complete a series of worksheets about areas and perimeters. These were given out one at a time so that the completion of any worksheet was quickly followed by the provision of another. David tried to circulate to mark work and encourage students to participate but it was difficult to get students to engage with the work and frequent reminders were needed to keep them on task. He worked hard to keep distractions under control by reminding students to be quiet and get on with their work. These attempts to impose a working environment dominated the session and, despite being calm and persuasive, David’s strategy seemed largely ineffective. Towards the end of the lesson students who had completed the work were allowed to go early whilst the others were retained and urged to continue until the official end of the lesson.

In the vocational session students were expected to adopt professional standards of behaviour and take significant responsibilities such as making decisions about treatments, supervising other students and providing customer care. In contrast, the Functional Mathematics lesson was a tightly structured, teacher-controlled session, closely resembling a typical school mathematics classroom. Students had little opportunity to make decisions about the learning process or take responsibility for their own progress as the whole process was largely controlled by the teacher.

Within the training salon there were clear rules regarding personal appearance and professional conduct but there was also considerable freedom. Students were expected to focus on their client during the session but walking around to collect equipment or products was part of the normal routine. Unprofessional chatter with their peers was prohibited but consulting with other students for support or advice was an accepted feature of working practice. In the functional mathematics classroom, space was constrained and students were expected to remain seated throughout the session. This created a very different environment and influenced the way in which learning took place.
David’s approach to teaching was topic-based and the lesson involved an explanation of the mathematical content before demonstrating the processes through worked examples on the board. This was followed by student work on further examples that they were expected to complete quietly and independently. For David, mathematics should be learned in an organised, orderly classroom with clear rules enforced by the teacher. In contrast, the teacher’s role in the salon was mainly to observe and advise. Students learned from one other as well as from their teacher in this collaborative and supportive environment.

There were further contrasts in the type of tasks used. In the vocational session practical skills and theory were integrated into tasks. For example, relevant theory about skin types needed to be recalled and used during consultations with clients. Tasks in the salon would generally take some time to complete and there was some flexibility about the time taken for each component as long as the overall treatment was completed within a reasonable timescale. Learning in David’s classroom mainly involved short written tasks with the expectation that students would remain ‘on task’ and completion would be followed immediately by additional written work.

These two approaches to teaching and learning seemed to be based on contrasting values and assumptions regarding the role of the teacher, the environment and the processes that would be most effective for learning. Relationships between the teachers and students in these two examples were very different, as were the social structures and classroom cultures in which roles and relationships were embedded. Comparisons with other observations of vocational sessions in salons, workshops and classrooms, showed that this session was very typical. This cross-case analysis led to the identification of four main areas in which there were common characteristics:

- **Responsibility, agency and freedom.** Students worked within loose frameworks of rules that related to health and safety requirements or professional standards but had freedom to make individual decisions. They were expected to take responsibility for their learning and were placed in positions of responsibility for clients or other students. There was freedom of movement around the vocational salons, workshops and classrooms.

- **Vocationally-related values and expectations.** Adult and work-related values, dispositions and behaviours were encouraged and evident in most sessions.

- **Student-focused learning through guided activity.** Learning processes centred on developing practical competencies through replication of skills demonstrated by respected vocational experts. Their role was to facilitate learning, with students acting as apprentices in a community where informal peer learning was often evident.

- **Integration of knowledge and skills into substantial tasks.** Practical skills were highly valued but knowledge from theory sessions was often intertwined into tasks. Tasks were usually substantial with multiple elements and time-scales stretching over days or weeks. Students worked at their own pace, making individual decisions about the order of the sub-elements and the methods to use.

These four areas contrasted with the formal, traditional approach to teaching mathematics in David’s lesson where the following key features were identified:

- **Teacher authority and control.** The rules in the classroom reflected the values and priorities of the teacher-authority who expected students to comply. The teacher directed and controlled the learning process. Students had little agency in their work. They were expected to remain seated throughout the session, to work quietly, individually and follow directions.

- **Academic values and expectations.** The students were learning a subject as a series of disconnected topics, through a process of knowledge transfer rather than developing a set of skills.
Teacher-led activity. The lesson was planned and closely directed by the teacher. Mathematical knowledge was delivered to students who did not aspire to be mathematicians and had little sense of how this learning might be useful.

A focus on written work. There was a reliance on worksheets and written solutions to questions. The tasks were usually short and students were expected to remain ‘on task’ throughout the lesson.

Not all of the mathematics lessons were, however, like David’s. We now consider those cases in which the Functional Mathematics teachers adapted to the vocational environment with lessons that were better connected to the students’ vocational learning experience. The key features of these lessons are, again, presented using a short lesson observation as an exemplar, followed by a summary of the common characteristics of similar lessons from the cross-case analysis.

Observation C: Functional mathematics with Hairdressing students

The session took place in a separate building, some distance from the main Hairdressing area. As the students arrived the teacher, Richard, greeted them individually and engaged in relaxed conversations about what they had been doing both inside and outside college since the last class. His introduction to the lesson involved a class discussion about using units of time. Students readily talked about their difficulties, both asking and responding to questions until they were satisfied that they understood the concepts and processes involved. The main task in the lesson was to draw up an appointment schedule for a hair salon from a list of requests for appointments involving different hair treatments. This required students to use vocational knowledge about the time needed for each treatment and considerations about appropriate business decisions, in conjunction with mathematics. The students produced individual schedules, using different methods and formats, but discussed their strategies and decisions freely with each other. The teacher supported and guided by asking students individually about their methods, assumptions and decisions. Finally, the teacher checked their progress with a longer-term integrated homework assignment in which students were using vocational knowledge, English and mathematics to produce a business plan for a new hairdressing salon.

Although the physical separation of the mathematics classroom from the students’ vocational base was similar to the situation of the Public Services lesson, the key pedagogical features contrasted with those observed in David’s lesson and were more closely aligned to the vocational session. Similar features were evidenced in a number of Functional Mathematics sessions and the cross-case analysis suggested the following key features of a more ‘connected’ functional mathematics classroom:

1. Teachers adopted pedagogies that made connections through context, classroom discourse and programme synchronization:
   - Using vocational situations as the context for mathematical problems. This was effective when the details of these scenarios were accurate and resembled situations that students had actually experienced;
   - Encouraging an integrated discourse about mathematics in students’ lives by using informal conversations and interests as a basis for improvising discussions about applications of mathematics;
   - Synchronizing the Functional Mathematics scheme of work with the vocational programme to increase perceptions of relevance.

2. Teachers developed classroom cultures that were more in keeping with values of the surrounding vocational culture by:
   - Creating flatter social structures than those in traditional school mathematics classrooms;
   - Adopting a supportive, facilitating role;
• Developing equitable relationships with students;
• Using peer learning as a key learning strategy.

In cases where these features were present, our cross-case analysis suggested that students responded more positively to learning mathematics than in classrooms where the pedagogy and culture were more traditional. These features seemed to reduce the sense of disconnection between the mathematics classroom and the vocational programme and as a result their engagement with mathematics improved.

**Discussion**

For many of the students in this study, learning mathematics was perceived as separate from their vocational learning. However, when learning mathematics was connected to students’ vocational development, values and culture then the subject generally became more relevant, meaningful and coherent. Although students retained a narrow focus on their vocational area (Hodgson & Spours, 2008) and only identified a limited utilitarian purpose for mathematics (Ernest, 2004), their acceptance of Functional Mathematics as a vocationally-relevant subject represented a shift in perspective that had a positive effect on their engagement with mathematics.

The students in this study were in a transition from school education to the workplace and were experiencing the tensions between formal, abstract academic learning and the development of vocational skills to achieve professional competence. As FitzSimons (1999) explains, mathematics in the workplace becomes a tool, in contrast to being the object of activity in mathematics classrooms. The transition from school to the workplace therefore involves changing students’ perceptions of mathematics from object to tool, but this is a gradual process and not straightforward. In the interim period of being a ‘trainee’ in college students are caught between these two positions.

The mathematics learning of vocational students is situated in a complex socio-cultural environment, influenced by contrasting educational and vocational values and traditions. Although historical, social and cultural influences affect values generally in mathematics classrooms (Bishop et al., 1999), the co-existence of Functional Mathematics lessons within vocational programmes require students to change between cultures with typically dissonant values, unless cultural divisions can be bridged and values harmonized. In practice, students tend to adopt the values of their vocational area, as indicated by previous research (Colley et al., 2003) and the alternative value system, that frames much mathematics teaching, generates tensions. Some reconciliation of these different cultures is necessary to enable students to see learning mathematics as an integral and meaningful component of their vocational training.

Values relating to employment and adulthood were dominant in the general college culture and were also important to students. In some cases Functional Mathematics teachers created social structures that facilitated a more open and equitable classroom culture and this was better aligned to these values. Others embraced specific vocational values, such as teamwork for Public Services, in their teaching approaches. These adjustments to classroom culture provided a more coherent learning experience and helped stimulate student engagement.

In the observed vocational sessions, the role of the teacher was one of an occupational expert in a learning community similar to a ‘community of practice’ (Lave & Wenger, 1991; Wenger, 1999). In this social arrangement students were learning from the teacher’s expertise and from one another by developing practical competencies coupled with technical knowledge. Functional Mathematics lessons involved a different learning process as students were neither aspiring to be mathematicians nor intending to be teachers of mathematics and therefore a ‘community of practice’ model was inappropriate.

The analysis suggests that the practices of a connected mathematics classroom in colleges can enable students to bridge some of these divisions by presenting mathematics as a subject that
is not confined to the domain of academic knowledge but can also constitute vocationally-related skills. The pedagogy of the connected classroom in this study reflects some of the principles of embedding from previous research (Eldred, 2005; Roberts et al., 2005) but it also highlights the importance of shared values and compatible cultures in mathematics classrooms for vocational students. Bridges between different practices, of vocational learning and mathematics teaching, were constructed using key points in these separate discourses to make connections (Evans, 1999). These connections enabled a form of ‘boundary crossing’ that reconciled some of the conflicts for students between their vocational training and their learning of mathematics. Although the learning processes for mathematics and vocational skills retains some fundamental differences, these approaches suggest ways in which greater coherence and better engagement can be brought into the student experience of learning mathematics in vocational education.

Conclusions

The academic-vocational divisions and tensions of the English education system were evident in the student experience through contrasts in the pedagogy and purpose of learning in vocational and mathematics sessions but there were also important differences in the social structures, culture and values within the two separate learning environments. For students in transition from school to the workplace, the vocational training phase is characterised by changing values and shifting perspectives as students become more orientated towards employment. Bridging the divisions and providing a coherent, meaningful experience of mathematics learning for vocational students requires an understanding of this transition, a non-traditional approach to mathematics teaching and a classroom culture that reflects the values of the surrounding environment that are important to students. The effects of these features within the classroom were significant for students in the study and suggest aspects of teaching in a vocational environment that need to be considered seriously alongside general and subject-specific pedagogy.

In the light of recent policy changes in England it seems that the move towards the more knowledge-based, academic GCSE mathematics qualification rather than a ‘functional’ curriculum is likely to create a greater distance between mathematics and vocational learning for students. Further research is needed to ascertain the actual effects of these policy changes on the dispositions and attainment of students who are required to re-sit GCSE mathematics courses but there are clear indications in this study that addressing the cultural divisions between mathematics and vocational learning is an important factor in creating a meaningful and successful experience for students. These findings have implications for the training of mathematics teachers for Further Education. They also raise questions for policy-makers for whom the achievement of an academic minimum standard in mathematics is privileged over engaging students in a meaningful experience that prepares them for the workplace.

Acknowledgements

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References


Table 1.

**Student Views on What College is Like**

<table>
<thead>
<tr>
<th>QUESTION B: What is college like? (compared to school)</th>
<th>SA</th>
<th>A</th>
<th>N</th>
<th>D</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is more freedom than there is in school</td>
<td>45</td>
<td>42</td>
<td>9</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>It has been easy to make friends</td>
<td>32</td>
<td>48</td>
<td>23</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>I get on with the staff in college</td>
<td>25</td>
<td>58</td>
<td>16</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>You are treated better at college than school</td>
<td>26</td>
<td>50</td>
<td>21</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>College work is easier than school</td>
<td>8</td>
<td>32</td>
<td>38</td>
<td>21</td>
<td>4</td>
</tr>
<tr>
<td>The staff treat you like adults</td>
<td>23</td>
<td>51</td>
<td>15</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>My course is interesting</td>
<td>47</td>
<td>44</td>
<td>8</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>I like the subjects I do</td>
<td>32</td>
<td>57</td>
<td>10</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 2.

**Student Experiences of Mathematics in School**

<table>
<thead>
<tr>
<th>QUESTION D: When you did Math at school how did you feel?</th>
<th>AA</th>
<th>S</th>
<th>H</th>
<th>O</th>
<th>AN</th>
</tr>
</thead>
<tbody>
<tr>
<td>I worked hard</td>
<td>13</td>
<td>34</td>
<td>31</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>It was difficult</td>
<td>9</td>
<td>29</td>
<td>28</td>
<td>28</td>
<td>8</td>
</tr>
<tr>
<td>I got distracted</td>
<td>22</td>
<td>31</td>
<td>16</td>
<td>29</td>
<td>4</td>
</tr>
<tr>
<td>I liked Math</td>
<td>9</td>
<td>20</td>
<td>14</td>
<td>20</td>
<td>38</td>
</tr>
<tr>
<td>I felt stressed</td>
<td>15</td>
<td>20</td>
<td>19</td>
<td>29</td>
<td>19</td>
</tr>
<tr>
<td>I was bored</td>
<td>21</td>
<td>20</td>
<td>26</td>
<td>27</td>
<td>7</td>
</tr>
<tr>
<td>I liked the teacher</td>
<td>11</td>
<td>23</td>
<td>19</td>
<td>13</td>
<td>36</td>
</tr>
<tr>
<td>I felt confident</td>
<td>4</td>
<td>22</td>
<td>21</td>
<td>38</td>
<td>17</td>
</tr>
<tr>
<td>It was interesting</td>
<td>2</td>
<td>14</td>
<td>18</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>I understood it</td>
<td>6</td>
<td>30</td>
<td>27</td>
<td>24</td>
<td>15</td>
</tr>
<tr>
<td>It was confusing</td>
<td>14</td>
<td>21</td>
<td>23</td>
<td>38</td>
<td>6</td>
</tr>
<tr>
<td>I could have done better</td>
<td>34</td>
<td>30</td>
<td>17</td>
<td>19</td>
<td>0</td>
</tr>
</tbody>
</table>
Adult Students’ Experiences of a Flipped Mathematics Classroom

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Abstract
The flipped classroom is a flexible blended learning model that is growing in popularity due to the emergent accessibility to online content delivery technology. By delivering content outside of class time asynchronously, teachers are able to dedicate their face to face class time for student-centred teaching approaches. The flexibility in implementation of a flipped classroom allows for a diversity in student experiences. The study presented in this paper uses qualitative methods of analytic induction to conduct a case analysis on survey and interview data collected from students participating in a flipped adult mathematics upgrading course at an urban Canadian university near Vancouver, BC. The key phenomenon of interest in the study is how adult students experience a flipped mathematics classroom. Of secondary interest is how factors such as autonomy and goals interrelate with these experiences. It is found that flipped classrooms can bifurcate into two types of student interaction: completely engaged and self-paced. Key interrelated factors in this bifurcation include adoption of cognitive autonomy support, goal orientation, and attendance.

Keywords: flipped classroom, autonomy, goals, classroom experience

Introduction
Empowering adults to learn mathematics, especially when they have encountered low mathematical performance in their past and have returned to the subject for the key purpose of obtaining high school prerequisites required towards a new career path, can be very challenging. The underlying goal of this study is motivated by the desire to enrich the experiences of this population of adult learners by providing them with a student-centred learning environment, which differs from the dominant teacher-centred learning environments they were most likely exposed to in their public school experiences.

In a teacher-centred learning environment, the focus is on pursuing the teacher’s agenda, which is not directly related to emergent student learning needs. In contrast, student-centred learning approaches focus on the student and their learning journey. The notion of a student-centred learning environment is rooted in constructivism and embraces student agency. Knowledge is actively constructed by the learner rather than imparted by the teacher, and “goals are negotiated and selected by the learners” (Elen, Clarebout, Léonard, & Lowyck, 2007, p. 107). In this research, Elen et al.’s (2007) transactional view of student-centred learning is adopted, where there is a “continuous interchange between students’ and teachers’ responsibilities and tasks” (p. 108). The key premise is that the teacher observes student interactions and adapts teaching interventions accordingly to student needs.

Overall, student-centred approaches have been found more effective than teacher-centred ones (Åkerlind, 2003; Barr & Tagg, 1995; Grubb & Associates, 1999; Grubb & Cox, 2003; Kember & Gow, 1994; Prosser & Trigwell, 1999). However, creating student-centred
learning environments can be challenging for teachers, especially in mathematics, where curriculum constraints are demanding. Wang (2011) notes that “student-centred teaching tends to be more time-consuming and unpredictable than whole-class lecturing” and that “teachers working under a fixed curriculum and schedule are inclined to organize the class in a more teacher-centred manner to secure the completion of required tasks” (p. 157). In an effort to relieve these tensions between allowing for student-centred learning practices and maintaining adherence to the curriculum, educators have become drawn to the affordances provided by increasingly accessible technologies to deliver content asynchronously out of class time while dedicating class time for student learning. Bergmann and Sams (2012) have coined the phrase ‘flipped classroom’ in reference to this teaching approach.

The concept of reversing content delivery and practice time is not a new phenomenon in education, but the increasing accessibility to technology that allows teachers to create their own content videos and the improved ability available for teachers to share their teaching practices to a wider audience online have contributed to the increasing popularity of the flipped classroom model. Media outlets such as USA Today (Toppo, 2011), Washington Post (Strauss, 2012), and CNN (Green, 2012) have covered experiences and opinions regarding the flipped classroom. However, research based literature pertaining to flipped classrooms is still limited. Several studies report increased student achievement in flipped classrooms (Day & Foley, 2006; Green, 2011; Johnson, 2013; Kirch, 2012; Mussallam, 2010), but few of them relate directly to a mathematics context, let alone the adult population.

The most notable studies within a mathematics context focus on student perceptions. One of these studies looks at an undergraduate level statistics course (Strayer, 2008) and the other looks at a set of high school level mathematics classes (Johnson, 2013). Strayer (2008) compares student responses from a flipped classroom version of an undergraduate statistics course with that of a traditional classroom version of the same course. He finds that students in a flipped classroom can experience higher levels of innovation and cooperation than those in a traditional classroom but that they can also experience feelings of unsettledness due to the unpredictability of class time. Students in the flipped classroom can also find the learning model difficult to accustom to if they are used to a traditional approach. In contrast, Johnson (2013) finds that high school mathematics students experience the flipped classroom approach more positively. His students evidence enjoyment from classroom learning activities, frequent interaction with teacher and peers, and a reduction in time necessary to spend on homework outside of class time. Johnson (2013) also finds evidence of improvement in students’ perceptions of engagement, communication, and understanding. The varying and almost contradictory results in these studies may in part be attributed to various methods of implementation and a difference in student population. Based on these two small-scale studies, one could conclude that adult learners may have a more difficult time adjusting to the teaching approach than high school students. However, the evidence for such an argument is not substantive enough and needs further exploration.

More importantly, there is no single method of implementation of a flipped classroom, and just like with any student-centred teaching approach, its success rests on a teacher’s pedagogical sensitivity and ability to adapt to student needs. Although student-centred approaches are desirable, they are not always easy to carry out. The flipped classroom approach provides teachers who want to evolve their classes into student-centred learning environments with the option to deliver direct instruction outside of class time, leaving time during class for student-centred tactics. Flipped Learning Network (2014) has defined flipped learning as “a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter” (para. 2). They claim that flipped classrooms can lead to flipped learning through a flexible environment, a rich learning culture, intentional content, and a professional educator, but that a flipped classroom in itself does not promise flipped learning. Rather, a flipped classroom offers teachers a means with
which to employ student-centred approaches. Kachka (2012) notes that “the increase of teacher-student interaction during class time is what characterizes [the flipped classroom model’s] success” (para. 6). Student-centredness within a flipped classroom, by its nature, affords student autonomy over learning, and is closely tied with factors such as goals, self-efficacy, and anxiety.

The research presented in this paper is therefore motivated by the question of how adult mathematics students experience a student-centred flipped classroom environment that offers opportunities for student autonomy over learning in the context of an adult mathematics high school level upgrading course at the University of the Fraser Valley in British Columbia, Canada. A secondary question that guides the study pertains to how factors such as goals, self-efficacy, and anxiety are interrelated with adult student experiences in this classroom. For purposes of brevity, only factors of autonomy and goals are detailed in this paper. In what follows, key literature, background, results, and conclusions from the study are overviewed as pertaining to autonomy and goals. Possible implications for the field of mathematics education are also discussed.

Key literature

Analysis of the context of this study is informed by literature on the provision of autonomy support. Student experiences in the context are examined in relation to literature on goal orientation. These theories are briefly overviewed in order to ground the results.

Autonomy

Student-centred learning environments by nature allow for student autonomy. In general, autonomy is viewed as the availability of choice, which is evident in Black and Deci’s (2000) definition: autonomy is supported by providing students with “pertinent information and opportunities for choice, while minimizing the use of pressures and demands” (p. 742). Studies have shown that students of autonomy supportive teachers experience more classroom engagement, positive emotion, self-esteem, creativity, intrinsic motivation, psychological well-being, persistence in school, academic achievement, and conceptual understanding (Assor, Kaplan, & Roth, 2002; Benware & Deci, 1984; Deci & Ryan, 1985, 1987; Deci, Nezlek, & Sheinman, 1981; Hardre & Reeve, 2003; Koestner & Ryan, 1984; Reeve & Jang, 2006; Reeve, 2009; Ryan & Grolnick, 1986; Vallerand, Fortier, & Guay, 1997). Therefore, it is important to consider the role of autonomy and its implications for mathematics classrooms.

Although positive effects are associated with autonomy in classrooms, it is important to emphasize that autonomy cannot simply be provided, it needs to be supported. Autonomy supportive teaching should “adopt the students’ perspective, welcome students’ thoughts, feelings, and behaviours, and support students’ motivational development and capacity for autonomous self-regulation” (Reeve, 2009, p. 162). Stefanou, Perencevich, DiCinto and Turner (2004) classify autonomy support into three dimensions: organizational autonomy support, procedural autonomy support, and cognitive autonomy support.

Organizational autonomy support allows students to control their environment by directing them to choose classroom rules, the pace at which they learn, due dates which they set, students with whom they work, and ways in which they are evaluated. Meanwhile, procedural autonomy support allows students to control the form in which they present their work by inciting them to choose materials they use for a project, the ways in which they display work, and the ways in which their materials are handled. Finally, cognitive autonomy support allows for students to control their learning by encouraging them to generate their own distinct solutions, justify their solutions according to mathematical principles, evaluate their own
work, evaluate work of their peers, discuss multiple approaches, debate ideas freely, ask
questions, and formulate personal goals.

Stefanou et al. (2004) argue that although organizational or procedural autonomy support may
be necessary, it may be insufficient in maximizing motivation and engagement. They claim
that cognitive autonomy support is the most essential type of autonomy support in order for
positive educational benefits such as motivation and engagement to occur. Although Stefanou
et al. (2004) do not clearly indicate whether organizational and procedural dimensions are
best structured or left autonomous, a study conducted by Jang et al. (2010) suggests that
student engagement can be more prominently observed when a learning environment has
higher levels of structure (i.e. structured organizational and procedural dimensions) as long as
students are provided with high levels of cognitive autonomy support. They note that structure
should not be confused with control. Even when a dimension is more structured than
autonomous, the teacher should maintain respect for student thoughts, feelings and actions
within the structure. Although the necessity of organizational and procedural autonomy
support is not clearly defined in the literature, there is consensus with regard to the
importance of cognitive autonomy support in relation to heightened student engagement and
motivation.

**Goals**

Additionally, goal orientation can have a positive influence on performance and motivation in
the face of a challenging task, such as that of learning mathematics (Grant & Dweck, 2003).
The predominant view of goals that informs analysis in this study is that of Achievement Goal
Theory. This theory is rooted in the belief of intelligence as being either fixed or malleable
giving rise to either performance (self-enhancing) or learning (mastery) goal orientations,
leading to various motivation driven behaviour patterns that depend on self-efficacy beliefs
(Dweck, 1986; Pintrich, 2000).

In a learning goal orientation, “individuals seek to increase their competence, to understand
or master something new” whereas in a performance goal orientation, “individuals seek to
gain favorable judgements of their competence or avoid negative judgments of their
competence” (Dweck, 1986, p. 1040). Grant and Dweck (2003) provide evidence that a
learning goal orientation positively affects performance and motivation in the face of
challenge while the performance goal orientation only positively affects performance and
motivation if no challenge is present. In extension of Dweck’s (1986) theory, Dupeyrat and
Mariné (2005) discover that for adults returning to school, “mastery [or learning] goals have a
positive influence on academic achievement through the mediation of effort expenditure”
(p. 43).

Further, Hannula (2006) shows evidence that “students may have multiple simultaneous goals
and [that] choices between them are made” (p. 175). He claims that motivation is structured
through the mediation of needs and goals with emotions and that a desired balance of goals
can be promoted by offering students a safe learning environment that focuses “on
mathematical processes rather than products” (Hannula, 2006, p. 176). Such an environment
can be created through the provision of cognitive autonomy support and is possible within a
flipped classroom context.

**Background**

In what follows, the context of the study and the methods used to collect and analyse data are
overviewed.
Context

The context of this particular study is a full-term 60 hour adult mathematics upgrading course referred to as Math 084 offered through the Upgrading and University Preparation Department (UUP) at the University of the Fraser Valley (UFV). UFV is a fully accredited public multi-campus university primarily located in the Fraser Valley just east of Vancouver, British Columbia, Canada. The UUP department at UFV offers programmes in Adult Basic Education (ABE) for adults of all backgrounds and ages who want to meet their educational goals such as completing prerequisites for post-secondary programmes, earning the BC adult graduation diploma, or improving skills for personal benefit.

Math 084 serves as a requirement for the Dogwood Diploma (graduation diploma in British Columbia) and is the first out of two courses that together serve as a prerequisite for most undergraduate programmes that lead to career paths such as teaching, nursing, business diplomas, etc. The course covers a variety of topics including linear equations, linear inequalities, quadratic equations, radical equations, operations with polynomial, rational, and radical expressions, and function graphing. It is traditionally taught with 60 lecture hours and 30 individual or group work hours, which makes it a primarily teacher-centred learning atmosphere.

In contrast, the flipped classroom implementation of Math 084 fostered a student-centred learning atmosphere. Video lecture lessons1, online quizzes, announcements, and practice problems were posted in an online learning management system (i.e., Blackboard Learn), and students were asked to preview this content prior to class as homework. More importantly, having the content available online afforded time during class for student-centred content-related discussions, group learning activities, practice time, and assessments. This means that the class design was aligned with the tenets of the Flipped Learning Network’s (2014) description of flipped learning, which may emerge within a flipped classroom. Classes typically consisted of approximately 80 minutes of teacher facilitated discussions and/or group learning activities and 80 minutes of time for completing assignments. This means that classes were facilitated by the teacher, who decided on which activities to initiate based on their interpretation of student needs.

An example of an open ended group learning activity problem facilitated by the teacher during the course is the National Council of Teachers of Mathematics (2008) Barbie Bungee Activity. During this activity, students were asked to find the maximum number of rubber bands required to allow a Barbie doll to ‘bungee jump’ from a certain height without hitting her head. Students, in random groups, were given rubber bands and a doll and were asked to make the prediction for the number of rubber bands required. Eventually, through discussion, students noted the linear relationship between the number of rubber bands and the measure of the doll’s descent. This led to further discussion on linear equations and slopes.

Another instance of an activity facilitated during the course is that of student-generated examples2. This is not referring to Watson and Mason’s (2005, 2002) concept development approach to learner-generated examples, but rather the opportunity for students to generate examples for purposes of involvement in the learning process. One instance of a student-generated example activity is when students were provided with a collection of 3-dimensional geometric objects and were asked to build a new object composed of two or more smaller objects. They were then asked to give their new composite object to another group to find the surface area and the volume of the given composite structure. This activity led to some interesting discussion and even a Google search regarding the surface area of a cone because it was not provided in the course textbook. Yet another case of a student-generated example activity is when students were asked to use whiteboards to develop exponential expressions

1 Videos can be viewed by visiting Judy Larsen’s YouTube Channel.
2 Student-generated examples are used colloquially here in the sense that students were asked to generate examples for the purposes of assessment or engagement and not in the more defined sense that Watson & Mason (2005, 2002) indicate in respect to constructive concept development.
that needed simplification. They were then asked to pass their problems to another group for simplification. Interesting examples arose from such activities. One example in particular was that of a student who created a complicated exponential expression, but created it so that the entire expression was taken to the power of zero indicating that the student understood the implication of a power of zero (See Figure 1 below).

![Figure 1. Student generated example 1.](image)

Other group learning activities consisted of group concept review sessions. For example, students used whiteboards to develop reasoning for why certain properties exist, such as the rules for simplifying exponential expressions. Products from review sessions were often documented with a camera and posted on the course website to help provide study materials for students in preparing for tests.

Equally important to the choice of activities in the promotion of engagement and understanding was the method of grouping students so that they would productively collaborate. Liljedahl (2014) asserts that visibly random groups lead to positive observable changes such as “an elimination of social barriers, [an increase in] mobility of knowledge between students, [a decrease in] reliance on the teacher for answers, [and an increase in] engagement” (p. 130). During the first half of the term, students were always grouped together randomly to increase the likelihood of students working with as many other students as possible in alignment with Liljedahl’s (2014) suggestions for student grouping. Eventually, students found their favourite peers to work with and they settled into preferred groups.

Anything that contributed to a student’s final grade (assignments and tests), with a few exceptions, was completed and submitted during class time. In essence, the in-class workload and the out-of-class workloads were swapped or flipped as compared to a traditional class. Most importantly, class time provided students with opportunities to engage with collaborative problem-based learning tasks, a facilitative teacher, and a variety of learning tools.

**Method**

The Math 084 flipped classroom outlined above was implemented during the Winter 2013 term. The course started with 25 total students enrolled, 18 of whom completed the course. It should be noted that low completion rates are very common in these courses and many students often stop showing up due to life circumstances. Out of the 18 students who completed the course, two were registered, but were completing the course at a distance, and therefore were not part of the flipped classroom experience. This leaves 16 students who experienced the flipped classroom throughout the entire term, 14 of whom gave consent to participate in the research study. All 14 of these students appeared to be in their twenties and were completing the course either to satisfy prerequisites towards career-driven programmes or to complete their high school diploma.
Data collected consisted of observational data, interviews, and surveys (including in-class surveys and follow-up email surveys). As researcher and instructor of the course, I collected observational data throughout the term in relation to classroom interaction, goal statements, self-efficacy, anxiety, etc. and tabulated each observation into an Excel spreadsheet document for analysis. Interview and survey data was collected by an external co-investigator during the term while I was away from the room in compliance with local research ethics requirements. After final grades were posted, I was given access to all data collected by the external co-investigator.

Analysis of data was performed according to the tenets of analytic induction, a qualitative method of analysis rooted in grounded theory. Much like in grounded theory, the inductive analyst recursively codes the data looking for themes to emerge; however, analytic induction allows for an a priori proposition or theory driven hypothesis to be used as a lens to deductively analyse the data in contrast to grounded theory, which begins inductively through open coding (Glaser & Strauss, 1967, cited in Patton, 2002). In this research study, the key a priori theory used in the deductive phase of the analysis was that of Stefanou et al.’s (2004) distinction between types of autonomy support. Other theories used in the analysis pertained to goals, self-efficacy, and anxiety in the context of mathematics education (Ashcraft, 2002; Bandura, 1997; Biggs, 1985; Dweck, 1986; Hannula, 2006; Jang et al., 2010; McLeod, 1992; Zimmerman, 2000).

Prior to the theory driven deductive phase of analysis, a preliminary analysis of data was performed to draw out data relevant to the goal of this research, which is to characterize student experiences in a flipped classroom. During this preliminary investigation, it quickly became evident that there were three levels of student interaction in the class. The class design provided students with a diversity of learning tools, and although most students utilized all learning tools during the first part of the term, they eventually gravitated towards certain learning tools as they pursued completion of the course. In particular, some students chose to utilize class time completely in order to gain better understanding of topics. These students willingly participated in all classroom activities. Others chose to focus more on out-of-class learning materials such as the online videos and the textbook. These students tended to attend less regularly or chose to opt out of activities offered during class time. There were also those who shifted between these types of interaction throughout the term.

For each of these three types of interaction, two participants whose actions were reflective of each of these types of interaction were carefully selected. This means that the six participants selected as cases consisted of two students who participated completely in both in-class and out-of-class components of the flipped classroom (Group 1), two students who at first participated completely with the flipped classroom model but later fell behind and chose only to participate in out-of-class components (Group 2), and two students who tried participating in the flipped classroom model completely, but quickly participated only in what was absolutely required in the course (Group 3). These cases are summarized in Table 1 below.

Table 1. 
Grouping of Cases

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Students who completely engaged in both in-class and out-of-class components.</th>
<th>Alexa (A) Kristy (A+)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 2</td>
<td>Students who at first engaged in both in-class and out-of-class components, but chose to opt out of class time activities near the end of the term.</td>
<td>Mark (A+) Ryan (A-)</td>
</tr>
<tr>
<td>Group 3</td>
<td>Students who tried engaging in both in-class and out-of-class components, but as soon as they could opt out of the activities, they did.</td>
<td>Lindsay (B+) Vanessa (A-)</td>
</tr>
</tbody>
</table>

Note. All names are pseudonyms to maintain anonymity.
These cases were reflective of the three types of interaction in the course because out of the 14 participants, five were categorized as Group 1, five were categorized as Group 2, and four were categorized as Group 3. Further, grades obtained by these cases were within the grade range obtained by the majority of the students in the class (11 out of 14 students attained a B+ or higher and no students completed the course with a grade lower than a B-).

The data related to these six participants was aggregated to form cases that reflected various student experiences in the course. Each case was then analysed and coded according to the key a priori theories of autonomy, goals, self-efficacy, and anxiety in the context of mathematics education. This case analysis was followed by a cross-case analysis that inductively derived common themes across the data. As previously noted, the scope of this paper has been limited to only factors of autonomy and goals in order to provide adequate depth and detail.

**Results**

Results are presented by providing sample case data from the study as well as a cross-case analysis of key factors that are of focus in this paper: autonomy and goals.

**Cases**

In what follows, three cases are briefly outlined to provide samples from each of the three groupings described in the previous section: Kristy (Group 1), Mark (Group 2), and Lindsay (Group 3). These are chosen for their strength in presenting key issues resulting from the study pertaining to autonomy and goals in a flipped classroom environment.

**Kristy**

Kristy was selected as a case in Group 1 because of her complete engagement in both in-class and out-of-class activities. She attained an A+ in the course and serves as an example of someone who experienced the flipped classroom to the fullest extent. Kristy attributed her success in the course to several factors including the ability to progress through lectures at her own pace, the time available to discuss concepts that were troubling during class, and the opportunity to teach others in the class. Although she was initially shy and nervous about being in the course due to her past negative experiences with mathematics, she soon found the learning environment comfortable and conducive to learning. She claimed in an initial survey that “up until this term, [she had] never liked mathematics and never grasped the concept.” She noted that in high school, she kept falling behind with notes, didn’t receive enough individual attention and was not shown things in a kinaesthetic manner, which resulted in poor achievement. Although she initially expressed concern about doing things the “right” way during classroom activities, she soon discovered that seeing multiple approaches is beneficial to understanding the concept. She summarized her engagement in classroom activities on the follow-up survey:

> Although I want to say that the at home lectures were the most valuable part of the class, the group activities played an equal role in how well I learned the mathematical concepts. Being forced (I use the term lightly) into group activities during class allowed me to get to know my classmates, which made me feel a lot more comfortable asking any questions I had. Secondly, the other ideas and approaches that students had towards problems allowed me to see different ways of understanding the questions and different techniques to use when finding an answer … The way I see it is, solving a problem is great, but being able to

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3 For complete case data, see Larsen (2013).
explain how the problem works means you truly understand it. I was almost testing myself by teaching others. It became another way of studying for me … I was beginning to “know” math. I was starting to truly understand the concepts because I was able to study as much as I needed to since the lectures were always available to me.

(Follow-up survey)

In addition to her in-class engagement, her out-of-class engagement was also notable. On a survey taken at the middle of the term, she responded that outside of class time, she watched all of the videos (sometimes more than once) and took detailed notes from them. She also re-watched the videos if she was stuck on a concept, and if she couldn’t figure something out, she made note of it and moved on knowing that she could ask about it during the next class. She made decisions about how much practice she needed to complete on each section claiming on a survey during the middle of the course, “If I feel strong on a concept I don’t do all the examples and if I feel weak I do more than the given” (Week 8 survey). She showed appreciation for the videos on the follow-up survey:

Having the lectures in video form allowed me to study them at my own pace and take notes a lot more accurately. The option of being able to pause or rewind the video instead of asking the instructor to stop or repeat was great as well since it does not stop anyone else’s learning process.

(Follow-up survey)

During an interview, Kristy noted, “I feel like I’m walking out of the classroom knowing something. I’m not just wasting my time trying to get a letter grade, I’m actually taking something away from the class too” (Week 3 interview). By attending almost every class, participating completely in all in-class tasks, leading group discussions, and working on material at home frequently, she was able to develop a new interest in mathematics.

In summary, Kristy participated completely in all components of the flipped classroom throughout the entire term. However, she may not have been as successful in the flipped classroom environment had there not been initial organizational structure and continued cognitive autonomy support provided. She noted that she greatly appreciated being placed in random groups at the beginning of the course (an organizational structure) because otherwise she would have been too shy to communicate with others. At first, she was also uncomfortable with not knowing how her assignment was supposed to look, indicating a resistance towards procedural autonomy support. She also reacted negatively when I probed her to think on her own, indicating an aversion towards cognitive autonomy support. However, this quickly diffused as she participated in the course consistently and completely. Eventually, she came up with her own ways of solving problems and taught others comfortably, indicating that she found use in the cognitive autonomy support that was being provided as part of the classroom culture. Even though she entered the class wanting to satisfy prerequisites for a programme path, indicating a performance goal orientation, she managed to cultivate a learning goal orientation within the flipped classroom environment. Given that Kristy decided to continue in the course after finding out that she no longer needed the course as a prerequisite, the flipped classroom was a truly empowering experience for her.

Mark

Mark was selected as a case in Group 2 because he first engaged in both in-class and out-of-class components, but chose to opt out of class time activities near the end of the term when he wanted to get farther ahead with the material more efficiently. Mark attained an A+ in the course and showed complete interaction with the flipped classroom during the beginning of the term, but became more motivated to work individually after missing a few classes in the second part of the term due to a bad case of the flu. His favourite part about the flipped classroom model as stated on the follow-up survey was that he could “come to class with questions and actually get the questions answered instead of being stuck out of class time.” He also noted on this survey that he appreciated the freedom he had to learn content at his own pace and out of class time. From the beginning of the term, Mark showed inquisitiveness and engagement. He noted on his initial survey that he chose to take Math 084 “to get a better
understanding of Math” because he is “just fascinated by how it works.” Even though he completed Math 11 and 12 in high school eight years ago, he noted that he did not find it enjoyable at the time and he found that he had forgotten too much of it when he recently attempted to complete a first year calculus course. This informed his choice to take Math 084.

As mentioned, after a series of absences due to being sick in the latter part of the term, it was observed that Mark began to opt out of activities and worked on his own in the back of the classroom. During these times, he took the liberty to choose when to engage in the entire class and when to engage in his own work. He did this by looking up when something interesting was happening and looking down at his work when he felt he didn’t need to be paying attention. In a survey completed near the end of the term, he noted, “I used class time more for doing homework [as the term progressed] so that I could ask questions.” He clarified this later claiming, “Near the end of the term, the topics we were doing I was very familiar with and I wanted to get ahead on my homework so that I could go back and check and think of any questions I could ask before the final” (Follow-up survey). He was actively engaged in course content out of class time throughout the term and was able to develop his own method of studying for a test by taking questions from each section and making mock tests for himself.

To showcase Mark’s search for understanding, it is worthy to mention his classroom interactions during the first half of the term. First of all, Mark consistently asked questions that demonstrated his desire to test his own conjectures and search for generalisations. One example of such a question, noted in the observational data, was when he inquired about whether there existed a general method for finding the domain and range of any function after he determined the domain and range for a few rudimentary functions. Secondly, Mark was often observed attempting to complete activity problems in several different ways and working collaboratively with others, encouraging them to think in various ways. In his follow-up survey, he noted that his favourite type of activity was “one that allows you to come to the same solution but with multiple paths.” Based on my observations, he thrived within activity problems that were open-ended because he worked towards creating difficult scenarios in order to challenge himself. One example of this was when he created a very complicated three dimensional shape consisting of a cone nested within a cylinder with a half-sphere on top (See Figure 2 below). He then encouraged his group to figure out the volume and surface area of the shape. We hadn’t learned how to find the surface area of a cone, so it led the class to learn more than was expected. Combining several shapes also gave students the opportunity to learn how to alter formulas they had learned.

Mark was also interested in developing reasoning. In a survey during the early part of the term, Mark reflected on an activity that asked students to justify reasoning for various exponent rules on the whiteboards in groups. He claimed that the activity was “very helpful in
understanding the way rules for exponents work instead of just memorizing them” and that that is his “favourite way to learn things” (Week 3 survey).

In summary, Mark participated in all components of the flipped classroom until about two thirds of the way through the course, when he began to opt out of class time activities. Interestingly, Mark exhibited a learning goal orientation right from the beginning with his original intent for taking the course being to get a better understanding of mathematics. During the beginning of the course, he readily communicated with others and was intrigued by the activities, using all tools that were available to him. He participated in the classroom culture by proposing interesting ideas to others and helping them with their work. Based on the examples provided of his interactions in the problem solving activities, it is evident that Mark embraced cognitive autonomy support during the first part of the term. Additionally, his increasingly independent thinking and learning throughout the term contributed to his ability to make good use of the organizational and procedural autonomy support that became increasingly available. After being sick for a while and being away from class, he began to come to class without engaging in classroom activities. Due to his absences and low classroom involvement, I perceived his actions as that of someone who had fallen behind in his work and needed to catch up. However, Mark was actually moving ahead. He wanted to learn further material, engaging autonomously with it, so that he would know what to ask questions about. However, as the term neared completion, time constraints seemed to alter his goals. He began to participate less and less in the classroom activities, and although his goals were still predominantly of learning, he showed goals of performance in his expressions of concern around completing course requirements. Overall, Mark’s experiences with the course were very positive because even when he was sick and had to miss class, he was not greatly inconvenienced by it because of the accessibility of learning materials.

**Lindsay**

Lindsay was selected as a case in Group 3 because although she initially tried engaging in both in-class and out-of-class components, she soon opted out of class activities after falling behind with the material and realizing that the activities were not required towards course completion. Remarkably, even though it was noted that she was absent a lot during the last third of the term, she was able to complete the course with a B+ by watching the videos, completing examples from the videos, and completing assigned graded textbook problems. Although Lindsay engaged in the course in an individual manner, it proved to be more beneficial for her than another completely individually paced course she had previously taken because she had a greater variety of resources available. Lindsay also noted on the follow-up survey that although her primary goal with Math 084 was to get a good grade and complete her prerequisite requirements towards an animal health technician program, the flipped classroom environment was beneficial for her because it helped her learn how to ask questions and provided her with enough material out of class time to work through and catch up with when she fell behind.

Lindsay particularly enjoyed learning from the videos out of class time because she was able to “go through [each video] slowly and do the example questions one step at a time” (Week 8 survey). She also noted that she really appreciated the opportunity to “pause and rewind the video whenever” she needed to (Week 3 survey). At the end of the term, Lindsay wrote, “The ability to watch lessons at home and at [my] own pace was probably the thing I liked the most about the class” (Week 14 survey). On the Week 8 survey, she noted that she watched every video in great detail, took notes from the videos, and paused the videos in order to try the example questions on her own before proceeding with the video. She also claimed on this survey that she referred to textbook examples often and tested her understanding by completing the online quizzes. It was observed that when she didn’t understand a concept well, she gravitated towards re-watching the videos before asking any questions.

Lindsay tended to work individually and as a quiet observer during class time. She tried engaging in the group activities during the first third of the course, but always seemed
overwhelmed in the group setting. When in her proximity, she would often ask me probing questions seeking confirmation of the work her group was doing. During the latter part of the course, it was observed that Lindsay began to use class time even more individually. As the material became more difficult, Lindsay began to be absent more often. She soon fell behind with the material and began to treat the flipped classroom as a place to learn individually. During one set of consecutive absences, she emailed me explaining that she needed to stay home because she wanted more time to go over the videos and complete missing graded problems. It was evident that she was avoiding group work and desired to complete course requirements as efficiently as possible. This is evidenced in the following survey response:

One thing I didn’t really like was the amount of group work we had to do. Sometimes it was helpful but sometimes it seemed to complicate things … [As the term progressed], I used class time to hand in work, work on graded problems and do tests. I [made] sure when I [got] stuck on something to ask for help.

(Week 14 survey)

However, on a survey taken during the middle of the term she wrote, “This class has helped me realize that asking for help more when I need it is OK” (Week 8 survey). During the latter part of the term, she watched the videos in great detail and then came to class to clarify concepts that she struggled with. I observed that most of her clarifications pertained to implementation strategies of the various procedures outlined in the videos and used in the textbook. These clarifications were very important for her.

In summary, although Lindsay tried to engage in all components of the flipped classroom, she quickly began to avoid components that expected her to adopt cognitive autonomy support. Upon entering the class, Lindsay held a strong performance goal orientation with her main reason for engaging in the class being to satisfy a career prerequisite. The organizational structure of requiring students to work in random groups at the beginning of the term allowed her to experience a classroom culture of learning. However, during the times when she was asked to work with others, she tended to observe the others in the group rather than initiate discussion. She seemed to resist cognitive autonomy support within problem solving opportunities and often became confused by other students’ approaches to solving problems. This was at times frustrating for her and it may have interfered with her performance goal orientation because it compromised the efficiency of learning the material. As soon as more organizational and procedural autonomy support was available, she chose to focus on the videos as her main learning tool and was grateful for their accessibility. When she was behind with the material, she did not feel adequately prepared to participate in group activities, causing her to avoid class time. Although she missed a lot of class time in the second half of the course, she was able to complete the course successfully due to the availability of the online videos. The flipped classroom seemed to be beneficial for her because as she noted, it helped her learn how to ask questions.

Cross-case analysis

The aggregated case data and case by case analyses of all six cases in the study evidenced a bifurcation in how participants experienced the flipped classroom during the second part of the term once students became accustomed to the class structure. A cross-case analysis clarifies that the bifurcation was made possible, in part, by the autonomy support provided in the structure of the Math 084 flipped classroom’s learning environment. Student goals were interrelated with the bifurcation, and attendance surfaced as an emergent theme. These results are overviewed in the subsequent paragraphs.

Autonomy

The flipped classroom, as implemented in this study, offered students an opportunity for autonomy by allowing them to engage in a variety of components: learning activities,
classroom community, and accessible learning materials. Most importantly, cognitive autonomy support was provided during class. This can be seen in Alexa’s survey response:

If I was confused about anything, we would explain everything in great detail and have debates about it … I learned different ways to solve problems during the activities and others learned from me. This was fantastic.

(Follow-up survey)

At first, all students participated in all components of the class when procedural and organizational structure was provided in an autonomously supportive way, through the use of random groups, due dates, specified assignment submission procedures, etc. As the term progressed, more autonomy support was provided over procedural and organizational dimensions in the class. Simultaneously, a bifurcation of student experiences occurred. In particular, election of cognitive autonomy support began to change.

Figure 3 below serves as a subjective visual representation of students’ expressed desires for either high cognitive autonomy, occasional cognitive autonomy, or no cognitive autonomy as coded from the case data in relation to the time in the term.

![Figure 3. Cognitive autonomy over term.](image)

When procedural and organizational autonomy support was provided during the latter half of the term, students split into those engaging in the flipped classroom completely and those interacting with it in a more or less self-paced manner by either opting out of classroom activities or choosing to not attend class.

Falling behind seemed highly associated with absence. Some students fell behind because of external factors which influenced absences (Mark and Ryan), while others chose to be absent because of internal factors such as falling behind (Lindsay). Falling behind can be extremely frustrating and can lead adults to withdraw from a course (McAlister, 1998). In the flipped classroom outlined in this study, procedural and organizational autonomy allowed self-pacing to be a management skill, a sort of coping mechanism for falling behind. Remarkably, students who fell behind were able to catch up through the use of the video resources that were provided as part of the flipped classroom. Had these students not been able to access content delivery materials out of class time, they may have not been able to complete the course with so many absences, which could have led to withdrawal or failure.

**Attendance**

Some students downgraded to the self-paced mode of interaction after a series of absences because they had to catch up with the material that they fell behind with. Mark and Ryan encountered uncontrollable challenges in their lives that caused them to be absent due to external factors, altering their interactions in the class, while Lindsay chose to be absent due to internal factors related to her choice of interaction with the class. In particular, Mark
missed several classes due to illness. After this period of absence, he began to work individually. At first, he used the self-paced mode of study to catch up with material he missed, but then he continued to use it in order to move ahead of schedule. Similarly, Ryan missed several classes due to a funeral, and then an English paper that took more precedence for him. After these periods of absence, Ryan used his class time in a self-paced manner in order to catch up with the material. He did not return to engaging in the complete class experience. Lindsay was also absent a lot. However, unlike the others, there was no significant external reason for her absence. She noted that she was absent when she was too far behind to participate in class activities. Absence seemed more like a coping mechanism for her.

**Goals**

Finally, the bifurcation into two key types of learning experience may be more prominently attributed to a variety in student goal orientations. Students who engaged in all components of the class (Alexa, Kristy, and Mark) tended to exhibit learning goal orientations. Whereas students who treated the class in a self-paced manner (Ryan, Lindsay, and Vanessa) by opting out of the more collaborative class components, tended to portray performance goal orientations. Those with strong performance goal orientations evidenced a focus on efficiency in completing the course requirements. For example, Ryan agreed on the follow-up survey that he tended to avoid coming to class when he was behind because he “felt [he] could use [his] time more effectively outside of class, rather than covering more material [that he] would not understand.” In contrast, Alexa and Kristy pursued learning activities regardless of whether they contributed to their grade of not.

**Summary of analyses**

Essentially, the students who engaged in the complete flipped classroom as presented in this paper were taking advantage of the collaborative elements of the class that provided them with cognitive autonomy support, primarily within the problem solving learning activities. These students held strong learning goal orientations. Meanwhile, the students who experienced the classroom in a self-paced manner focused on less collaborative components of the classroom where they could work individually and efficiently in an effort to satisfy their performance goal orientations. These students also tended towards embracing cognitive structure rather than cognitive autonomy support. The bifurcation of student experiences in the class occurred halfway through the term when procedural and organizational autonomy support was more prominent. Students tended to opt-out of attending class or participating in group activities during this time if they were so inclined. It is interesting to note that once students downgraded to using the course in a self-paced manner, they did not return to using the elements of the course completely. However, what is most important is that all of the cases were able to successfully complete the course with a final grade of B+ or higher regardless of the manner in which they chose to experience the course. A visual summary of these analyses is provided in Table 2 below.

<table>
<thead>
<tr>
<th>Table 2.</th>
<th>Summary of Analyses of Components by Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive Autonomy Support</td>
<td>Alexa</td>
</tr>
<tr>
<td>Attendance</td>
<td>●</td>
</tr>
<tr>
<td>Learning Goal Orientation</td>
<td>●</td>
</tr>
<tr>
<td>Performance Goal Orientation</td>
<td>●</td>
</tr>
</tbody>
</table>

● high
○ occasional
◆ low
Complete
Incomplete
Flipped Classroom
Self-Paced Classroom
Conclusions

The main intent of this research is to describe how students can experience a flipped classroom that is designed to promote flipped learning (The Flipped Network, 2014) and a transactional student-centred learning environment (Elen et al., 2007). Although the flipped classroom in this study afforded the capacity for a collaborative student-centred learning environment where the teacher was guided by student learning needs, it also provided students with an autonomous opportunity to choose ways in which they could interact in the class. In summary, students in the adult mathematics upgrading course Math 084 bifurcated into experiencing the flipped classroom in one of two ways: the complete flipped classroom and the self-paced option that the flipped classroom afforded.

Students who experienced the complete flipped classroom tended to exhibit strong learning goal orientations and engaged themselves autonomously in the collaborative learning tasks provided, the facilitative role of the teacher, and the social culture of learning in the classroom community. These students had more consistent class attendance and were less swayed by changes in organizational and procedural structure than their self-paced counterparts. On the contrary, students who experienced the flipped classroom as more of a self-paced classroom tended to exhibit strong performance goal orientations, often resisting cognitive autonomy support in an effort to maintain efficiency in completing tasks, and did not embrace engagement in collaborative learning opportunities.

Interestingly, this bifurcation of student interaction coincided with the increase in provision of procedural and organizational autonomy support in the latter half of the term during which class times were less structured procedurally and organizationally. As more organizational and procedural autonomy support was provided, self-paced performance oriented students tended to focus on completing the minimum requirements of the course. The bifurcation of student experiences also coincided with increasing student absences. Once students fell behind in the material or experienced a series of absences, they typically resorted to treating the course in a self-paced manner, an interaction that they continued until the completion of the term. It should be noted, however, that these students may have easily dropped out of the course had they not been provided with an extensive set of resources to help them complete the course as many adult students do when they fall behind in course material (McAllister, 1998).

Both the complete flipped classroom and the self-paced option that the flipped classroom afforded were highly student-centred and allowed students to pursue their goals orientations in the context of the course, regardless of their nature. Some students evidenced a shift in goal orientation from performance oriented to learning oriented, likely due to the contagious nature of engagement during collaborative problem based activities, but others did not exhibit this shift. Hence, it is important to note that although it is desirable for students to pursue goals of learning, it is not always what they desire. This speaks to the ever-present tension between student and teacher goals. It is also a good reminder of the fact that a goal cannot be forced onto anyone. Instead, the goal can be encouraged and nurtured through providing opportunities for developing deeper understanding if a student so desires. This is the essence of a student-centred learning environment.

The flipped classroom in this study provided students with an invitation to pursue goals of learning without forcing it to be the only option. Students could still complete the course and satisfy the prerequisites they needed by interacting in a self-paced manner, but more importantly, those who became interested in developing deeper meaning in mathematics were given the opportunity to do so through the collaborative nature of the classroom learning environment. Cognitive autonomy support in particular served as a determining factor in classroom interaction. This research supports the premise of Jang et al.’s (2010) theory that classrooms conducive to engagement give both structure and autonomy. In particular, organizational and procedural dimensions should be structured, while the cognitive dimension should be provided with autonomy support in order to promote student engagement in
opportunities for collaboration with peers during meaningful classroom activities. Therefore, the main result of this research is that it affirms that cognitive autonomy support is an essential ingredient in promoting student engagement in learning opportunities.

**Implications**

The most important implication of this research for the adult mathematics education community is that it is an illustration of a learning environment that is conducive to providing adult students opportunities for pursuing goals of learning while maintaining accessibility of prerequisite completion through self-paced options. Although this study was conducted as a small scale exploration of six case studies in one particular implementation of the flipped classroom, it provides a basis for future research opportunities.

Future studies may want to look at exactly how each of the two ways of interaction in a flipped classroom (complete and self-paced) affect student understanding of the material in comparison to each other and in comparison to a control group that is not taught according to a flipped classroom model. Student achievement in a flipped classroom could also be studied further. All participants in this study who completed the course did so with a B- or higher. This leaves room for investigation of whether the flipped classroom in general pushes students into either succeeding in the course or dropping out of the course, or if it was just an instance that occurred within this small scale study.

Finally, a flipped classroom is merely a mindset with no clear method of implementation. Further implementation approaches could be explored. For example, content delivery videos could be used as content review rather than content preview. Class time could be treated in a more structured manner. Assessment strategies such as standards based grading could be also be explored. There are many opportunities for exploration of various approaches to flipped classroom implementation. That is the beauty of the flipped classroom model: it provides a mode by which teachers can accomplish their goals of evolving a student-centred learning environment without compromising the delivery of the curriculum.

**Acknowledgments**

Primarily, I’d like to thank Dr. Peter Liljedahl for valuable collaboration in this study. I’d also like to thank the anonymous reviewers for their helpful comments.

**References**


Adult Learners and Mathematics Learning Support

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Abstract
The provision of some level of Mathematics Learning Support (MLS) is now standard in the majority of Higher Education Institutions in Ireland, the UK, and in many other countries. This provision is, in part, a response to the large numbers of students entering Higher Education who do not have the mathematical skills required and this cohort includes a significant number of adult learners. Research indicates that these students have different motivations and approaches to learning than traditional age learners. This paper considers the analysis of a large scale student evaluation of Mathematics Learning Support in Ireland. In particular, it presents the responses and engagement levels of adult learners and compares these to those of traditional students. The findings are key to ensuring best practice in the provision of MLS for the wide variety of students who engage with it.

Keywords: adult learners, engagement, evaluation, mathematics learning support

Introduction
The availability of some form of Mathematics Learning Support (MLS) is now what students can expect to find in the majority of Higher Education Institutions (HEIs) in Ireland and the UK. MLS is also available in HEIs internationally, for example in Switzerland, Canada and Australia (Gill et al., 2008; Perkin et al., 2012). MLS has been defined as a facility offered to students which is surplus to their traditional lectures and tutorials, the purpose of which is to
offer non-judgemental and non-threatening one-to-one support with mathematics (Ní Fhloinn, 2007; Lawson et al., 2003; Elliot and Johnson, 1994).

The main reason for the establishment and significant growth of MLS was to tackle the well documented ‘Mathematics Problem’. One of the ways O’Donoghue (2004) defines the ‘Mathematics Problem’ refers to the mathematical preparedness of incoming students in terms of their mathematical shortcomings or deficiencies at the university interface. Significant numbers of students entering HEIs are deemed at-risk of failing or dropping out because they do not appear to be appropriately prepared for mathematics in HE and often exhibit very weak mathematical backgrounds. This ‘Mathematics Problem’ is common place in HEIs in Ireland, the UK and internationally (Gill et al., 2010; Lawson et al., 2012). These at-risk students are the main target of MLS.

One benefit of the economic downturn has been the welcome increase in adult learners returning to HE (Golding and O’Donoghue, 2005). In the Dublin Institute of Technology (DIT), adult learners constituted one fifth of the attendants at the Mathematics Learning Support Centre (MLSC) in its opening year (Ní Fhloinn, 2007). In 2012 adult learners accounted for 15.3% of full time students enrolled in HE in Ireland and 21% of full and part time students. Faulkner et al. (2010) stated that the presence of so many adult learners is one contributing factor to the increased numbers of at-risk students in first year courses.

In order to establish best practice in the successful provision of MLS, it is essential that it is comprehensively evaluated on a regular basis (Matthews et al., 2012). For example, quantitative research suggests that appropriate engagement with MLS can have a positive impact on student retention and progression (Lee et al., 2008; Mac an Bhaird et al., 2009). One of the initial aims of the Irish Mathematics Learning Support Network (IMLSN), which was established in 2009, was to conduct a large scale survey of student opinion on MLS. A full report on this survey was published in November 2014, and is available from http://epistem.ie/wp-content/uploads/2015/04/IMLSN-Report-16102014Final.pdf. There is some overlap between the final report and results presented in this paper (submitted June 2014).

Given the increasing proportion of adult learners in mathematics in first year courses, it was considered key that they should be identifiable in the survey so that their responses regarding the evaluation of MLS could be studied in detail. A chi-square test for independence carried out on the data collected indicated a statistically significant association existed between type of student (i.e. adult learners or traditional learners) and whether a student used MLS (p<0.001), thus demonstrating that adult learners were more likely to seek support than traditional age learners. Further investigation however demonstrated that 38% of the adult learners surveyed never accessed MLS in their institutions. The authors decided to investigate the underlying reasons behind these findings further.

The main research questions we are trying to address are:

1. What are the motivational factors of adult learners who seek MLS?
2. Why do some adult learners of mathematics not seek MLS?

**Literature review**

There is a concern that a lack of preparation in mathematics can lead to increased failure rates and low self esteem (Symonds et al., 2007) in HEIs. Aligned with that is a worry of impeding students in the study of other disciplines, e.g. engineering, science (Pell and Croft, 2008; Gill, 2006). Many students arrive in their HEI having chosen mathematics-intensive courses unbeknownst to themselves (FitzSimons and Godden, 2000). Most degree programmes, even non-specialist mathematics degrees, contain some mathematics and/or statistics component, as prospective employers require graduates to be proficient in mathematics, with some even setting numeracy tests as part of their selection process (Lawson et al., 2003). The mismatch
between the knowledge of many students and the expectations of HEI teachers is one contributory factor to the problem and this mismatch arises partly through the increase in diversity of the backgrounds of students (Lawson et al., 2003; Faulkner et al., 2010). Diversity in the standards of teaching and class size in HEIs tend to exacerbate the situation (Lawson et al., 2003; Gill, 2006).

One of the key responses to the ‘Mathematics Problem’ was the opening of Mathematics Learning Support Centres (MLSCs) to attempt to deal with the mathematical shortcomings of students (Pell and Croft, 2008; Gill, 2006). In 2004 in the UK it was reported that 62.3% of 106 surveyed universities offered some form of MLS (Pell and Croft, 2008, p. 168). In 2012, this number had jumped to 85% (Perkin et al., 2012). In 2008, an audit carried out by the Regional Centre for Excellence in Mathematics Teaching and Learning (CEMTL) in Ireland demonstrated that 13 out of 20 HEIs provided MLS in some form (Gill et al., 2008). Seven years later, it is believed that this number is much higher. Most MLSCs are committed to servicing the needs of traditional and non-traditional (i.e. international and adult learners) students (Ni Fhloinn, 2007; Gill and O’Donoghue 2006). Carmody and Wood (2005) reported on the benefits of a drop-in MLSC for easing the transition to HE for first-year students. The drop-in centre caters for students from all faculties and has become a meeting place for collaborative learning. Tutors use a variety of teaching methods and resources, which is easier to do in a one-to-one situation than in front of a large class. Engagement with MLS has been shown (through mostly quantitative research) to impact positively on mathematics performance and grades and retention (Burke et al., 2012; Mac an Bhaird et al., 2009; Pell and Croft, 2008; Symonds et al., 2007). Pell and Croft (2008) state that while MLS is provided first and foremost for ‘at-risk’ students, it is more often the case that users tend to be high achievers working to attain high grades, a view supported by Mac an Bhaird et al. (2009) who have also shown that many ‘at-risk’ students still do not engage with MLS.

An Adult Learner, or Mature Student, is classified in the Republic of Ireland as a student that is 23 years of age or older on 1st January of the year of registration to HE (Ni Fhloinn, 2007). Entry for adult learners who have not got the minimum requirement for entry to their chosen course of study is usually gained via interview and is based on a number of factors including life experience and motivation, in addition to prior qualifications. Faulkner et al. (2010) studied the student profile in service mathematics programmes at the University of Limerick (UL) since diagnostic testing began there in 1997. The increase in adult learners of mathematics in these modules was quite pronounced. In 1997 there was one registered in Science and Technology Mathematics, two of the biggest service mathematics modules provided by this university; in 2008, there were at least 55 adult learners. This statistic is supported by Gill (2010) who states that in 2009/10, adult learners in UL constituted 14% of the entire cohort, an increase of 49% on the previous year. In 1997, 30% of students in one service mathematics modules at UL were deemed to be at-risk. Fast forward to 2014 and 66% of students in the same module are categorised as at-risk.

Adult learners of mathematics who return to education constitute a heterogeneous cohort. For example, participants on the ‘Head Start Maths’ bridging programme at UL range from 23 to over 45 years of age. A significant number of the students on the programme in 2008 had not studied mathematics in any formal sense for up to 20 years and 30% of participants had not taken the Leaving Certificate (LC) examination (Gill, 2010). The LC is the terminal examination taken by pupils at the end of secondary school in Ireland. Mathematics is compulsory for students and can be taken at three levels: Higher (HL), Ordinary (OL) and Foundation (FL). In DIT, Ni Fhloinn (2007) outlines how adult learners fall into the full-time, part-time or apprenticeship categories, with each type of student presenting with different characteristics and issues relating to their preparation, their approach to learning mathematics and confidence issues. It can be very difficult for students to catch up with forgotten fundamentals and keep up with current studies simultaneously (Gill, 2010; Lawson et al., 2003).
Diez-Palomar et al. (2005) and O’Donoghue (2000) acknowledge the difference between adult learners of mathematics and traditional learners. Adult learners carry with them an abundance of experiences that need to be considered in pedagogical practices. This view is supported by Tusting and Barton (2003) who add that adult learners have different motivations for studying than traditional learners and are more inclined to be autonomous and reflective learners. The decision to return to education has generally been their own decision and a deliberate one (FitzSimons and Godden, 2000). Though adult learners may lack confidence in their own abilities, they tend to be highly motivated (Ní Fhloinn, 2007; FitzSimons and Godden, 2000). Traditional lectures and assessments are not conducive to learning for many adult learners (Gordon, 1993 cited in FitzSimons and Godden, 2000) so many rely on MLSCs for support. In 2009/10 adult learners of mathematics at UL constituted 54% of the attendance at the drop in centre, even though they represented just 14% of the entire student population (Gill, 2010).

While the importance of research in the teaching and learning of mathematics among adult learners has been duly recognised in recent years (Coben, 2003) it remains an ‘under theorised and under researched’ area (Galligan and Taylor, 2008, p. 99). Furthermore, research conducted on the teaching and learning within MLSCs is sparse (Galligan and Taylor, 2008).

Methodology

The IMLSN was established in 2009, and its guiding principles are similar, on a smaller scale, to the leading experts in the provision of MLS, the sigma (The Centre of Excellence in Mathematics and Statistics Support) network (http://sigma-network.ac.uk/) based in England and Wales. The IMLSN aims to support individuals and HEIs involved in the provision of MLS in Ireland. Once set up, the network decided it should promote the benefits of MLS to both staff and students on an institutional, national and international basis and agreed that a student survey was the best approach initially. The IMLSN asked the panel of researchers listed on this paper to undertake this student survey.

Student questionnaires are commonly used in the evaluation of MLS services (Lawson et al., 2003) in individual HEIs, so it was decided to create a student survey that could be used in all HEIs which provide MLS. HEIs who already distributed questionnaires on MLS were invited to submit them to the committee; these were amalgamated and a communal questionnaire was formed as a result. This questionnaire was piloted in 4 HEIs with 100 students and subsequently refined based on analysis of the findings and expert statistical advice.

The resulting questionnaire (See Appendix I) had 17 questions, a combination of open questions and questions which required a response on a 5-point Likert scale. There were three main sections: Section A determined the students’ backgrounds; Section B focused on users of MLS; and Section C focused on non-users of MLS. First year service mathematics classes have the largest percentage of at-risk students and are the main target of MLS in terms of student retention and progression, so it was decided to issue the questionnaire to these cohorts only. Service mathematics refers to users of mathematics (e.g. engineering, science, business), rather than mathematics specialists (e.g. pure or applied mathematicians) (Burke et al., 2012). Evaluation sheets are usually distributed within MLSCs but this can lead to bias as users already rate the MLSC to some extent if they attend it (Lawson et al., 2003). With this in mind, it was decided that the questionnaire should be issued in mathematics lectures to get a blend of user and non-user feedback and to reduce bias. The questionnaires were anonymous and there were no identifying characteristics. The questionnaire was issued to members of staff involved in the provision of MLS in HEIs in Ireland and they were asked to distribute paper copies in first year service mathematics lectures during the second semester of the 2010-11 academic year.
The HEIs surveyed were Universities and Institutes of Technology (IoTs), and these have different and complementary roles and missions within HE in Ireland. At undergraduate level Universities focus on Level 8 (Honours Degree programmes), and IoTs emphasise career-focused HE offering Level 8 programmes but also Level 7 (Ordinary Degrees) and Level 6 (Higher Certificates) programmes. IoTs also have a larger proportion of adult learners and students from disadvantaged areas and are stronger than the Universities in part-time and flexible provision (http://www.hea.ie/en/node/981). In the IoTs that participated in the survey, the ratio of Level 8: 7: 6 students was 49:39:12% which is similar to the 53:38:9% proportion of Level 8: 7: 6 students in IoTs nationally in the 2011-12 academic year. There are 7 universities and 13 IOTs in the Republic of Ireland. All institutions were invited to take part in the study by contributing their current evaluation methods and/or distributing the resulting survey to their students. 5 universities and 4 IOTs volunteered to take part, culminating in 1633 responses, 13.5% of whom were adult learners.

Two graduate students were hired to input the data into SPSS, and SPSS was also used to analyse the quantitative data. NVivo was used to analyse the qualitative data. A general inductive approach was used to analyse the data guided by the specific research questions (Thomas, 2003). Data was read and analysed by two researchers independently, one from this panel of researchers and an external person to identify emerging themes. Further details on the analysis to date for all respondents (traditional students and adult learners combined) can be found in (Mac an Bhaird et al., 2013 and Ní Fhloinn et al., 2014).

Results

In Section A of the survey questions were asked which focused on students’ backgrounds. Of the 1633 respondents, there were 221 (13.5%) adult learners, 73% of these were male and 91% were full-time students. In terms of students’ mathematical background, they were given the 4 options outlined in Table 1. Generally, a minimum of OL mathematics would be needed for most service mathematics courses in HEIs and this is reflected among respondents (18 of the 1546 students who provided their LC results in the survey had studied mathematics at FL). If they had not taken the LC, then they could select the Other option.

Table 1.

<table>
<thead>
<tr>
<th></th>
<th>Higher Level LC</th>
<th>Ordinary Level LC</th>
<th>Foundation Level LC</th>
<th>Other/N/A</th>
<th>Missing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Learners</td>
<td>37.1% (516)</td>
<td>60.7% (843)</td>
<td>0.6% (9)</td>
<td>0.9% (12)</td>
<td>0.6% (9)</td>
<td>1389 *</td>
</tr>
<tr>
<td>Adult Learners</td>
<td>9% (20)</td>
<td>67.4% (149)</td>
<td>4.1% (9)</td>
<td>14.1% (31)</td>
<td>5.4% (12)</td>
<td>221</td>
</tr>
</tbody>
</table>

*Out of 1633 responses, 1389 identified themselves as not being adult learners, 1 was an exchange student and 22 did not tick any box.

A lower percentage of adult learners (than of the traditional learner respondents) had taken HL, and higher percentages (compared with the traditional age students) in the remaining three categories, with the majority studying mathematics at OL.

When the breakdown of the disciplines that students were in was considered, we found, for most discipline areas, the proportion of adult learners was in line with the proportions of the traditional learner respondents, see Table 2.
Table 2.  
**Degree Programmes of Adult Learners and of Overall Survey Respondents**  

<table>
<thead>
<tr>
<th>Subject</th>
<th>No. of Adult Learners</th>
<th>%</th>
<th>No. of Traditional Learners</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>80</td>
<td>36.2</td>
<td>494</td>
<td>35.6</td>
</tr>
<tr>
<td>Engineering</td>
<td>50</td>
<td>22.6</td>
<td>183</td>
<td>13.2</td>
</tr>
<tr>
<td>Business</td>
<td>55</td>
<td>24.9</td>
<td>418</td>
<td>30.1</td>
</tr>
<tr>
<td>Arts</td>
<td>7</td>
<td>3.2</td>
<td>58</td>
<td>4.2</td>
</tr>
<tr>
<td>Education</td>
<td>6</td>
<td>2.7</td>
<td>83</td>
<td>6</td>
</tr>
<tr>
<td>Computing</td>
<td>23</td>
<td>10.4</td>
<td>148</td>
<td>10.7</td>
</tr>
<tr>
<td>Health Sciences</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>221</strong></td>
<td><strong>100.0</strong></td>
<td><strong>1388</strong>*</td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

*1 exchange student and 12 missing data

Section B of the questionnaire focused on MLS users. The majority of adult learners 136 (61.5%) availed of MLS, compared to only 32.2% of traditional learners. A Chi-Square Test for independence indicated a statistically significant association exists (p<0.001) between type of student (i.e. Adult or traditional learner) and whether a student uses MLS: adult learners were more likely to seek MLS than traditional learners. In terms of gender 68.3% of female adult learners compared to 43% of female traditional learners used MLS, and 59.4% of male adult learners in comparison to 23.3% of male traditional learners availed of MLS.

The mathematical backgrounds of both users and non-users of MLS among the adult learner sample were very similar, and the percentage breakdown was close to that of the adult learner population (See Table 1). When we considered subject discipline, the proportions of adult learners using MLS was very similar to the proportions of overall adult learners in each subject discipline (See Table 2).

Students who availed of MLS were asked, in an open-ended question, to comment on why they first decided to use MLS. There were 577 comments from attendees which were coded using GIA and the majority fell into 6 main categories as outlined in Table 3. This table contains comments from 122 of the 136 adult learners who responded.

A comparison of the frequency of responses in each category given by adult learners compared with traditional learners provides some interesting differences. The frequency of responses from adult learners showed they are much more likely to make comments indicating that they:

- look for help as they have a long time away or suggesting poor confidence in their mathematical ability (19.67% as against 3.96% for traditional learners),
- seek general extra help (38.52% as against 15.17% for traditional learners),
- are struggling (9.02% as against 3.74% for traditional learners).
Table 3

Frequency of Adult Learner Reasons for Using MLS

<table>
<thead>
<tr>
<th>Categories of comments</th>
<th>Frequency of comments (n=122)</th>
<th>Sample comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra help</td>
<td>38.52%</td>
<td>“Needed help with maths”, “I had gone to the tutorials and still had trouble with a particular area”, “I wanted help with a Mathematics Problem and to understand where I was going wrong”, “Because the pace of the main lectures were too fast and I wasn’t keeping up”, “I had to catch up on missed lectures”</td>
</tr>
<tr>
<td>Background/Ability: Comment about being away from Maths for a while prior to entry (from mature students) or comment suggesting poor confidence in maths ability</td>
<td>19.67%</td>
<td>“Hadn’t done maths in ages so I needed extra help”, “Because I haven’t studied maths in ten years and really felt quite daunted by the thoughts of returning to study maths”, “Coming back to study after a long break, needed all the help at hand!”, “Because I am not great at maths”</td>
</tr>
<tr>
<td>Assignments/Exams: Looking for help with specific aspect of coursework assessment during the semester (upcoming test, assignment) or attending for revision or preparation for end of term examinations</td>
<td>13.93%</td>
<td>“Struggling with maths assignments”, “I was stuck on understanding a part of an assignment and was spending a lot of time trying to figure it out”, “To help with revision”</td>
</tr>
<tr>
<td>Struggling</td>
<td>11.48%</td>
<td>“I was struggling with the subject”, “Was lost with maths”</td>
</tr>
<tr>
<td>Improve Understanding: Positive comments about attending to try to improve or gain better understanding</td>
<td>5.74%</td>
<td>“Because I thought it will be a great idea to use drop-in clinic if I want to get good grades”</td>
</tr>
</tbody>
</table>

In contrast, the frequency of responses from adult learners shows they are much less likely to make comments indicating that they:

- seek help specifically to get assistance with particular coursework assessment or revision for tests (13.93% as against 47.47% for traditional learners)
- attend MLS to improve or gain better understanding (5.74% as against 18.24% for traditional learners).
- state they find mathematics difficult (2.46% as against 11.43% for traditional learners).

MLS users were asked to rate, on a 5-point Likert scale, the specific services available in their HEI and they were also given the opportunity to comment. The main support offered was a drop-in centre, so we focus on that support in this paper. The distribution of ratings and responses from adult learners for the other services (e.g. ICT supports, workshops, support tutorials) are in line with that of the overall cohort.

All nine HEIs had a drop-in centre and 519 users rated them. 119 were adult learners and 89% of these rate it as worthwhile. There were 244 additional comments, 57 from adult learners and coding of responses placed them into the following three main categories (Table 4):
Table 4. *Adult Learner Rating of MLS Services*

<table>
<thead>
<tr>
<th>Categories of comments</th>
<th>Frequency of comments (n=57)</th>
<th>Sample comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfaction with service</td>
<td>38.5%</td>
<td>“Very helpful – I am even starting to enjoy maths now”, “Would not have a clue what I was doing if it was not for support”</td>
</tr>
<tr>
<td>Physical Resources</td>
<td>40.4%</td>
<td>“Class size was small for the amount of students”, “If there were more opening hours and people available as it is very busy”, “Sometimes a long waiting time; too busy”</td>
</tr>
<tr>
<td>Quality of Tutors</td>
<td>17.3%</td>
<td>“Always as helpful as they can be with the exception of one of the tutors who tends to be very rude and arrogant”</td>
</tr>
</tbody>
</table>

20 (38.5%) responses related to satisfaction levels with the service provided, 19 of which were positive. 23 (40.4%) comments related to the physical resources, including staff and contact hours of the centres. Without exception, all comments stated that all of the above should be extended. 9 (17.3%) related to the quality of tutors; 5 positive, 1 negative and 3 which were positive and negative simultaneously.

In Questions 11-15, MLS users were asked about their perception of the impact of MLS on various aspects of their education, the questions had a 5-point Likert scale and they could also comment on their answers. Students were asked to rate the impact MLS had on their confidence. 539 users responded, 125 were adult learners and 66.4% of these rated the impact as helpful in comparison to 52.3% of traditional learner users. There were 106 additional comments, 21 from adult learners with 20 of these positive, “It has helped me a lot. I don’t need to struggle alone to figure out things that I don’t understand”, “Still find it difficult but have a better understanding of maths”. For traditional learners, approximately 71% of comments were positive.

Students were also asked if MLS had impacted on their mathematics performance in tests or examinations to date. There were 534 responses, 122 from adult learners and 61.5% of these stated that it had an impact, in comparison to 52.8% of traditional learner users. There were 103 additional comments, 21 by adult learners, 16 of which were positive (93% of comments from traditional learners were positive), for example: “I would have failed if the extra help had not been there”.

Students were asked to rate how MLS had helped them cope with the mathematical demands of their courses. There were 527 responses, 120 from adult learners and 72% of these indicated that MLS had been helpful in comparison to 62.5% of traditional users. There were 55 additional comments, 14 from adult learners, 12 of which were positive, for example “It has been a huge help”, “Wouldn’t be able to do maths without all the extra services and wouldn’t have a hope of passing the year”. One of the (two) negative comments stated “Some of the tutors in the centre might be good at understanding maths but not good at teaching it”.

In Question 11 students were asked if they had ever considered dropping out of their studies for mathematics-related reasons. 128 of the 136 adult learners answered this question with 25 (19.5%) stating that they did consider dropping out, this is a smaller proportion to that of the traditional student population (22.8%). Question 12 asked (those who answered yes to Question 11) if MLS had been a factor in them not dropping out. 22 of the eligible 25 adult learners answered and 17 (77%) of these stated that MLS was an influencing factor in their decision not to drop out (compared to 54.3% of the traditional learner cohort). Additional comments included: “Greatly. It has given me the confidence to turn maths as my worst
subject into one of my best” and “Encouraged me to trust that my worries were normal and that practice would improve me”. 8 students left comments stating that they never considered dropping out because of the MLS that was available to them, “Never felt the need because of the support provided” and “No, but did worry about failing maths before using these facilities”.

Section C of the survey focused on students who had not availed of MLS. 85 (38.5% of) adult learners (compared with 67.8% of traditional learners) stated that they did not use the MLS facilities provided in their institution. In Question 16, non-attendees were asked to select from 7 fixed options, as to why they did not avail of MLS. For adult learners, the frequency of response in each category is interesting when compared with the traditional 941 students who did not use MLS, see Table 5 (note that students selected more than category).

Table 5.
Frequency of Reasons for Not Using MLS Between Adult Learners and Traditional Students

<table>
<thead>
<tr>
<th>Category of response</th>
<th>% of Adult Learners who did not avail of MLS (n=85)</th>
<th>% of traditional students who did not avail of MLS (n=941)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>I do not need help with Maths</td>
<td>43.53%</td>
<td>49.4%</td>
</tr>
<tr>
<td>The times do not suit me</td>
<td>43.53%</td>
<td>27.8%</td>
</tr>
<tr>
<td>I did not know where it was</td>
<td>5.88%</td>
<td>18.6%</td>
</tr>
<tr>
<td>I hate Maths</td>
<td>3.53%</td>
<td>16%</td>
</tr>
<tr>
<td>Other</td>
<td>15.29%</td>
<td>12.6%</td>
</tr>
<tr>
<td>I was afraid or embarrassed to go</td>
<td>8.24%</td>
<td>11.8%</td>
</tr>
<tr>
<td>I never heard of the MLSC</td>
<td>15.29%</td>
<td>7.8%</td>
</tr>
</tbody>
</table>

*1609 answered the question ‘Have you used any of the Maths Learning Support Centre’s services?’, 583 answered ‘yes’, 1026 answered ‘no’, 24 gave no reply.

In terms of individual respondents, it is worth noting that of the 85 adult learners who did not avail of MLS, 43.53% of these stated that they did not need help. In comparison, for the 941 (67.8%) traditional learners who did avail of MLS, 49.4% of these stated that they not need help. We can see in Table 5 that a larger percentage of responses from adult learners stated that the times did not suit and that they had not heard of the MLSC. The proportions of adult learners responding that they hated mathematics, did not know where MLS was or were afraid or embarrassed to go, were much lower than in the traditional cohort.

There was an opportunity to provide additional comments on responses given to Question 16 and 34 adult learners did so. 20 comments stated that they did not need help or were able to work it out by themselves; 8 comments stated that the session timings did not suit them due to timetable or living circumstances; 2 stated that they never heard of the MLSC services; 2 comments related to a reluctance to attend: “Just felt a bit uncomfortable; felt the questions I had may seem a bit irrelevant”. These responses were consistent with overall student comments.

In Question 17, non-users of MLS were asked to comment on what would encourage them to use the MLS facilities. The responses were coded into categories using GIA and Table 6 below gives the breakdown of responses from the 41 adult learners who answered. Compared with the traditional student responses, adult learners were more likely to comment that they would access MLS if they needed. They were less likely to comment on resources/location or the need for student feedback or advice as reasons that would encourage them to engage with MLS. No adult learners mentioned examinations or results as a prompt for them to access MLS.
Table 6.

Frequency of Comments from Adult Learners who are Non-Users of MLS about What Would Encourage Them to Engage with MLS

<table>
<thead>
<tr>
<th>Category</th>
<th>% of Responses (n=41)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Go if needed</td>
<td>46.34%</td>
</tr>
<tr>
<td>Results/Exams</td>
<td>0%</td>
</tr>
<tr>
<td>Better times</td>
<td>19.51%</td>
</tr>
<tr>
<td>More Information</td>
<td>19.51%</td>
</tr>
<tr>
<td>Resources/Location</td>
<td>4.88%</td>
</tr>
<tr>
<td>Advised to go</td>
<td>2.44%</td>
</tr>
<tr>
<td>Student Feedback</td>
<td>2.44%</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>4.88%</td>
</tr>
</tbody>
</table>

Discussion and conclusion

In this paper we have considered the data concerning adult learners in our large-scale student evaluation of MLS. We also compared, where possible, these results with from the traditional learners. Our two main research questions were:

1. What are the motivational factors of adult learners who seek mathematics learning support (MLS)?
2. Why do some adult learners of mathematics not seek MLS?

When we considered the backgrounds of the respondents, we did not find a significant difference between adult learners and the traditional learner cohort in terms of the disciplines that they were studying. This will be investigated further in the next stage of our analysis when we consider the breakdown of results in terms of the individual institutions that respondents attended. However, as one would expect, adult learners did present with a wider range of mathematical backgrounds than the traditional cohort, with a smaller proportion taking HL and a higher percentage taking OL. This is consistent with research elsewhere, e.g. Gill (2010).

When students who engaged with MLS were considered, there was a statistically significant association (Chi-Squared Test, p<0.001) between student type (i.e. adult learners or traditional) and whether a student uses MLS, demonstrating that adult learners are more likely to seek support than traditional learners. This supports other research, e.g. Ní Fhloinn (2007) who states that adult learners in DIT seek support much earlier than traditional learners, even as early as the first day of term. However, in our study, we found no significant difference in the mathematical backgrounds of adult learner users and non-users of MLS.

Partial answers to our first research question are provided when the reasons why students engaged with MLS were investigated. Analysis suggests that adult learners in our study were more likely than traditional students to mention the following reasons for engaging: having been a long time away from education; poor confidence in their mathematical ability; seeking general extra help; struggling with mathematics. In contrast, adult learners were much less likely than traditional students to mention the following reasons: to get help with specific coursework assessment or as revision for tests; to improve or gain better understanding; to state they find mathematics difficult. Being an adult learner, having not studied mathematics in any formal sense for a long time lends itself to having gaps in knowledge due to forgotten or perhaps never learned material. Lawson (2008) states that some students avoid support due to a fear of embarrassment or feeling that they just have too many mathematical problems to deal with. This gap in knowledge appears to act as an impetus rather than an obstacle for the adult learners in our study to engage with support “As I have been out of the education system for many years I felt I needed the extra support”. These adult learners were motivated to engage because of their worry about gaps in their mathematical knowledge and the length of time they had been away from studying mathematics “As a mature student I needed a
refresher”. Wolfgang and Dowling (1981) may partially explain this finding as they maintain that traditional and adult learners have different motivations and approaches to study. Safford (1994, p. 50) supports this stating that while adult learners may carry ‘intellectual baggage’, they are generally self-directed and making the decision to return to education implies a motivation for change and growth.

A significantly smaller proportion of adult learners did not avail of MLS when compared to the overall cohort. In terms of our second research question, we considered the reasons given by students for non-engagement with MLS. According to Ashcraft and Moore (2009) avoidance is often the consequence of mathematically anxious students. Bibby (2002) reports that math anxiety and shame of own mathematics ability are reasons that students fail to seek help with mathematics. In a study carried out by Grehan et al (2011, p. 79) at NUI Maynooth, the reasons divulged for lack of engagement with MLS included ‘fear; lack of personal motivation; the anonymity of large classes; and to a lesser extent the lack of awareness of support services’. Symonds et al. (2008) list a fear of embarrassment and a lack of information regarding the whereabouts of the mathematics support as reasons why students do not engage. Our findings largely contrast with those just mentioned. The largest proportion of responses from both adult learners and the overall cohort who did not engage with MLS indicated that they simply did not need to: “Good service for students – just didn’t need to avail of it”; “I would definitely find time to attend if I needed to”. It is reassuring that many of those who do not utilise the resources provided simply do not feel the need. 5.88% of adult learners who had not engaged with MLS stated that they did not know where it was and 15.29% had not heard of the support. 8% stated that they were afraid or embarrassed to go “Just felt a bit uncomfortable, felt the questions I had may seem a bit irrelevant”. As we discussed earlier, fear and embarrassment were more of a motivation to attend rather than not attend MLS. 43.53% of adult learners who did not engage with MLS stated that the times were unsuitable. These statistics are enlightening as they have implications for MLS practitioners in terms of marketing and advertisement of services and extension or alteration of opening hours to maximise participation for those who require additional help.

Overall, respondents were very positive about the MLS experience they received in their institution, with adult learners especially so, e.g. users of MLS reported increased confidence in the mathematical abilities and finding it easier to cope with the mathematical demands of the courses “I’ve had a fear of maths all my life so with MLC help I’ve become more confident”. It is clear from the comments that MLS provides a mathematical lifeline, so to speak, for many adult learners: “I would be seriously lost without the MSC and the extra maths classes ran. Now I actually like maths”; “Excellent and I credit the help I receive here to me passing all my maths tests so far”.

Many of the comments highlighted the important role of MLS tutors. Lawson (2008) states that students attend MLSCs precisely because they offer emotional and MLS to students who suffer from mathematics anxiety. FitzSimons and Godden (2000), and Safford (1994) recommend the provision of this warm supportive environment in which individual needs are met and adult learners of mathematics can thrive. The quality of staff is crucial to the success of MLS (Lawson, et al., 2003) and in particular in relation to the education of adult learners (FitzSimons & Godden, 2000). Gill (2006) states that the one-to-one attention students receive in MLSCs is most highly favoured. Some of the responses in this study referred to how they preferred the teaching approach used in the MLSCs to those in their regular tutorials “People in the MLSC explain the questions or doubts you have the way the people in the tutorials should”.

However, Lawson et al. (2003) states that not everyone will make a good MLS tutor and this is reflected by the small number of negative comments about certain MLS tutors, e.g. “Possibly some training in social skills for some of the tutors”. Benn (1994) encourages teachers to tread carefully when dealing with Mature Students of mathematics as it will influence how students perceive the subject. It is in the nature of MLS evaluation that both positive and negative comments can be used constructively. To this end, the IMLSN is in the
process of developing MLS tutor training materials which will be used in the academic year 2015/16 to help ensure best practice in the recruitment and training of tutors across all institutions in Ireland. There were some other negative comments, e.g. in relation to the timing of the drop in centre or classes, the volume of students in attendance and hence the lack of one-to-one attention at busy times: “It’s sometimes very crowded and the instructors cannot get to you”, “Sometimes the wait for assistance is 30-45 minutes”. These findings resonate with those of Lawson et al. (2003) who state that MLSCs are inclined to be very busy at certain times, such as at examination time, and there will be waiting times as a result. Again, these comments were not standard across the survey and will be of more relevance to the individual institutions when further analysis is presented.

It is very difficult to claim that MLS is responsible for increases in retention or student success rates in mathematics (Lawson et al., 2003). Mac an Bhaird et al (2009) tell us that we cannot take full credit as a number of factors are in play when it comes to student progress such as motivation etc. However, the findings from this study indicate a high level of satisfaction with the services provided by the MLSCs throughout Ireland, and many adult learners indicated that MLSCs are responsible for their not dropping out of their studies. “It was a very valuable experience, whereby without it I would have certainly failed.”

**References**


Ni Fhloinn, E., Fitzmaurice, O., Mac an Bhaird, C., & O’Sullivan, C. Gender differences in the level of engagement with mathematics support in higher education in Ireland, to appear.


Appendix I: Sample mathematics learning support survey

This appendix contains a sample from one institution of the questionnaire used. All questions with the exception of Question 10 were identical in all HEIs in which the questionnaire was distributed. The structure of Question 10 was the same as the sample shown here but the list of supports and names used to describe the supports which the students were given in Question 10 was localised to take account of the specific supports offered in that HEI and the names they are given there. The only other variation in the questionnaire was the localisation of the name given to MLS in that HEI – for example in one HEI the provider of MLS is known as the MLSC (Mathematics Learning Support Centre), in another it is known as the MLC (Mathematics Learning Centre) and in another it is known to the students as CELT Mathematics Services.

Mathematics Learning Support Survey

We are looking for your feedback on the Mathematics Learning Support Centre (MLSC) and its services. This evaluation is designed to help us to improve the MSC for you and other students. Even if you have not used the MLSC’s services, your feedback is important.

Section A

1. Degree Programme:
2. Year: Certificate 1st year 2nd year 3rd year 4th year Postgrad
   Student Category: Full-time Male
   Female
3. Gender: Male Female
4. Leaving Certificate Mathematics Level (if applicable): Higher Ordinary Foundation
5. Leaving Certificate Mathematics Grade (if applicable):
6. Leaving Cert 1991 or before: A B C D E Other
   D3 Other
7. 1992 or after: A1 A2 B1 B2 B3 C1 C2 C3 D1 D2
   D3 Other
8. If you started off doing Leaving Certificate Higher Level Mathematics, but changed to Ordinary Level, roughly when did that happen? (Please circle)
   Before Christmas in 5th year
   Before Christmas in 6th year
   Before the end of 5th year
   After the Mocks in 6th year
   N/A
9. Are you registered as a mature student? Yes No
10. Have you used any of the Maths Learning Support Centre’s services (drop-in centre, support workshops, online courses)? Yes No

If YES, please proceed to Section B.
If NO, please proceed to Section C.

Section B (Students who used the MLSC)

11. Why did you first decide to use the MLSC or its services?
12. Being as honest as you can, rate the following services that you have used below on a scale of 1 to 5 where 1=Not at all Worthwhile and 5=Extremely Worthwhile

   Drop-In Centre
   1 2 3 4 5 N/A
   Comments/Suggestions:
   Online Courses
   1 2 3 4 5 N/A
   Comments/Suggestions:
   Workshops
   1 2 3 4 5 N/A
   Comments/Suggestions:

   1. Did you ever consider dropping out of your course/college because of mathematical difficulties?
Comments:

13. If yes, has the MLSC influenced your decision not to drop out?

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>

Comments:

14. Rate how the MLSC has helped your confidence in maths on a scale of 1 to 5 where 1=Not at all and 5=Extremely Helpful

| 1 | 2 | 3 | 4 | 5 |

Comments:

15. Rate how the MLSC has impacted on your maths performance (in exams/tests) so far on a scale of 1 to 5 where 1=No impact at all and 5=Has had a large impact

| 1 | 2 | 3 | 4 | 5 |

Comments:

16. Having used some of the MLSC’s services, rate on a scale of 1 to 5 how you feel the MLSC has helped you cope with the mathematical demands of your course where 1=No help at all and 5=Has been a huge help

| 1 | 2 | 3 | 4 | 5 |

Comments:

Any other comments or suggestions about the MLSC Services would be very valuable!

Section C (Students who did not use the MLSC)

18. If you did not use the MLSC, why not? Tick as many reasons as apply:

☐ I do not need help with Maths
☐ I never heard of the Mathematics Learning Support Centre
☐ I did not know where it was
☐ The times do not suit me
☐ I was afraid or embarrassed to go
☐ I hate Maths
☐ Other (please specify):
☐ Comments:

19. What would encourage you to use the MLSC and its services if you needed to?

Any other comments or suggestions about the MLSC Services would be very valuable!