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
- 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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In this Volume 15(1)

Díez-Palomar, J., Evans, J., Galligan, L., Ginsburg, L. & Griffiths, G. (2021). Editorial. *Adults Learning Mathematics: An International Journal*, 14(2), 4-5.

Editorial

The current issue of Adults Learning Mathematics: An International Journal includes four articles -- three research articles and the Journal's first published Article of Practice. One common theme spanning all four articles is the importance and influence of *preparation* in a variety of transitions: between types of programmes; between countries; between institutions and teaching approaches; and in a transition to digital approaches.

Andrew Bell, Linda Galligan and John Latham, in reviewing the existing body of research relating to paramedicine education, found that many of those preparing for paramedicine studies have limited confidence and weak numeracy skills, both in calculation precision and mathematical understanding. Such unpreparedness is of profound importance since the work of paramedics most often occurs in stressful and unpredictable settings outside of hospital settings and requires quick decisions and accurate enactment of appropriate procedures. The authors provide suggestions for effective and relevant instructional practices to improve paramedicine educational programs.

Norman Maphosa and Helen Oughton examined the current expectations and perspectives of a group of immigrants from Zimbabwe, who are now studying numeracy in England. The learners' prior learning experiences reflect the historical development of mathematics instruction in their home country from it's colonial past. Findings highlight the mismatch between the learners' embedded perceptions resulting from their own past experiences and their current realities, provoking conflicting visions of how mathematics is to be taught and learned as well as what mathematics content is valued. They expressed frustration in that they believe their prior learning and earned qualifications have not been recognized and they see their progress towards entry to work and further study being inhibited by cultural and social challenges. The authors suggest that practitioners consider carefully the backgrounds and experiences of their learners when preparing for teaching and critique approaches that might be considered 'good practice' in other circumstances.

Diane Dalby explores the changing views of mathematics of learners making the transition from schools to studying vocational courses at further education colleges in England. On the whole, this cohort of learners, through their examination results at age 16, have demonstrated themselves to be less successful at academic pathways leading to higher education. They elect to leave their institution and embark on a new route with an employment focus. The learners in this study, instead of following a programme to retake their prior mathematics qualification, have been offered Functional Skills Mathematics provision, which has a focus on the application of mathematics in life. Evidence is presented showing that many learners develop a more positive attitude to mathematics through this transition of institution and curriculum. The study was relatively small scale, and as such is exploratory, but does suggest some important messages for practitioners and researchers.

Our final article in this issue is our first practitioner article following the request for such submissions in the last issue. Marcus Jorgensen examined the process through which he, as a university instructor of a quantitative reasoning course, prepared to transition to using a digital technology-enhanced collaborative classroom environment for his class. His planning and decision-making process included consideration of how and when the technology might enhance or disrupt students' learning activities as well as their interactions with other students in small groupings. Further, he needed to consider how to manage the transition to complement rather than replace his preferred teaching practices. This article presents a good example of how a teacher can intentionally customize a classroom environment to best meet the needs of the particular students while fitting with the teacher's own priorities.

Unfortunately, due to the unprecedented difficulties stemming from the COVID-19 pandemic, ALM-IJ was not published in 2020. A forthcoming special issue of the Journal will focus on how adult numeracy educators and researchers dealt with the pandemic in their communities.

The Editorial Team

Bell, A., Galligan, L., & Latham, J. (2021). Numeracy in paramedicine education: a literature review. *Adults Learning Mathematics: An International Journal*, 15(1), 6-18.

Numeracy in paramedicine education: a literature review

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Abstract

The introduction of paramedical science into universities has led to unprecedented enrolment numbers in Australian undergraduate paramedical science programs. At the same time however, there has been an associated increase in complexity of student learning expectations and requirements. One area of paramedical education that is proving challenging for universities is the numeracy preparedness of students and how to best support students in this area.

To examine how universities may begin to address the current challenges related to improving the numeracy of paramedical science students, this paper investigates the literature on the numeracy of paramedics and the underlying mathematical skills required for their programs of study. It also reviews the support programs that are available at university and considers how much these are reflecting effective pedagogies. The aim of this review is to identify ways numeracy and numeracy teaching in paramedical science may be improved and highlight possible directions for future research in this area.

Key words: paramedicine; paramedicine education; clinical education; numeracy; curriculum.

Introduction to paramedicine research

Since the turn of the century, paramedicine[1] in Australia has gone through a professional transition. As is occurring in other Western nations, such as the UK, US and Canada, the education of paramedics, once administered through 'in-house' (adult) vocational training programs, is now administered by universities through specific paramedical science degree programs (Devenish, 2014; O'Meara, Maguire, Jennings, & Simpson, 2015; Thompson, Grantham, & Houston, 2015). This

[1] According to Williams, Ross and Graham (2020, p.3) "Paramedics possess advanced clinical skills and manage a range of acute and chronic conditions under pressure. They solve complex clinical problems in public environments, subject to extreme environments and external distractions and complications and they are subject to time pressures imposed by the service and patient's conditions."

educational transition has also invariably influenced the scrutiny of what has now become a 'professional practice', with the concomitant development of a specific research agenda arising to examine the practices of the profession and guide the development of education programs that address both contemporary university student needs and contemporary community health issues.

As paramedical education has moved into the realm of universities, the curricula have been evolving to ensure academic rigour while at the same time seeking to meet a distinct set of industry practice needs. This includes accurate use of numeracy skills particularly in the area of drug calculations, where accuracy of 100% is the industry expectation. Tertiary education providers have, for example, in recent years increased the depth, breadth and consistency of curricula, with delivery by subject experts who have training in education and applied clinical health (Thompson et al., 2015). Indeed, the introduction of paramedical science into universities and the ongoing development of curricula to address contemporary health and education needs has led to unprecedented enrolment numbers in Australian undergraduate paramedical science programs (Thompson et al., 2015). Recent research suggests that the commencing paramedical science student population is dominated by young adults under 25 years of age, with a high proportion of dual qualified students, whether studying concurrently with nursing or those who have qualifications from previous tertiary studies (Hallam et al., 2016; Laing, Devenish, Lim, & Tippett, 2014; O'Meara, Williams, Dicker, & Hickson, 2014; Williams et al., 2013; Williams, Fielder, Strong, Acker, & Thompson, 2015). The authors have also observed that there is also a smaller population of students that are returning to study as mature aged students or transferring from allied industries such as nursing. With this increase in student numbers, however, there has been an associated increase in complexity of student learning expectations and requirements, and the related challenges of producing work-ready graduates within traditional academic curricula frameworks. Indeed, one area of paramedical education that is proving challenging for universities is the numeracy readiness of students and related numeracy education.

In the development of mathematics-related curricula for paramedical science, some educational elements that have proved successful in other areas of health care areas may also be applied to paramedicine education as there are many parallels between these other areas and paramedic practice. For example, like other medical professionals, paramedics perform a range of physically invasive treatments to their patients, such as drug administration which involves a degree of applied numeracy and associated drug calculation error risk (Bell & Latham, 2018). At the same time, however, the context in which paramedics operate is relatively unique and this means there is also a need to design curricula that recognises and responds to this unique context. For example, while most other disciplines are predominantly seen as 'in-hospital' based, paramedicine is unique in that it embodies 'pre-hospital' clinicians (Williams & Webb, 2015). This 'pre-hospital' context means the pressures on paramedics differ from those of other health care professionals. In treating patients, paramedics are frequently required to make rapid decisions under time critical, high-pressure circumstances where delay in treatment could have adverse effects for the patient. In this uncontrolled, dynamic environment, distractions such as bystanders, loud noise, poor lighting and other situational stresses are also often compounding factors, and diagnostic information, clinical support and resources may be limited (K. J. Eastwood, Boyle, Kim, Stam, & Williams, 2015; Williams et al., 2015). In the administration of drugs in the applied pre-hospital setting, such as the side of the road at a motor vehicle incident, calculations involving the use of set formulae are regularly performed without the aid of a calculator; and mistakes in the dose/volume can be the difference between life and death of the patient, or may lead to the unnecessary prolonging of pain (Bell & Latham, 2018).

The need to develop specialised curricula and a separate research agenda that reflect the nuances of the field which are distinct from, but complementary to, other medical disciplines has been recognised internationally through efforts to advance out-of-hospital and educational research agendas in Australia, Europe and North America (Devenish, 2014; O'Meara, 2011; O'Meara et al., 2015).

Compared to other health professions, however, that have developed distinct bodies of professional knowledge and theory to help guide their members, the literature relating to paramedical education and practice is still in its infancy. This immature educational development includes the use of numeracy in the clinical setting and its ongoing development is seen as an essential component of the skill set of a professional paramedic. To examine how universities may begin to address the current challenges related to improving the numeracy of paramedical science students, this paper investigates the literature on the numeracy of paramedics and the underlying mathematical skills required, and reviews what programs are available at university and how much these are reflecting effective pedagogies. The aim of this review to identify how numeracy and numeracy teaching in paramedical science may be improved, thus highlighting directions for future research in this area.

Numeracy skills of paramedics

Numeracy is an umbrella term that means to be literate in mathematics (Wilkins, 2016). While the words *mathematics* and *numeracy* are often used interchangeably, they are not the same thing. Evans, Wedege & Yasukawa, (2013) contend that it is not easy to discriminate between the different notions of numeracy and that in fact numeracy can provide a connection between mathematics and adult life. Dalby (2017) also concludes that numeracy does not refer to just a simplified presentation of mathematics but is defined further by the way a person utilises it. Johnston states (1994, p. 34), "numeracy is a critical awareness which builds bridges between mathematics and the real world, with all its diversity… In this sense … there is no particular 'level' of mathematics associated with [numeracy]". In the academic context, teaching numeracy thus requires that students are able to, in a given situation (such as a paramedical scenario), choose suitable mathematics to use and at the appropriate level as required by the context/situation, apply the mathematics competently and confidently, and ensure that the solution fits the situation (Galligan, 2011; Wilkins, 2016).

To be effective health care workers, paramedics must feel confident in their abilities to work in highly stressful and unpredictable scenarios; and this includes being able to accurately complete mathematical calculations whilst under pressure. Indeed, while it has been acknowledged that nurses need to be numerate under pressure (Coben et al., 2008), paramedics' numeracy is more specific in a time critical, high stress decision making environment (Bell & Latham, 2018). Laying the groundwork in numeracy during the undergraduate programs thus plays a crucial role in preparing paramedics for professional practice. Paramedicine education programs need to ensure students are able to successfully negotiate medical calculations by applying a range of basic mathematics skills, including mental operations (addition, subtraction, multiplication, and division), fractions, percentages and decimals, ratios and proportions, algebra, unit conversions and worded problems. The poor performance in mathematical calculations demonstrated by practicing paramedics and paramedical science students indeed highlights a need for greater – and potentially more effectively designed – mathematics education during undergraduate paramedical science degrees (Boyle & Eastwood, 2018).

An ability to accurately perform mathematical calculations without assistance from technology or calculation tools, as well as in a manner that is appropriate to the situation is an essential skill for all health professionals undertaking patient management. Indeed, the inability to perform accurate calculations may result in a compromise of patient safety, potentially leading to an under-dosing, over-dosing, or a major adverse event, such as death. As with other areas of health care, mathematical calculations are a fundamental component of paramedic practice, used to determine, for example, factors such as joules for defibrillation, endotracheal tube size, fluid resuscitation volumes, laryngeal mask size, and dosage requirements as based on a person's age, weight, or vital signs (Boyle & Eastwood, 2018; K. J. Eastwood et al., 2015). It is assumed that when paramedics administer drugs to patients, their drug dosage calculation are always 100% accurate (K. Eastwood, Boyle, & Williams, 2012); however the often uncontrolled and dynamic conditions within which paramedics typically operate can complicate the ability to provide accurate assessments as high stress environments can exacerbate mathematical deficiencies (K. J. Eastwood et al., 2015). For these reasons it is critically important that students studying paramedical science achieve mastery over the mathematics required to perform paramedical-related calculations, as well as confidence in applying the mathematics appropriately as required by the situation. Goliath (2007), concludes that champions of mastery learning such as Keller and Bloom consider that learners benefit maximally from instruction under conditions of good, qualitative instruction that is varied in relation to the learners' pace. Furthermore, although calculation aides or aide-memoire (such as calculators, mobile phones, calculation charts and paediatric tapes) may be used to support mathematical calculations, paramedics in the field regularly encounter situations where these aides may not be readily accessible or suitable (Bell & Latham, 2018; Boyle & Eastwood, 2018). As such, paramedics need to be able to conduct mathematical calculations without computational aides and to high standards of accuracy.

Despite the central role that numeracy plays in delivering sound patient care in paramedical practice, research conducted both locally and internationally has revealed alarmingly low levels of accuracy in the unaided mathematical calculations performed by paramedics and paramedical science students (Bernius, Thibodeau, Jones, Clothier, & Witting, 2008; Boyle & Eastwood, 2018; K. Eastwood et al., 2012; K. J. Eastwood, Boyle, & Williams, 2009; Hubble, Pascal, & Sanders, 2000; Leblanc, Mcarthur, King, & Lepine, 2005). Such research has found that calculation errors are among the most prominent medication errors in paramedic science (Crossman, 2009). In fact, it has been suggested that in a classroom setting, calculation and drug administration errors are likely to occur in up to half of all dosage calculations (Boyle & Eastwood, 2018; K. Eastwood et al., 2012). Such findings indeed highlight a problem in the paramedical science discipline, particularly when compared to research from other health fields, such as nursing, where, for example, research has concluded that there is little evidence that medication errors in nursing practice are caused by errors in calculation (Sneck, Saarnio, Isola, & Boigu, 2016; Wright, 2010).

While dosage errors in paramedic practice may be a result of the high pressure environments in which paramedics operate, research has shown that such errors may also be a result of factors that include skills decay in practicing paramedics (the loss of the ability to undertake manual calculations over time) (Boyle & Eastwood, 2018), pessimistic attitudes towards mathematics (K. Eastwood et al., 2012; K. J. Eastwood et al., 2015) and confidence (Harris et al., 2017). In many cases, such pessimistic attitudes and confidence – or lack thereof – can manifest as a result of mathematics anxiety. Mathematics anxiety is a well-documented occurrence across science and health disciplines both at the university and practice level (Bull, 2009; Choudhary & Malthus, 2017; Glaister, 2007; Williams & Davis, 2016). It is a feeling of tension, apprehension, or fear that not only interferes with mathematics performance (for example it can lead to poor performance on mathematics achievement tests), but it can also have a profound, negative impact on the acquisition and comprehension of new information (Ashcroft, 2002; Caffey, Crane, & Ireland, 2016; Hembree, 1990) and has been found to contribute to medication errors conducted in practice (Bull, 2009; Caffey et al., 2016; Choudhary & Malthus, 2017; Glaister, 2007; McMullan, Jones, & Lea, 2012; Williams & Davis, 2016). From a paramedical science perspective, research has found that dosage and ratio calculations are two aspects of practice that students feel most anxious about (Caffey et al., 2016); and one of the biggest fears paramedic students have regarding the commencement of a career in paramedicine is making a clinical mistake (Holmes, Jones, Brightwell, & Cohen, 2017).

Perhaps one of the most worrying findings to emerge from research investigating numeracy in paramedic practice and paramedicine education is the finding that the majority of mathematical errors result from a fundamental lack of understanding of mathematics (Boyle & Eastwood, 2018; K. Eastwood et al., 2012; K. J. Eastwood et al., 2015; K. J. Eastwood et al., 2009). This means that these errors are not simply random errors that may occur when one is distracted (such as basic computational errors in addition, subtraction, multiplication and division). Instead, they arise from either the inability to formulate an equation (conceptual errors) or the inability to operate an equation (arithmetic errors). This further means that by their very nature – as a product arising from lack of mathematical understanding – these errors will occur every time a calculation is attempted (K. J. Eastwood et al., 2015).

Such findings highlight an insufficient level of understanding of basic mathematical principles across the paramedical science discipline. Yet, from an Australian context, perhaps these results are not surprising given that most universities in Australia do not have mathematics as a pre-requisite for entry into their paramedical science degrees. Of the fifteen universities that offer a degree program in paramedical science in Australia, eleven do not have mathematics as a pre-requisite; and while two other universities do include mathematics as a pre-requisite, it is only included in a list of subjects from which students choose their pre-requisites, meaning they do not actually have to select final year high school mathematics as a pre-requisite. In a small number of the degrees, mathematics is listed as a recommended subject (a subject in which students are recommended to have a passing grade prior to enrolment in the degree), assumed knowledge (a subject that a student is assumed to have passed in completing their year 11 and 12 high school certificate or Australian Tertiary Admission Rank) or as a subject which students should consider undertaking a bridging course prior to commencing their degree program. This means, given the current lack of emphasis being placed on the numeracy skills of potential degree candidates, there is potentially a large proportion of students who enter paramedicine degrees without a sufficient and current mathematics skillset.

As universities generally seem to assume that students entering their paramedicine programs will have some knowledge of mathematics beyond the basics, courses within these programs tend to focus more on further building on those assumed skills rather than re-teaching the basics (Bell & Latham, 2018). For students without those assumed, basic mathematics skills, it is often difficult to ‘catch up’ and disengagement and potential attrition from the program are inevitable consequences. Further compounding the problem is the apparent disconnect between students’ belief in their own mathematical abilities and their actual mathematical abilities, with many students overestimating their calculation abilities (K. Eastwood et al., 2012; K. J. Eastwood et al., 2015). This overestimation of one’s abilities potentially inhibits that person from being receptive to suggestions that they need to improve their skills or be involved in continued maintenance of those skills (Bell & Latham, 2018; K. J. Eastwood et al., 2015). In paramedic practice, the overestimation of one’s abilities has also been identified as a cause of diagnostic error, as overconfidence can lead to a decreased likelihood of consulting with colleagues, or with utilising tools, protocols or other practice guidelines (Harris et al., 2017).

Improving mathematics education in paramedical science

As the research into paramedical science education is in its infancy, research exploring the design of curricula and pedagogies that address the development of paramedical science students’ mathematical competencies are limited. Such research includes a study of the mathematical abilities of first year undergraduate paramedic students, in which K. J. Eastwood et al. (2015) found that the mathematics and drug calculation skills of the students improved significantly after participation in tutorials that were specifically designed to address the identified mathematical deficiencies. In a study investigating subject-related anxiety, Caffey et al. (2016) found that the anxiety students felt about performing simple dosage calculations was significantly reduced when authentic learning contexts such as case studies and simulated debrief sessions were incorporated into the pedagogy. The authors also found that the use of case studies led to increased student interest in, and understanding of the learning materials. In an attempt to help students enhance their mental arithmetic skills, Bell and Latham (2018) designed a mental calculation app that incorporates basic elements of gamification to address the development of a range of mathematical skills, from simple arithmetic through to contextualized applications of drug calculation problem solving utilising Australian industry standard drug therapy protocols. As the app was a support resource and not part of compulsory course content, however, take-up by students was low.

As paramedical science falls within the wider health science field, future research into paramedical science education needs to consider how interventions successfully implemented in the other health science disciplines may be adapted and adopted for use in the paramedical science field. Indeed, because of the ongoing challenges universities face across all the health science fields with regards to declining mathematics skillsets and interest, there is significant research in this area in the health sciences (for reviews of the research see: Hunter Revell & McCurry, 2013; Stolic, 2014). While many of the interventions explored in the literature utilise diverse strategies, a number of pedagogical qualities can be seen to consistently contribute to the improvement of student outcomes in mathematics-related skill development. These include adopting a whole-of-curriculum approach where the numeracy needs of students is assessed from entry to the degree program and is characterised by consistency of approach and increase in depth of curricula and assessment and also incorporates active learning strategies into that curriculum, utilising online technologies to support learning (Elliott & Joyce, 2005). This whole-of-curriculum approach has been defined as, “An overall design of the numeracy expected at program level provides for continuity, so that each year level takes into account student autonomy and development, that is, from a high degree of structure or mastery of basic skills, to open inquiry and self-determined guidelines” (Galligan, 2017. p 741). Arguably, these approaches and strategies (a whole-of-curriculum approach, active learning, and online technologies) also need to be applied and explored in the paramedicine context and thus need to become a focus of future research and intervention design in paramedical science education.

In developing pedagogies to increase mathematical competence, research in the broader health science field has shown that adopting a whole-of-curriculum approach to the teaching of mathematics is more likely to provide a better means of improving applied numeracy skills than once-off, single interventions that are not linked to the wider degree curriculum (Choudhary & Malthus, 2017; Hunter Revell & McCurry, 2013; Jackson & De Carlo, 2011; Jarvis, Kozuskanich, Law, & McCullough, 2013; Sulosaari, Huupponen, Puukka, Torniainen, & Leino-Kilpi, 2015; van de Mortel, Whitehair, & Irwin, 2014). In adopting a whole-of-curriculum approach, research points to the importance of having a consistent mathematical formula teaching method adopted and demonstrated by all faculty within a given health science program. Such research has found that when mathematics is taught in individual clinical courses with no consistency in teaching methods, each course tends to exist in isolation (Hunter Revell & McCurry, 2013) thus potentially increasing confusion and the propensity for errors, while also reducing opportunities for scaffolding learning and for practicing the methods learned across different scenarios (Choudhary & Malthus, 2017). This does not discount the use of multi-modal, blended learning approaches within individual subjects, but rather indicates that the various modes of delivery are consistently utilised and developed throughout the curriculum.

In delivering a whole-of-curriculum approach, researchers also highlight the importance of teaching mathematics skills early in the curriculum, reinforcing those skills often throughout the curriculum, scaffolding the learning and providing learners with opportunities for reflection (Glaister, 2007; Rainboth & Demasi, 2006; van de Mortel et al., 2014; Zahara-Such, 2013). Ongoing mathematical mastery may be achieved, for example, by making mathematics classes mandatory every semester or through repeated testing of students’ competence in numeracy over the course of an entire degree program. Bell and Latham (2018) note that there has been a recent trend towards integrating the numeracy components across all years of university study in an effort to improve student outcomes as few students are in the habit of maintaining their mathematical skills. In enhancing student outcomes and confidence, scaffolding of learning involves starting with simple calculations and anchoring learning in concrete representations, then slowly progressing through more complicated concepts, calculations and more abstract representations of a task. The sense of progression that scaffolding can create in students can thus lead to improved confidence, an increased likelihood that those students will attempt more complex tasks, and improvements in numeracy (Latimer, Hewitt, Stanbrough, & McAndrew, 2017; van de Mortel et al., 2014). To further consolidate their learning and encourage improved confidence in their mathematical abilities, research shows that students need to be provided with opportunities to engage in regular reviews and reflections of their learning (Caffey et al., 2016; Shelton, 2016). Such reflection is also an important process of active learning (Andres, 2017).

Also reflecting the wider literature on active learning, which promotes the use of real life examples and authentic experiences to situate learning, research in the health science area similarly emphasises the important role that tailored, contextualised, hands-on approaches to learning can play in improving the mathematical skills of health science students (Caffey et al., 2016; Choudhary & Malthus, 2017; Hou, Rego, & Service, 2013; Jarvis et al., 2013; Latimer et al., 2017; Ramjan et al., 2014; Sulosaari et al., 2015; Wright, 2009, 2012; Zahara-Such, 2013). This research suggests that the use of case-based teaching scenarios, real life examples, and simulated medication calculation and problem-solving scenarios that are embedded in authentic clinical practices can help to demonstrate the application of theoretical concepts and increase the relevance of the content to the learner. In addition, as mathematical competence from a professional perspective is situation-bound (contextual) (Dubovi, Levy, & Dagan, 2017; Wright, 2012), it is particularly important that the teaching and learning of mathematics takes place within the context in which it will be practiced. That is, students need to be provided with learning approaches that align mathematics to the ways they will use and experience mathematics in clinical practice, and testing needs to be completed through contextualised calculation tests and assessments rather than traditional ‘pen and paper’ tests (Hutton et al., 2010; Ramjan et al., 2014; Wright, 2008). Indeed, research has shown that when mathematics in the health science disciplines is situated in the clinical practice environment in which it will be practiced, for example through the use of case studies, students respond more positively to the learning environment, show increased understanding of the effects of medical treatment in real life, and are better equipped to practice decision-making in medication care (Caffey et al., 2016; Coyne, Needham, & Rands, 2013; Sulosaari et al., 2015).

In situating mathematical learning into the contexts in which it will be practiced and concomitantly increasing the propensity for active learning to occur, online technologies are playing an increasingly important role in health science education. Such technologies provide a cost effective and replicable way to enhance realism and improve authenticity in practical classes where opportunities to engage with actual clinical practice would otherwise be limited or unavailable (Clarkson, 2018; Hou et al., 2013). Technologies such as podcasts and videos with flipped classrooms (in which students review an online lecture before the lecture session and come to the classroom to have an interactive session with the teacher), mobile devices with apps, and video games and simulations (part-time trainers, integrated simulators, virtual reality) are all being used to enhance the mathematical education and numeracy skills of undergraduate health science students (e.g. Bell & Latham, 2018; Birt, Moore, & Cowling, 2017; Clarkson, 2018; Coben & Weeks, 2014; Cotta, Shah, Almgren, Macias-Moriarity, & Mody, 2016; Foss et al., 2014; Foss, Mordt, Oftedal, & Løkken, 2013; Huang, Hew, & Lo, 2018; Kay & Kletskin, 2012; McMullan, 2018; Schwartz, 2014).

The use of online simulations and virtual learning spaces, for example, enable learners to develop procedural knowledge in safe, controlled environments that eliminate risk to patients, while also providing students with authentic contexts and realistic visualisation that is integral to contextual learning (Guze, 2015). From a learning perspective, research has shown that the use of online simulations, virtual learning spaces, online practice quizzes and online activities and resources promote active learning (Hunter Revell & McCurry, 2013; Stolic, 2014) and increase propensity for student engagement with the mathematical content of a course (Clarkson, 2018; Hunter Revell & McCurry, 2013; Stolic, 2014). Online resources designed as an intervention to target mathematical concepts and skills have also been found to lead to increases in overall pass rates in medication dosage calculation tests (Mackie & Bruce, 2016), improvements in students' arithmetic skills (Karabag Aydin & Dinc, 2017) and calculation confidence (Ramjan et al., 2014). It has been suggested that that as online technologies empower students to learn at any time, in any environment, and at their own speed, these technologies thus increase success rates by permitting as many repetitions and as much engagement as required (Karabag Aydin & Dinc, 2017; Ramjan et al., 2014). While technology plays an important role in more fully engaging students with mathematics learning in a way that also leads to increased mathematics understanding, research also points out that the most successful pedagogical interventions utilise multi-modal, blended learning approaches where traditional face-to-face lectures and/or tutorials are combined with multiple online, self-directed learning resources (Choudhary & Malthus, 2017; Mackie & Bruce, 2016; Ramjan et al., 2014; Stolic, 2014).

Conclusion

The paramedical science discipline is not alone in needing to address the way mathematics education is approached in its degree programs; across Australia and across all disciplines there has been a general decline in the mathematical preparedness of all students entering universities, with many students embarking on a degree without the fundamental mathematical skills they will need to start their university education (Dalby et al., 2013; Joyce, Hine, & Anderton, 2017; Nicholas, Poladian, Mack, & Wilson, 2015; Varsavsky, 2010). One of the major difficulties with raising the mathematics skill base of a country or region is the under-preparedness in mathematics of incoming students to universities, which subsequently results in low levels of success with university-level mathematics (Rylands & Shearman, 2015; Varsavsky, 2010). Such low levels of success are certainly worrying for health-related degrees, such as paramedical science, where robust mathematical skills are essential to students' future careers and the safety of patients with whom they will potentially come into contact.

The literature exploring mathematics education in the health sciences identifies a number of approaches and strategies that consistently contribute to the improvement of student outcomes in mathematics-related skill development in the health sciences. While these approaches and strategies may already be currently used, either fully or in part, by some paramedicine educators, research into the application of these approaches and strategies in the paramedical context is lacking. Future research into mathematics education in paramedical science thus needs to explore such questions as: How can paramedical numeracy be improved through a whole-of curriculum approach? How can educators implement a consistent and collaborative approach to mathematics education across an entire paramedicine degree and which methods for teaching mathematics might be best suited for this? Which active learning strategies will best promote mathematics success in paramedicine education? How can paramedicine educators provide students with learning approaches that align mathematics to the ways they will use and experience mathematics in clinical practice? How can assessment be modified to reflect this more 'real-life' experience of mathematics (rather than traditional 'pen and paper' tests)? How can online technologies be used to increase and improve the situational or contextual learning of mathematics? And, how can online technologies be used to increase and improve student engagement with mathematics?

This last question – how to improve student engagement in mathematics – is indeed an important research area, as student engagement in mathematics is arguably integral to the development of strong numeracy competency. Yet, while research has focused on the importance of teaching for the contextual application of mathematics, as well as the important role technology plays in supporting contemporary learning experiences, there is a dearth of research specifically examining how improving student engagement in mathematics in health science courses, including paramedicine, can lead to improved student outcomes in numeracy specific to that discipline. Certainly, there exists a need to explore how the often-weak numeracy skills of paramedicine (and other health science) students may be addressed through strategies that increase their engagement in academic numeracy. There also exists a need for the development of innovative pedagogies that utilise active engagement strategies and interactive technologies in the teaching of mathematics to undergraduate paramedicine students in a way that increases mathematics engagement while also increasing health-related numeracy skills.

Finally, from the wider perspective of academic numeracy, there is also a question around theorising numeracy, as it is arguably still in an untheorized state (Coben, 2006; Craig & Guzmán, 2018). The theorisation of numeracy is important because numeracy has, by and large, not been accomplished despite its prioritisation since the early 2000s as an area of education that 'matters' (Bass, 2003). While there are various explanations as to why numeracy has not been accomplished (see: Craig & Guzmán, 2018), it is important we continue to question and explore why numeracy has developed – or failed to develop – despite its apparent importance and scholars' prolonged attention. In addition, as longstanding debates about how to best teach and organise numeracy skills are increasingly unsettled by the changing communication technologies through which we learn and carry out our day-to-day lives (Hamilton, Hillier, & Tett, 2006), we need to continue to explore how theory can positively inform practice and vice versa. As argued by Craig and Guzmán (2018), a dialogic relationship between developing programs and theorizing can exist productively, playing a role in advancing our thinking and in disrupting our common-sense conceptualizations that arguably lead to stagnation.

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"What am I doing here?" Perspectives of Zimbabwean adult learners on the relevance of adult numeracy to their needs and aspirations

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Abstract

Many adult learning centres in England provide numeracy (or mathematics) education to adults in all sectors of society, including migrants from countries across the world. This study takes one group of migrants – those from Zimbabwe – and explores the relevance of adult numeracy education to the needs and aspirations of Zimbabwean adult learners in England. The accounts, beliefs and attitudes expressed by learners and their teachers were collected through questionnaires, focus groups and in-depth interviews. The study found that most of the learner participants did not feel that they needed to improve their numeracy skills for everyday life and work, and had undertaken their adult numeracy learning in order to enter higher education or professional career pathways. They felt that their prior learning of mathematics in Zimbabwe had been higher than their Level 2 adult numeracy programmes and therefore felt that their prior learning had not been recognised or valued. Tutor participants were in agreement with learner participants concerning high levels of prior learning experience. Furthermore, the study found that teaching and learning approaches commonly offered in England, such as the use of games, did not meet the expectations of adult Zimbabwean learners, who considered them childish. The study also found that the current emphasis on 'real-life' contexts for adult numeracy learning and assessment presented challenges to Zimbabwean learners. Many of these contexts were based on British culture and were unfamiliar to the learners. They expressed a preference for what they called 'academic' (or pure) mathematics, which they had studied in Zimbabwe, and some participating learners suggested that the focus on British contexts represented cultural imperialism in requiring them to conform to the norms of British culture.

Keywords: adult numeracy, migrant learners, prior learning, international qualifications, real-life context

Introduction

Recent decades have seen an increased focus on adult numeracy[i] education in England both from researchers and policy developers (BSA, 1997; Carpentieri, Lister & Frumkin, 2010). Factors driving this have included international assessments such as PIACC, and the requirement for numeracy skills to participate in higher education and employment (Felstead, Gallie, Green, & Zhou, 2007). A series of initiatives over the last two decades have led to the introduction of qualifications in Adult Numeracy and Functional Skills Mathematics at a range of levels up to Level 2, the standard normally expected from young people completing schooling at the age of 16. Programmes leading to these qualifications have been offered in a variety of adult education settings in England, such as colleges, adult community education centres, workplaces and prisons.

The aim of this paper is to explore the experiences of Zimbabwean migrant adult learners enrolled on such programmes in England, and in particular, the relevance of the classes to their needs and aspirations, in light of recognition of their prior learning, qualifications and experience.

Since the year 2000, many Zimbabweans have migrated to other countries, including the United Kingdom, due to the deteriorating social and economic situation. Political oppression, shortage of basic commodities such as food, caused by the compulsory Land Reform and Resettlement Programme, eroded the livelihoods of many people. The result was a massive exodus of people at all levels of social stratum in pursuit of better life opportunities (Bloch, 2005). Most of those who came to the United Kingdom sought to regularise their stay by applying for asylum in order to have access to education and employment opportunities.

Many Zimbabwean migrants entered the education system for various reasons that included taking advantage of free adult education in England, upgrading their professional qualifications to align them with the requirements in England and to support changes in their career paths. The large numbers of Zimbabwean migrants to England justified our focus on this migrant population in this research.

Moreover, the main author of this paper, Norman Maphosa, is a Zimbabwean migrant himself and shares similar experiences with this study population. Maphosa was born, educated, trained and worked as a mathematics teacher in Zimbabwe. Maphosa came to England in 2006 to study for an MPhil after which, due to the same social and political reasons that prevailed in Zimbabwe, he sought asylum and continued with education to acquire a doctorate degree in education. Maphosa has worked as an adult numeracy tutor in England since 2012.

The primary research questions driving the study were:

- What prior learning and experience do Zimbabwean adult learners bring into their adult numeracy classes?
- Do Zimbabwean adult learners find their adult numeracy programmes relevant to their needs and aspirations?

Background: Mathematics and Adult Numeracy Education in Zimbabwe and England

Mathematics Education in Zimbabwe: the legacy for migrants

Migrants from Zimbabwe to England are a diverse group, and include professionals, refugees and asylum seekers whose academic prior achievement can vary from primary education level to postgraduate level. According to Bloch (2005), 97% of 500 Zimbabwean adult participants had formal qualifications above average compared to a similar British population and other migrant groups. English is a second language for most Zimbabwean migrants; the most common first languages being Shona and Ndebele.

Zimbabwe is a former British colony, previously known as Rhodesia until independence in 1980. Formal education only started with the advent of colonialism and the arrival of Christian missionaries. These two phenomena shaped the history and development of both formal education and cultural identity of the Zimbabwean people. The colonial education policies were largely shaped and constrained by the values and assumptions of a white settler elite determined to maintain a socio-economic and political dominance over other ethnic groups in the country (Hungwe, 1994).

Ajayi, Goma, & Johnson (1996) argue that colonial education caused the colonised to lose self-respect as the colonised people's heritage was deliberately excluded in the curriculum to maintain dominance and create a receptive indigenous society with a new identity. In Zimbabwe, the colonial education system was formulated and structured around the nineteenth century British middle-class education system (Shizha, 2006). Shizha further argues that the imposed hegemonic culture disrupted the values of pre-colonial indigenous knowledge and learning that reflected the social and cultural needs of the community.

There existed two separate education systems; the European Education system for the white community, and the African Education system for the Black community (Hungwe, 1994, Morris 1963). The colonial government claimed justification for separate education systems based on the perceived 'primitive' nature of the social background of the black child compared to the white child's background (UNESCO 1964).

The education provided for most black children was intended to create a strong labour force for the industrial and farming sectors. Although the church appeared sympathetic to the cause of indigenous people by providing formal education and building schools for black children, it too acted as a vehicle for colonialism (Dirks, 2006; Shizha, 2011). Basic mathematics was adapted from the British curriculum, and one peculiar feature before the 1970s was the use of British units of measurement such as miles, feet and inches; and British currency such as pounds and shillings. Many black African children were educated only to primary level in this era.

As the economy of Rhodesia developed, the need arose for a more skilled workforce, which forced the government to improve the quality and level of education for black children (Wilks et al, 1977; Hungwe, 1994). International examinations were then introduced in the African curriculum with Oxford and Cambridge University curricula and examinations adopted in secondary schools (Nyoni, 2012). The standard of education in Rhodesia became one of the highest in Africa until Zimbabwe's independence in 1980.

Over the first decade of Zimbabwe's independence, reforms in the education system focused on the principle of 'Education for all', adopted at independence (Kanyongo, 2005). Woolman (2001) argues that one of the greatest challenges faced by modern Africa is the reform of inherited educational systems that largely functioned to maintain the colonial order of dependency and elitism. The challenges involved reconstruction of the curriculum to reflect indigenous traditions, values, beliefs and knowledge systems at the same time integrating the demands of modernisation.

Major reforms included the amalgamation of the two separate education systems that were present before independence, and significant increases in the number of schools and colleges. There was a shortage of qualified teachers, especially for mathematics and science subjects, and to accommodate the expanded education program, the government introduced a low-cost teacher training scheme.

However, the mathematics curriculum remained greatly unchanged despite these reforms following Zimbabwe's independence (Nyaumwe, Bhunu, & Makonye, 2007). The Zimbabwe school mathematics curriculum (like other core subjects), has remained a close match to that of England (Chakanyuka, Chung, & Stevenson, 2009). Of particular interest to the study presented here, many school children gained qualifications at O-Level, very similar in scope and content to the GCSE qualifications still current in England today.

Post-Colonial Theory and Mathematics Education

Post-colonial theory considers how European nations conquered and controlled other cultures and how the former colonial societies have since resisted and responded to colonial legacy (Ashcroft, Griffiths, & Tiffin, 2002). Colonialism involves domination and subjugation of one group of people by another more powerful nation. The meaning of 'colonialism' is unsettled and discursive, depending on the time, place and situation referred to in history (Ashcroft, Griffiths, & Tiffin, 2002; Kohn, 2012). The aim of colonialism is to occupy lands, exploit resources, and set up means of control of the occupied territory through military conquest and suppression of indigenous culture (Childs & Williams, 1997; Said, 1993). Thus, colonialism was not only a military conquest but also a cultural conquest establishing social reforms that suit the aspirations of the coloniser.

To this end, education and educational curricula played a pivotal role in ensuring effective and continued suppression of indigenous culture which was pushed to the peripheries of power (Nkosi, 2002, Fanon, 1961). Ashcroft et al (2002) indicate that one of the main features of colonial oppression was control over language.

Mathematics was long considered to be universal and culturally neutral. The argument was that mathematical statements are true the world over, for example, 2+1=3 irrespective of culture. However, mathematical ideas were gradually recognised to be humanly constructed and therefore have a cultural history (Bishop 1990). Other cultures have their own mathematics, sometimes referred to as 'ethno-mathematics'.

Bishop (1990) argues that modern mathematics is a result of western cultural history and hence refers to it as 'western mathematics'; as opposed to other lesser-known mathematics developed by other cultures. To the colonized societies, 'the western mathematics curriculum was abstract, irrelevant, selective and elitist – governed by structures like the Cambridge Overseas Certificate, and culturally laden to a very high degree' (Bishop, 1990, p. 55). Hence, like language, mathematics could become a strong weapon of cultural colonisation as it affected the daily lives of all indigenous people who had to come to terms with such measures as the western calendar, time, distance and money.

The study of post-colonialism considers how the former colonial societies have since resisted and responded to colonial legacy (Ashcroft, Griffiths, & Tiffin, 2002). It focuses on the history of colonialism and its continued effect on the de-colonized societies and their identity.

> Coloniality refers to the continuity of colonial forms of domination after the end of colonial administrations, produced by colonial cultures and structures in the modern-colonial capitalist world-system (Grosfoguel, 2005, p. 287)

According to Said (1978), knowledge and power were the basic tools that made colonialism possible and sustainable. During colonialism, what counted as knowledge was what was seen as such in the eyes of the coloniser, and that had to be instilled into the minds of the colonised through carefully tailored education systems.

Migrants from formerly colonized countries may find that they are still disadvantaged by these lingering hegemonies. Pitman & Vidovich (2013) point out that educational institutions tend to privilege particular forms of accredited learning over that gained through experience. Miller (2008) notes that migrant professionals in England have their expectations dashed when their qualifications and work experience gained in their home countries are not recognised as legitimate by employers and accreditation bodies.

Mathematics and Numeracy Qualifications in England and Zimbabwe

In this section we briefly outline some of the numeracy and mathematics qualifications for adult learners in England, and their relationship to those in Zimbabwe. We ask the reader to bear with us, since a comparison of these qualifications is pertinent to the findings of this study.

The National Qualifications Framework allows the levels of different types of qualification in England to be compared. Although the Framework goes up to Level 7 (doctoral level), here we are interested in Level 2, the target level for 16-year-olds completing compulsory schooling.

A Level 2 qualification in Mathematics is a gatekeeper for access to many university courses and professional careers. For 16-year-olds in England, the usual Level 2 qualification is the General Certificate in Secondary Education (GCSE). However, for adult learners, alternative mathematics/ numeracy qualifications have been developed over the last couple of decades, including the National Certificate in Adult Numeracy, and the subsequent Functional Skills Mathematics qualifications. Like GCSE Mathematics, these qualifications could/can also be taken at Level 2, but the content is different, focusing on the mathematics regarded as useful for everyday life and work, and covering very little algebra and geometry.

The Department for Education originally hoped that these might be regarded by industry and higher education institutions as equivalent to GCSE Mathematics, whilst providing a more relevant and accessible route for adult learners. There is an ongoing reform process of Functional Skills in mathematics and English which aims to ensure that these qualifications meet employer and higher education needs in terms of the knowledge and skills that learners achieve (Beach, 2019, Ofqual, 2019). However, there are signs that participation in Functional Skills Mathematics courses has declined between 2015 and 2018 and that government policy is becoming less supportive of Functional Skills Mathematics (Dalby & Noyes, 2020). In practice, most universities and professional career paths still demand the more traditional GCSE Mathematics.

In Zimbabwe, the equivalent qualification is 'O-Level' (Ordinary Level) Mathematics. According to its awarding body, Cambridge Assessment (formerly UCLES), this qualification should be regarded as equal in status to GCSE Mathematics (Cambridge Assessment 2020). The Zimbabwe School Examinations Council (ZIMSEC), the successor to (UCLES) in Zimbabwe, continues to assess the relevance of mathematics skills taught within the O-Level curriculum to the requirements of the world of work (Matorevhu, 2020). It is also worth noting that 'O-Level' was the name of the forerunner of GCSEs in England; when the name was updated in England, it was retained for international qualifications. We therefore conclude that to consider the Zimbabwean 'O-Level' qualification as inferior to the British GCSE qualification would be unsustainable.

Methodology

To learn about the experiences and beliefs of Zimbabwean adult numeracy learners, a mixed method approach was adopted. An exploratory focus group and a questionnaire survey were used to obtain a broad picture, followed by interviews to obtain richer, more in-depth, and more open-ended accounts (Denzin & Lincoln, 1998; Bernard, 2000). Adult numeracy tutors with Zimbabwean students in their classes were also interviewed, thus providing an opportunity for triangulation. With an interpretivist perspective underpinning this research, an inductive approach was taken to identify patterns observed from the data for analysis and to construct a meaningful account of the lived experiences of the participants (Strauss & Corbin,1998, Charmaz, 2006).

The participants: Learners and Tutors

Learner participants for the initial focus groups were recruited from the migrant community in which the main researcher was working as an adult numeracy tutor.

To identify potential learner participants for the questionnaire survey, fourteen Further Education colleges, six community centres and seven churches in England were approached by a letter requesting permission to conduct research[ii]. One hundred fifty-two email addresses of potential participants were collected through "snowballing" (Noy, 2008), of whom 101 took part in this phase of the research. These included adult learners studying numeracy at all levels from Entry 1 to Level 2.

Purposive sampling was used to recruit learner participants for the in-depth interviews; invitations were sent to those participants who had provided full responses to all or most questionnaire items. Seven learner-participants in total took part in the in-depth interviews; all were black Zimbabwean learners aged nineteen years and older.

Five adult numeracy tutors were recruited for the in-depth interviews from an adult education service in a large city in the North of England. Tutor participants were selected firstly from institutions that had current Zimbabwean numeracy learners in their classes followed by those who had once taught Zimbabwean learners. Four of the tutor-participants were white British, three males and one female; the other tutor was female of Indian origin.

A table summarising participant profiles can be found in Appendix A.

Data Collection

The first phase of data collection involved an exploratory focus group of six adult numeracy learners, which was then used to inform the questionnaire survey. Participants were asked to freely discuss their experiences and opinions about their experiences enrolling on adult numeracy course in England, and their discussion was recorded and transcribed for analysis.

Following transcription, the focus group data was used as a basis for drawing up a questionnaire, which consisted of mostly closed-ended questions and a few open-ended questions (Gillham 2008). The questionnaire was piloted through the focus group participants, and modified accordingly. It was then distributed by a Smart-Survey link to 152 adult numeracy learners, of whom 101 responded. A copy of the questionnaire can be found in Appendix B.

The second phase of data collection involved individual in-depth semi-structured interviews of seven learner and five tutor participants. Learner interviews took place at participants' homes in order to offer a comfortable environment to participants. Again, each interview was audio-recorded for transcription and analysis.

Data analysis

Data collected during the focus group was transcribed and coded to identify emerging themes to inform the questionnaire design. The coding was also used as a basis for thematic analysis in the second phase of the study.

The questionnaire data was analysed using the online Smart-Survey software programme.

Data collected during the in-depth interviews was transcribed and coded using the same codes that were used for the focus group interview and the questionnaire data while also allowing new codes to emerge. Frequency and co-location of key words and phrases and ideas were used to identify the most commonly occurring themes, and a Venn diagram was used to map code overlap across emergent themes (Dawson, 2011).

Findings

Inductive analysis of all data strands resulted in a broad range of insights into the experiences of adult Zimbabweans learning numeracy in England. Full findings are presented elsewhere (Maphosa 2018), but here we particularly focus on the extent to which the learners found their numeracy classes relevant to their prior achievements and their future aspirations.

Reasons and goals for enrolling on adult numeracy courses

One of the research aims was to find out why Zimbabwean adult learners enrolled on adult numeracy courses and whether these courses met their expectations and goals. The questionnaire asked participants about their reasons for enrolling on adult numeracy courses, using a Likert scale to rate the importance of a range of possible reasons. The results are summarised in Figure 1 below.

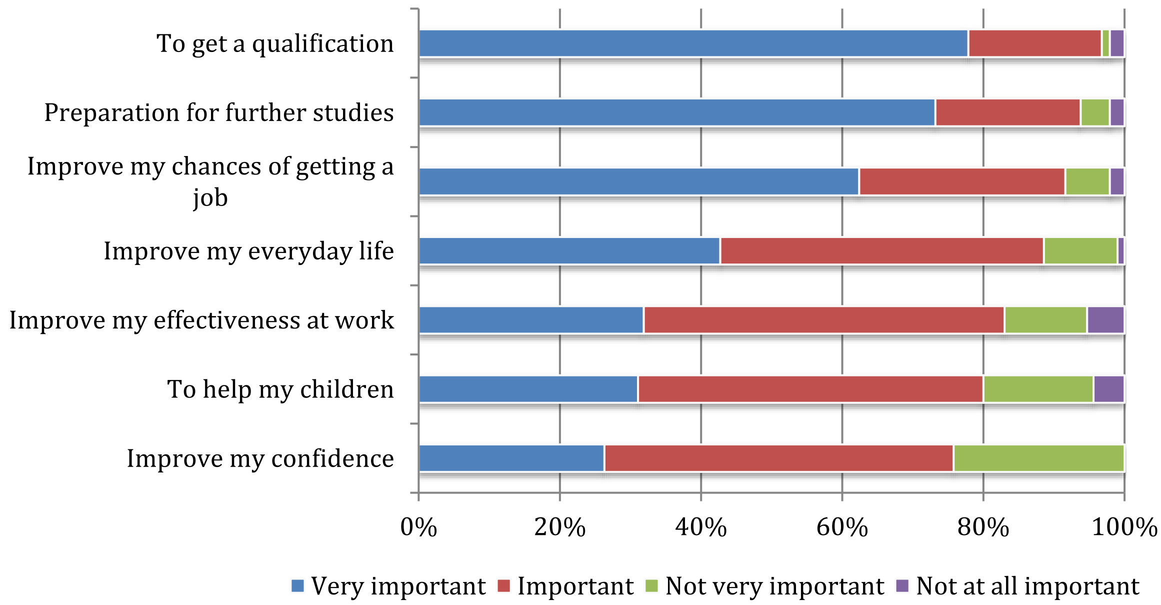

Figure 1. Frequency rating of reasons respondent enrolled on an adult numeracy course

Figure 1 shows the frequency and percentage of responses arranged in descending order of importance to the adult learners. Gaining qualifications, and being admitted to further educational opportunities and careers were rated highest, and it is notable that improvements to effectiveness in everyday life and work were not widely considered to be so important.

The need to further their education and get a qualification was further confirmed as important by learner participants during focus group and in-depth interviews. It is again worth noting that the need to improve effectiveness in everyday life and work were not spontaneously mentioned by any of the interview participants in their open-ended interview responses. However, some participants did consider helping their children to be an important factor in deciding to enrol on adult numeracy courses.

Farai. …but it's like some of the adults do mathematics in order to help their children and children do not have to think of all these complicated situations. May be what is important for me is to be able to work with numbers like multiplication so I can help my kids with maths.

Florence Yes, they [numeracy skills] do help because if you are in a situation that you cannot help your children it's not good… but if you can then you find that you are really supportive.

Prior learning experience and qualifications

Participants reported mixed experiences of education in Zimbabwe. Some interview participants reported that not everyone had access to schooling, and that this was often dependent on the family’s socio-economic status.

Gloria Yes when I was going to school… it would depend on the child’s background; some parents were not able to send their children to school because they had not had enough money

Maria It depends on whether the parents could afford sending their children to school or not

Conversely, other participants had had access to full schooling, and a wide range of qualifications, up to degree level. Questionnaire respondents were also asked to indicate the highest qualifications they had achieved in Zimbabwe.

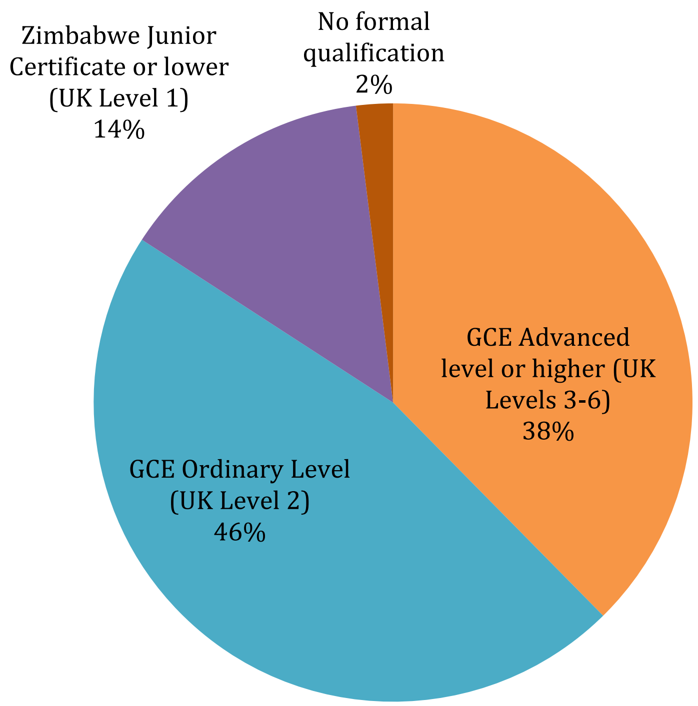

Figure 2 Highest educational qualification achieved in Zimbabwe

The majority in this participant cohort, 84%, had qualifications at GCE Ordinary level and above at the time they enrolled on adult numeracy courses. This finding is important as arguably, a GCE Ordinary level is equivalent to a GCSE qualification in England, as discussed above. However, some respondents expressed dissatisfaction with the manner in which their qualifications were not given credit for entry into higher education, and instead they were required to undertake a further qualification as a pre-requisite:

Farai Yah for example people come here with high levels of mathematics but they are placed in level 1 or level 2, then they are like ‘What am I doing here?’

Bongi But sometimes if you check, whether you have done ‘A’ level or ‘O’ levels or whatever, when you come here they will tell you that you did not do this here…

The opinions of tutor participants concurred with those of learner participants on the high level of prior educational experience possessed by Zimbabwean adult learners.

Isaac …generally Zimbabwean learners have been enrolled in higher levels, level 1 and 2 or GCSE as opposed to entry levels…

Sahida …the men that I have taught showed that they had gone through the schooling system in Zimbabwe, but when they came here, they were expected to do Level 2 English and maths, not that they really needed them, but it was something they had to do to access higher education courses. Because they had done the English and maths back home.

However, it should also be noted that some participants did feel that further numeracy learning was valuable for them, for example:

Florence When I wanted to go to university, I realised that my level of mathematics was really low and I could not meet the entry requirements for university. I decided to start at a lower level because I had last attended school long ago and I had not done GCSE level mathematics, so I couldn't do any higher education with the levels I had.

Phillis …yes because I could not have been able to enrol at university or manage to get a maths qualification after years of trying and failing to pass maths. I could have tried because I really wanted to get a maths qualification, now wherever I go I am able to say that I have an equivalent of O level maths, I am happy.

'Watered down' mathematics

Participants reported that they found mathematics to be a difficult subject to learn, both in Zimbabwe and in England. However, participants considered the mathematics they were learning in the English numeracy classes to be easier than the mathematics they had learned at school in Zimbabwe. This was reported by almost all learner participants irrespective of age, prior qualifications or gender. For example, according to Phillis:

Phillis …when I wanted to do my Masters in social care, I could not enrol because they wanted mathematics. To be frank I was not good in maths but I found that there was a shortcut to doing maths rather than going to do a full course in mathematics. Numeracy was easy; I did it over summer…it was an easier version of mathematics… which I found easy.

Many of the participants used their experience of O-Level mathematics in Zimbabwe as a point of reference to declare their background knowledge of mathematics, and to which they compared their learning in England. In particular they compared the topics covered at O-Level in Zimbabwe with those included in (or excluded from) the English Adult Numeracy Core Curriculum. For example, Phillis went on to explain that she found the numeracy content very easy because it did not cover algebraic equations and other of the more difficult topics covered at O-Level. Similarly, Dade suggested that adult numeracy is 'watered down' mathematics

Dade Yeah, yeah, I think there is too much watering down of their maths, as I was saying, back home it was purely academic with formulas

The use by participants of dichotomous perspectives of 'easy' and 'difficult' when describing their numeracy learning experiences is of interest here. Further analysis of the participants experiences of teaching and learning enabled us to unpack these terms. As reported in the remainder of this section, some participants associated the difficulty with the mathematical subject content; and others with the teaching and assessment methods used both in Zimbabwean mathematics classes and adult numeracy classes in England.

Teaching and learning approaches in Zimbabwe and England

To most learner participants, the teaching approaches used in numeracy classes in England were new and unfamiliar. Interaction in numeracy classes was reported to have presented many new learning experiences especially with regards to collaborative learning, where the learners were expected to work in groups and also to take responsibility for their own learning. The traditional rote learning model they expected, based on their experience of mathematics classes in Zimbabwe, was absent in these adult numeracy classes.

One of the teaching and learning approaches critically reported by most participants was the use of games during numeracy sessions, often regarded as 'good practice' in English classrooms (for example Steeds, 2001). Learner participants reported that games as a learning strategy were not appealing to them and viewed by some as childish, for example:

Dade — The approaches were good but at times you know, as an adult learner there are some things like games…games are good but as an adult some of these games are childish… I don't know how they can be changed because you don't want to feel like you are in primary school or something.

Dade goes on to compare such approaches to the 'academic' style of learning she experienced in Zimbabwe, focusing on the apparent conflict between her heritage culture and host culture:

Dade — Students were comparing methods… they were showing how they do things in their countries in a different way. On how they did their maths at home, I mean…where you play a game and you are supposed to learn from that, we never used games. Our learning of maths was purely academic, the teacher will come and teach and expect you to learn that. And this was common to all foreign students, they did not use, I mean games were a new thing to them. We did not use games.

Another area which learner participants found problematic was the contextualisation of the numeracy subject content, in which they found themselves having to contend with unfamiliar contexts, for example, cooking a turkey for Christmas dinner:

Tayina — Last year when I was doing Level 1 we were taught how to cook eh...what do they call this they cook for Christmas?

Group — A turkey!

Tayina — Yes a turkey, and when we asked why we were doing this in a maths class, our tutor told us that it is because there are measurements, there is hours and minutes for cooking.

A turkey is not a common dish in Zimbabwe, so talking about the method of cooking a turkey seems to have instilled anxiety on learners like Tayina and may have distorted the actual learning of numeracy. Even the concept of a turkey itself seems to be unfamiliar to Tayina as she refers to it as "this they cook for Christmas". The problem of contextualization was not confined to unfamiliar situations but also came up as an issue with other seemingly common contexts like travelling on a holiday.

Tayina — And we were taught about going on holiday and when we asked why, he said because there are miles to travel and there are heights…

Farai — Trying to make you understand…

Tayina — But in Zimbabwe I think that was taught in geography.

Tutor participant Regina defends the use of such contexts, arguing that it is driven by the demands of the examination:

Regina — I can use examples from other cultures like recipes and so on yes, but that will not come in the examinations because examinations are British based.

Regina argues that using English contexts for numeracy teaching contributes towards familiarising migrant learners with the culture of their new country. This argument is acknowledged by the learner participants, but not uncritically. For example, learner Tayina indicates feelings of cultural imposition on the learners:

Tayina — Here they educate you to know how they live in this country, which if you leave this country to another country you look like somebody who is not educated…

It is generally assumed that the teaching and learning approaches commonly offered in adult numeracy classrooms, such as the use of games and practical or 'real-life' contexts, will make mathematical learning more accessible. However, for the Zimbabwean migrant learners in this study, these approaches actually seemed to present barriers. In one particularly illuminating comment, Bernard suggests that his prior mathematical learning in Zimbabwe was actually needed to help him overcome these barriers:

> Bernard The methods some of them are difficult to follow especially … that is why it was a little bit difficult for me… Because of my background and knowledge may be on the field of mathematics, it could make it easier to follow it along. Yes, I found it easier because O-Level is difficult, that is what I found here, this Level 2 was a little bit easier than the O-Level that I did.

Discussion: a post-colonial legacy

The data presented above illustrate a number of recurrent and inter-relating themes. In our discussion, we argue that the participants have been subject to colonialist hegemonies both in Zimbabwe and in England. Their Zimbabwean schooling and qualifications were originally imposed on them by the British education system, with some of the participants receiving an inferior education. Later, for those that did receive a better education, their prior learning and qualifications were not sufficiently recognised and acknowledged when they entered adult education in England.

Thus, it seems, the post-colonial cultural legacy continues to impact on the Zimbabwean migrants' mathematical attainment and accreditation in a number of ways, which we explore in the remainder of this article.

'You did not do this here': non-recognition of prior learning in Zimbabwe

The survey of Zimbabwean adult numeracy learners in England showed that the majority of respondents were studying numeracy in order to gain a qualification leading to better employment or educational opportunities.

On starting to study for English adult numeracy qualifications, many participating learners found that they were being expected to study mathematics at a lower level than they had previously studied in Zimbabwe, and to embrace a mathematics 'skills deficit' that had apparently been imposed on them. They considered the numeracy they were studying in England to be a 'watered down' version of mathematics. These perceptions were echoed by the accounts given by tutors, who reported that their Zimbabwean learners often had good levels of mathematical skills from the outset. The learners also found some of the learning approaches used in English classrooms, such as games, trivialising and childish – and this has a further irony since some learner participants expressed a preference for the rote-learning originally introduced to Rhodesia by the British colonisers.

In their original schooling in Zimbabwe (or Rhodesia for older participants), participants had been obliged to engage with a curriculum imposed upon them, either by their colonial rulers, or as a hegemonic legacy of those rulers. As argued by Said (1978), what counted as knowledge during colonialism was that which was seen as such in the eyes of the colonizer.

For some of the participants, particularly those who had been at school prior to independence in 1980, this took the form of a lower tier education system, and some of the participants had not had the opportunity to gain a mathematics qualification in Zimbabwe.

However, most of the participating Zimbabwean learners studied a curriculum originally based on the English education system, often using textbooks published by English publishers, and leading to O-Level qualifications claimed to be equivalent to the English GCSE qualifications (Cambridge Assessment 2020). Thus, a significant proportion already had a GCE O-level mathematics qualification gained in Zimbabwe that was at the same or a higher level than the qualification they were studying for in England (National Certificate in Adult Numeracy or Functional Skills Mathematics at Level 1 or 2). Participants reported that their qualifications from Zimbabwe were not accepted by employers and educational institutions in England. They were told, ‘you did not do this here’. It appears that the post-colonial hegemony continues, in regarding qualifications gained in former colonies as inferior to those gained in England.

Indeed, several participants in this research had professional qualifications ranging from diplomas to degree level which they felt were under-recognized. Doyle (2009) reports on wasted skills and enforced dependence among Zimbabwean asylum seekers in the UK. The assessment of Zimbabwean qualifications as inferior or inadequate may be perceived as some form of colonial legacy intended to place the subjects of a former colony in their rightful place as ‘inferior others’ (Ashcroft, Griffiths, & Tiffin, 2002).

‘Here they educate you to know how they live in this country’

The emphasis on functional skills and contextualised questions – a keystone of adult skills policies in England (Wolf, 2011; Ofqual, 2015) – also caused difficulties for them. Firstly, the wordiness of questions made the problems harder for those with English as a second language; secondly, many of the contexts, such as cooking a turkey for Christmas, seemed unfamiliar and irrelevant to the Zimbabwean learners, who preferred the ‘academic’ or ‘pure’ mathematics they had studied in Zimbabwe.

For many of the participants, the notion that functional skills mathematics will help them to be functional in work, society and their everyday lives was not seen as applicable. For the majority, this was not their goal in learning numeracy – and indeed, some of them had been working as professionals for many years in Zimbabwe. McGrath, Madziva and Thondhlana (2017) noted that the experience of some migrant Zimbabwean professionals had made them more multi-skilled than their typical English counterparts.

Furthermore, to be functional within the context of British society could be perceived as cultural dominance by the host society over the migrant learner whose long-term goal may be beyond life in England. The participants in this study perceived the functional skills curriculum to be non-academic and a barrier to their academic progress. Some tutor participants argued that the use of British context is justified because the migrant graduates will function within the British society. However, learner participants disagreed with this notion and argued that even basing numeracy tasks on career jobs is not viable as learners in a class will normally have different career paths and experiences.

The vocationalisation of adult numeracy and functional skills mathematics with the view of satisfying the needs of the employer, may be seen as comparable with the vocationalisation of the African Education system in Rhodesia (Zimbabwe) was aimed at training the African people for service to their colonial master (Chakamba, 2013). Chakamba describes how the vocational route in colonial Zimbabwe was a practical biased curriculum meant for the majority who were declared unsuitable for the academic route. Considering that the long-term goal expressed by most of the learner participants was to progress to higher education, their interpretation of vocational education may differ from that intended by curriculum developers, particularly as adult numeracy and functional skills mathematics qualifications are often not accepted for entrance to higher academic studies.

Implications for policy and practice

This research suggests that many Zimbabwean adults have a unique historical background that strongly influences their experiences and perceptions of education and mathematical learning. Our findings thus have a number of implications both for classroom practice and for the acknowledgement of migrant learners' prior skills and qualifications.

We encourage teachers of adult numeracy to learn more about the background and history of their learners from the outset, and to consider the diversity of life experiences within the classroom to select appropriate teaching and learning approaches.

While we do not want to discourage the use of games and similar activities for learning, these should be used with discretion and cultural sensitivity, selecting activities that take cognizance of age and background of learners (Koivisto & Malik, 2020). One example is digital games, which can enhance motivation and engagement (Olaguro et al 2019, Hamari, Koivisto and Sarsa, 2014).

We encourage the use of critical pedagogies by tutors that allow learners to freely question certain ideologies and practices which they consider culturally oppressive in the classroom. Such an approach would allow learners to steer the learning experiences towards their own life experiences and reduce feelings of cultural imposition.

Lastly, we would like to see employers and institutions of higher education better equipped to assess the value of qualifications gained in other countries, and to acknowledge and recognise them appropriately. Where prior qualifications are considered to be insufficient or outdated, it is not necessarily appropriate to relegate the learner to a lower level of learning, but to provide more tailored routes to update knowledge or 'bridge' a skills gap (Robinson et al, 2019, Ofqual, 2019).

Conclusion

Our data and analysis in this article suggest that the majority of Zimbabwean adult numeracy learners participating in the study did not feel that they needed to improve their numeracy skills for everyday life and work. Instead, they had undertaken their adult numeracy learning in order to enter higher education or professional career pathways. They felt that their prior learning of mathematics in Zimbabwe had been higher than their Level 2 adult numeracy programmes and therefore felt that this prior achievement had not been recognised or valued.

Some teaching and learning approaches commonly used for adult learning in England, such as the use of games, were considered childish by adult Zimbabwean learners. The study also found that the current emphasis on 'real-life' contexts for adult numeracy learning and assessment presented challenges to Zimbabwean learners. Many of these contexts were based on British culture and were unfamiliar to the learners. They expressed a preference for what they called 'academic' (or pure) mathematics, which they had studied in Zimbabwe, and some suggested that the focus on British contexts represented cultural imperialism in requiring them to conform to the norms of British culture.

We have argued that the post-colonial legacy of the British rule in Rhodesia has not only impacted historically on the participants' learning experiences, but it is still actively presenting barriers to them in their new lives in England. We call for greater cultural sensitivity and acknowledgement of these issues by education providers, in order to develop learning experiences which better meet the needs of migrant learners, from Zimbabwe and from other countries around the world.

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Notes

[i] The terminology surrounding mathematics/ numeracy education for adults is complex and contested. For convenience, the term “adult numeracy” throughout this article refers to mathematics education for adult learners up to Level 2, the target level for 16 year-olds completing compulsory schooling in England.

[ii] All phases of this research received ethical approval from the University of Bolton.

Appendix

In-depth interviews: learner participant description

Pseudonym	gender	language group	Profession/occupation in:	
			Zimbabwe	England
Dade	F	Ndebele	secretary	nurse
Florence	F	Ndebele	unemployed	student
Maria	F	Shona	secretary	nurse
Phillis	F	Shona	secretary	social worker
Brenda	F	Ndebele	teacher	social Worker
Gloria	F	Ndebele	unemployed	carer
Bernard	M	Ndebele	mechanic	housing officer

In-depth interviews: tutor participant description

Pseudonym	gender	First language	Occupation/Position
Thomas	M	English	Adult numeracy and mathematics tutor
Isaac	M	English	Adult numeracy and mathematics tutor
Sahida	F	Urdu	Adult numeracy tutor and line manager
Regina	F	English	Adult numeracy and Family learning tutor
Nick	M	English	Adult numeracy tutor and curriculum manager

QUESTIONNAIRE

Experience with learning Numeracy (Mathematics) in England

Please answer the following questions.

1. Gender (please tick) Male ☐ Female ☐
2. What is your age range?
   - 18 – 25 ☐
   - 26 – 35 ☐
   - 36 – 45 ☐
   - 46 – 55 ☐
   - 56 + ☐
3. Employment status
   - Employed ☐
   - Unemployed ☐
   - Looking for work ☐
   - Unpaid work ☐
   - Retired ☐
   - Other ☐

If "Other" please write in here

4. What is the highest educational qualification you obtained in Zimbabwe?

   - None ☐
   - Grade 7 (Standard 6) or below ☐
   - Zimbabwe Junior Certificate (ZJC) ☐
   - Form 4 (“O” Level) ☐
   - Form 6 (“A” Level) ☐
   - National Certificate ☐
   - National Diploma ☐
   - Higher National Diploma ☐
   - First degree ☐
   - Master’s degree ☐
   - Doctorate ☐

5. What would you say are the reasons you were not able to further your education in Zimbabwe? (Please tick all that apply).

   - No money to pay for my education ☐
   - Because I was a girl ☐
   - Because I was a boy ☐
   - Education was not important in my family ☐
   - Schools were far from my home ☐
   - It was the time of war in Zimbabwe ☐
   - Other ☐

   If “Other” please write in here

6. At what age did you leave full-time education? (Please write **N/A** if not applicable) ☐

7. What is the highest educational qualification you have obtained in England?

None	☐
GCSE or below	☐
A level	☐
Certificate	☐
Diploma	☐
Higher Diploma	☐
First Degree	☐
Master's degree	☐
Doctorate	☐

8. What is the highest Adult Education numeracy course that you have completed in England?

None	☐
Entry level 1	☐
Entry level 2	☐
Entry level 3	☐
Level 1	☐
Level 2	☐

9. On which adult numeracy (mathematics) course are you currently enrolled?

None	☐
Entry level 1	☐
Entry level 2	☐
Entry level 3	☐
Level 1	☐
Level 2	☐

10. Please rate the items below in terms of their importance as reasons for your enrolment on an adult numeracy (mathematics) course.

	Very important	Important	Not very important	Not at all important
Preparation for further studies	☐	☐	☐	☐
Improve my effectiveness at work	☐	☐	☐	☐
Improve my chances of getting a job	☐	☐	☐	☐
To help my children	☐	☐	☐	☐
To get a qualification	☐	☐	☐	☐
Improve my everyday life	☐	☐	☐	☐
Improve my confidence	☐	☐	☐	☐
Help me fit in with life in England	☐	☐	☐	☐
For personal interest	☐	☐	☐	☐
A requirement by my employer	☐	☐	☐	☐
Other	☐	☐	☐	☐

If “Other” please write in here

11. How would you rate your progress in the learning of adult numeracy (mathematics) in England?

    Very good ☐

    Good ☐

    Average ☐

    Below average ☐

    Poor ☐

12. In what ways would you say the learning of numeracy in England differs from the way numeracy is learnt in Zimbabwe?

13. Which of the following factors if any, would you say were a challenge in your learning of mathematics in Zimbabwe?

    English language ☐

    Ways in which it was taught ☐

    Shortage of textbooks and other learning materials ☐

    The attitude of teachers ☐

    I just didn't like mathematics ☐

    None ☐

14. Which of the following factors if any, would you say are or were a challenge in your learning of adult numeracy in England?

English language ☐

Ways in which it is taught ☐

Shortage of textbooks and other learning materials ☐

The attitude of teachers ☐

I just don't like mathematics ☐

None ☐

15. What would say are the learning barriers during an adult numeracy (mathematics) lesson in England? (Please tick all that apply).

The use of English language ☐

Teacher accent ☐

Teaching methods ☐

Learning with people from different cultures ☐

Use of computer based methods ☐

Teacher attitude ☐

Attitude of other learners ☐

Mixed class (E3s in the same class with L1s) ☐

Other ☐

If "Other" please write in here

16. Which of the following do you find most useful to you in the learning of adult numeracy (mathematics)?

Working through problems in pairs ☐

Working through problems in small groups ☐

Working through problems alone ☐

Working through problems on a computer ☐

Other ☐

If “Other” please write in here

17. Please rate the items below in terms of your experience learning adult numeracy (mathematics) in Zimbabwe.

	Strongly agree	Agree	Disagree	Strongly disagree
Memorizing of (e.g. times tables and formulae) was important	☐	☐	☐	☐
Computers were not used	☐	☐	☐	☐
Learning aids e.g. sticks, stones were used to help in learning	☐	☐	☐	☐
There were shortages of textbooks and other learning materials	☐	☐	☐	☐
Girls always performed better than boys	☐	☐	☐	☐
Methods used were better than those used in England	☐	☐	☐	☐

18. Please rate the items below in terms of your experience learning adult numeracy (mathematics) in England.

	Strongly agree	Agree	Disagree	Strongly disagree
Memorizing of (e.g. times tables and Formulae) are important	☐	☐	☐	☐
Computers are used	☐	☐	☐	☐
Learning aids e.g. counters, shape models games etc. are used to help in learning	☐	☐	☐	☐
There are shortages of textbooks and other learning materials	☐	☐	☐	☐
Females always perform better than males	☐	☐	☐	☐
Methods used are better than those which were used in Zimbabwe	☐	☐	☐	☐

19. Which of the following mathematics topics do you find most difficult? (Please tick all that apply).

Fractions	☐
Multiplication	☐
Division	☐
Ratios	☐
Metric units	☐
Other	☐

If “Other” please write in here

20. How would you rate your experience with learning numeracy (mathematics) in England?

Very satisfactory ☐

Satisfactory ☐

Unsatisfactory ☐

Very unsatisfactory ☐

21. What changes do you think could be made in order to improve the teaching and learning of adult numeracy (mathematics) in England?

Increase the time allocated for numeracy ☐

Avoid mixed level classes ☐

Include life examples from other cultures ☐

Other ☐

If “Other” please write in here

22. What other comments would you like to make?
Please write in here

Thank you very much for taking time to complete this questionnaire

Dalby, D. (2021). Changing images of mathematics in the transition from school to vocational education. *Adults Learning Mathematics: An International Journal*, 15(1), 45-57.

Changing images of mathematics in the transition from school to vocational education

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Abstract

Public perceptions of mathematics in England are often of a remote inaccessible academic discipline, and disaffection with the subject is a widespread problem. Results from a multi-method study of post-16 students in vocational education in England show however how students' experiences of mathematics after their transition from school to vocational education can lead to changes in their beliefs, emotional responses and attitudes to mathematics. The construct of a personal image of mathematics provides a model to capture these changes and leads to an examination of the features of students' learning experiences that allow positive images of mathematics to develop. Negative images are often grounded in prior experiences of failure and disaffection at school but exposure to a mathematics curriculum with a focus on application rather than knowledge, in a different educational setting, helps students develop an alternative view of the subject to the common image in society. Experiences of a different teaching approach also contribute to these new images, whilst shifts in students' values make their new encounters with a more applied form of mathematics particularly relevant.

Key words: Mathematics, images, affect, vocational education.

Introduction

An extensive review of post-16 mathematics education in England (Smith, 2017) highlighted the prevalence of poor attitudes to mathematics in society and the need to gain better understanding of this problem. Negative views of mathematics have been reported for some time in England (e.g. Buxton, 1981; Cockcroft, 1982) without evidence of any improvement or how this might be achieved. Although dominant attitudes in some countries differ, England is not alone in identifying negative attitudes to mathematics permeating society (Basic Skills Agency, 1997) and public images that commonly capture the subject as being remote and inaccessible (Ernest, 2008; Leder & Forgasz, 2010). Mathematics has historically been considered in many countries as the domain of a select minority with special ability (Buxton, 1981; Picker & Berry, 2000; Volmink, 1994) leading to contrasts between the views of mathematicians and the general public (Furinghetti, 1993). Impressions of secrecy, exclusivity and a 'gate-keeping' role have created a controlling but divisive function for the discipline (Volmink, 1994), which is often associated with polarised self-beliefs, of either having the capacity to understand the subject or being unable to comprehend it at all (Furinghetti, 1993). Such beliefs have led to opposing opinions, in which mathematics is claimed to be either loved or hated.

In contrast to these responses, ethnomathematics (d'Ambrosio, 1985) presents an alternative view of the subject as an intrinsic part of local cultures across the world, naturally embedded into the life experience of an individual. This suggests an accessible type of mathematics of a more applied nature that is used widely, although this frequently remains invisible in everyday life and work (Coben, 2002; Wedege, 2010). This view of mathematics does not feature strongly within an academically orientated education system such as exists in England and may be largely unrecognised by the public but is nevertheless woven into the fabric of daily life.

A dichotomy between a public image of mathematics as a remote academic discipline and experiences of mathematics in applied forms surfaces in English post-16 vocational education when students encounter alternative curricula such as functional mathematics. Functional skills mathematics focusses on applications in a range of contexts, in contrast to the more knowledge-based General Certificate in Secondary Education (GCSE) taken at age 16 years in school. Students' experiences of GCSE mathematics in school and functional skills in post-16 vocational education are the main focus of this paper and how exposure to two contrasting mathematics curricula in different educational settings affect their responses.

The construct of an *image of mathematics* (Belbase, 2013; Ernest, 2008; Furinghetti, 1993) is used to explore changes in students' perceptions of mathematics as they make this transition from school to vocational education and begin studying for a functional skills qualification. Research findings from a study of students (aged 16-19 years old) learning mathematics in vocational education (Dalby & Noyes, 2016) are re-examined to understand how changes in classroom experiences and curriculum affect students' images of mathematics, particularly focusing on those with lower than average attainment in the subject at age 16. Although the data is not recent, the findings are particularly relevant to current issues with post-16 mathematics that remain unresolved. The paper seeks to address two questions:

- What changes in students' images of mathematics take place in the transition from school to vocational education?
- How are students' images of mathematics shaped by new learning experiences and social values?

The context for the study will first be described before presenting a conceptual framework and discussing the notion of an image of mathematics. A summary of the main findings follows and key points are then discussed in the light of current policy before reaching some conclusions about the implications.

Context

The English education system is characterised by a historically grounded division of academic and vocational pathways. Students take the General Certificate in Secondary Education (GCSE) examinations in a range of subjects, including mathematics, at the end of lower secondary education (age 16 years) and these largely determine whether they subsequently follow an academic or vocational pathway. Most vocational education in England takes place in large further education (FE) colleges, whilst schools are the main providers of post-16 academic courses. Students who follow a vocational pathway would therefore normally experience changes in both curriculum and educational institution as they move into post-16 education. Such transitions are often associated with adjustments to social cultures and a re-shaping of personal identities (Ball, Macrae, & Maguire, 2000; Hernandez-Martinez et al., 2011) but, for students who undertake vocational study programmes, this is a significant step in a journey towards employment that influences their values (Turner, Harkin, & Dawn, 2000). Students' trajectories towards employment are often complex and fragmented (Cohen & Ainley, 2000) but vocational education involves a process of 'becoming' (Colley, James, Diment, & Tedder, 2003) in which new identities are constructed within an institutional culture where work-related values are dominant. In this transitional period, the reshaping of personal identities in a different educational setting provides an opportunity for new experiences of mathematics.

Since 2014, government policy in England has required post-16 students who have failed to achieve a satisfactory GCSE Mathematics grade (Grade 4) to continue studying mathematics and re-sit the examination. This may involve taking an interim qualification such as functional skills mathematics, which focuses on application and problem solving in 'real life' scenarios before retaking GCSE. Some students therefore experience a different type of mathematics in this period with an emphasis on application rather than an academic knowledge-based curriculum.

In schools, disaffection with mathematics is a significant problem (Brown, Brown, & Bibby, 2008; Nardi & Steward, 2003) and is often accompanied by a disinterest in continuing to study the subject. It is therefore not surprising that many low-attaining post-16 students initially exhibit negative attitudes when mathematics becomes a compulsory part of their vocational programme (Dalby & Noyes, 2016; Higton et al., 2017). A better understanding of these students' images of mathematics and the factors that encourage more positive dispositions, seems fundamental to developing strategies to re-engage them with mathematics.

Images and affect

In general, an image is considered to be a mental representation, idea or conception which can offer rich information and capture a holistic view of inter-related concepts. These mental representations may be expressed verbally or visually in, for example, drawings and metaphors (Picker & Berry, 2000; Sterenberg, 2008). These expressions may capture some elements of the mental image but not necessarily the full meaning or the origins of the views and dispositions they represent.

Presmeg (1997) refers to a distinct form of visual imagery based on memory that is created from personal experiences. Similarly, Ernest (2008) suggests that personal images of mathematics originate in past experiences but adds that these are influenced by social talk and therefore affected by dominant images encountered by the individual in society. Within students' images of mathematics we might then expect to find evidence of influence from common social images, alongside elements based on personal memories of previous encounters with the subject. This may well include the *separated* image of a difficult, cold, abstract and inaccessible subject which is prevalent in Western society (Ernest, 2008) and dispositions that are legacies of students' personal experiences of learning mathematics.

In a study of the dominant perceptions of mathematics amongst the members of the public, Sam and Ernest (2000) utilise a conceptualisation of image with a number of key elements, suggesting that these mental images may provide some important indicators of behaviour. The elements listed include a range of beliefs, attitudes and feelings (emotive descriptions) with statements about the nature of mathematics and the learning of the subject (Sam & Ernest, 2000). This conceptual view identifies fundamental constructs of mathematical affect such as beliefs, attitudes and emotions (McLeod, 1992) as constituent parts of personal images of mathematics, although the concept of values (DeBellis & Goldin, 2006) which is widely recognised as an important addition, is not included. Debates about the meaning of these terms have been on-going (Di Martino & Zan, 2010; Zan, Brown, Evans, & Hannula, 2006) but there are some key points of relevance to this study concerning the affective elements of an image of mathematics and cognitive development.

First, the distinction made between stable traits and transient states (McLeod, 1992) for these affective constructs suggests that changes in personal images may occur over short or long time periods. The possibility of short-term changes is particularly relevant to the transition of young people into vocational education where they may only be studying mathematics for less than a year before taking a further qualification.

Secondly, the claim that emotions and attitudes can influence cognitive functions (Zan et al., 2006) suggest that personal images of mathematics can have an important influence on the learning process. The exact nature of interaction between affective and cognitive functions remains unclear and the variety of models that incorporate different beliefs, attitudes, emotions and behaviour into one framework indicates the complexity of capturing such interactions (Di Martino & Zan, 2011; Goldin, Epstein, Schorr, & Warner, 2011).

Methodology

The data that informs this paper is part of a larger multi-method study of post-16 students in three large English further education colleges. Although the study was reported earlier (Dalby, 2014; Dalby & Noyes, 2016) the findings have been re-examined and provide evidence relevant to current issues.

Students from three vocational areas participated in the study: Hairdressing, Public Services and Construction. These areas were selected to ensure a balance of:

- Vocational areas with different gender biases;
- Vocational areas with strong and weak links to mathematics;
- Vocational areas with a practical or theoretical focus.

Case studies of 17 student groups in these areas and their mathematics teachers were carried out. The majority of the students were on a similar level of vocational programme (Level 2) and were all learning functional mathematics as an additional subject, taught in weekly lessons over the course of one academic year. All the teachers were considered as subject specialists (i.e. they taught mathematics as their main subject). Data were obtained from semi-structured interviews with teachers, teacher questionnaires, observations of classes and termly meetings with a focus group from each class. A total of 14 teachers were involved and 103 students took part in the focus groups.

In the first term, members of the focus groups completed an individual card-sorting activity and participated in discussions to explore:

- why they had come to college;
- what college is like compared to school;
- what functional mathematics is like compared to school mathematics;
- what learning mathematics in college is like compared to learning mathematics in school.

The card-sorting activity was designed to capture the views of individual students through an accessible ‘hands on’ task. Each student was provided with a Likert scale on a long strip of card and a set of statements on small separate cards. The researcher asked a question verbally and the students placed the cards, one by one, under the most appropriate heading on the Likert scale to indicate their view. For example, students were provided with the statements shown in Table 1 with a Likert scale for frequency (hardly ever/sometimes/about half the time/often/almost all the time) and asked to place the cards to describe their experience of mathematics lessons in school. They were then asked to repeat the exercise to describe their experience of mathematics lessons now in college, emphasizing that this may be exactly the same, or it could be different. Students were asked to complete the activity without discussion so it reflected their personal views.

After placing the cards, which were numbered on the back, students wrote their card numbers under the appropriate heading on a pre-prepared record sheet to show their arrangement against the Likert scale. These records were later transferred into a spreadsheet by the researcher and used to carry out the analysis. During the activity, the researcher observed the students, answering any queries about the meaning of the statements and checking that they were taking sufficient time to read and place the cards thoughtfully. Assistance was given where needed to transfer the card numbers to the record sheet.

The statements on the cards were derived from discussions with student focus groups in other colleges about their experiences and what they felt were the important issues. This led to a draft set of statements which were piloted with other students and revised following their feedback on the readability, intended meaning and accessibility of the language.

In the second term students discussed their responses to a selection of contextualised mathematics tasks. These included tasks in contexts from their own vocational areas that may be familiar and some contexts that would be unfamiliar. Students were not expected to work through these tasks but to give their views of the relevance, including how realistic, authentic the context appeared to be. In their final meetings they repeated some of the earlier card-sorting activities about their experiences of mathematics in college and discussed their overall experiences of mathematics in college.

The research was both exploratory and explanatory, based on a grounded theory approach with concurrent data collection and analysis from which case studies of each class and their teacher were developed. This multi-method design allowed triangulation of both sources and methods to be incorporated into the study. Students' experiences of learning mathematics in school and college were explored using the card-sorting activities and group discussions. Data from the card-sorting activity was numerically coded and analysed using simple quantitative methods, whilst qualitative data were analysed using coding and constant comparison methods to identify key themes. These themes were then further explored through within-case and cross-case comparisons, with particular attention to comparisons between cases with contrasting student attitudes.

Within this paper, a detailed analysis of data concerning students' attitudes to mathematics will be presented. Further details of other parts of the study are reported elsewhere (Dalby, 2014).

Findings

There are four data sources that are examined in this paper:

- the individual card-sorting activities about students' beliefs and attitudes towards mathematics in school and college;
- focus group discussions about students' experiences of mathematics in school and college;
- individual card-sorting about students' beliefs about functional mathematics;
- focus group discussions about functional mathematics.

Summaries of these results are presented briefly before highlighting the main points that emerged from a more extensive synthesis. The beliefs and attitudes of students about mathematics are self-reported in this study and therefore have limited reliability as actual measures of these constructs, especially since the sample size is fairly small. However, this is a study that is largely exploratory and the use of these data is to gain insight into students' images of mathematics. For this purpose the way they present their beliefs in discourse is of particular interest.

In the first card-sorting activity students placed cards on a 5-point Likert scale to indicate how strongly they agreed or disagreed with given statements about mathematics in school and in college. After summarising students' ratings in a spreadsheet, the Likert scale was converted to an ordinal scale so further analysis could be carried out. The ordinal data was used to calculate differences in student ratings for the same statement for school and college and these were then tested for significance using the sign test. *Table 1* shows the number of students with a negative change, no change and a positive change in their ratings of each statement for school and college with the level of significance.

Statement	Negative change	No change	Positive change	Z value	Significance
I liked maths	23	39	41	-2.13	5%
I liked the teacher	17	22	64	-5.11	1%
I understood it	14	37	52	-4.55	1%
I felt confident	13	47	43	-3.88	1%
It was interesting	17	33	53	-4.18	1%
I was bored	50	26	27	-2.51	5%
It was confusing	42	41	20	-2.67	1%
I could have done better	51	28	24	-3.00	1%
It was difficult	55	28	20	-3.93	1%
I felt stressed	55	33	15	-4.66	1%

Table 1. Differences between students' perceptions of mathematics in school and college

There is evidence of several (self-reported) changes in students' beliefs, emotional responses and attitudes to mathematics in their transition from school to college. Overall, students found mathematics in college easier than mathematics in school and more interesting. They were less stressed in college, more confident, less confused, liked their teachers more and understood the mathematics better. There was also some evidence, although less significant, that students liked mathematics more and were less bored.

Changes in students' beliefs, attitudes and emotions were explored further through discussions in the focus groups and some common themes emerged that supported the above results. Students with negative responses to mathematics frequently linked these to poor learning experiences in the past. Descriptions of disaffection, disengagement and failure were common features of their discussions about school, often accompanied by expressions of strong negative emotions. Students' provided examples of previous experiences that showed how negative attitudes and emotions had often led to deliberate avoidance behaviour, or frustration about being unable to make progress. These students typically approached mathematics in college with a fear of on-going failure, a general anxiety about mathematics and low self-efficacy.

Qualitative data from the focus groups also suggested a shift towards more positive attitudes, beliefs and emotional responses to mathematics in college for some students. Oliver, a student on a Forensic Science course explained the change as follows:

> I was terrified because I knew I was weak at it. I couldn't do percentages, I couldn't do ratios, I couldn't do fractions, I couldn't do formulas. I certainly hadn't got a clue about algebra. I can do it all now. (Oliver, Forensics course)

Oliver's journey from a fear of mathematics to a position of confidence was echoed by other students from his group who had struggled in school but was also evidenced in other groups:

> Oh yeah, I'm a lot more confident now than I was at the start. (Damien, Public Services)

> I understand things more, better now. Everything seems a lot more clearer. (Ellie, Hairdressing)

These increases in confidence and understanding of mathematics were often attributed to the approaches used by their teacher and the particular course that they were taking, which was functional skills mathematics.

Students also placed cards on a 5-point Likert scale to indicate how strongly they agreed or disagreed with given statements about functional mathematics in college. The results showed strong agreement with the following statements:

- maths is a subject you need to get on in life;
- I will need to use maths in a job one day;
- the skills are useful;
- I need the qualification to progress.

Functional mathematics in college was viewed by many students as a subject with value in relation to life and work, either because they could see how the mathematics itself was useful, or because the qualification was necessary for their progression to a higher level course or the workplace.

Ben (Construction), for example, explains the difference between mathematics in college and school as follows:

> In this one they relate it to real life so you can understand it better. The one in school used to be from a text book and the teachers just used to make us copy out of the textbook for an hour. That's it. (Ben, Construction)

Ben identified that the mathematics in college was different because he could see links to his life outside the mathematics classroom. In contrast, he connected mathematics in school closely to a text book and repetitive activity that had little personal meaning.

Differences between school mathematics and functional mathematics were also identified by other students in the focus groups, for example:

> Because at school you was doing maths to get grades where you'd do certain types of maths just to get you better grades but here you do maths that's going to help you with future life and stuff that you're always going to need. (Connor, Construction)

Connor perceived school mathematics to be about passing an examination but functional mathematics was useful in daily life. The differences were however not just in the mathematics but also in the way it was taught, as a group of Hairdressing students explain:

> Ellie: Yeah, he always puts it into a problem where he would say if you was in a hairdressing salon how would you do this? How would you solve this? What ratios would you need on that?
> Leanne: Or a supermarket, how do you figure out like you know…
> Ellie: He does it to everyday life problems.
> Leanne: If you give money in do you know how much change you're giving back and all like that? He does it with us with stuff like that.

In the experiences of these students, functional skills mathematics was taught with frequent references to familiar scenarios outside college in their personal lives and it was this that made it appear different.

The usefulness of functional mathematics contrasted strongly with the dominant themes in focus group discussions about school mathematics, which was viewed as remote and inaccessible.

Some students with strong beliefs that functional mathematics was useful to their lives and vocational aspirations also acknowledged that GCSE mathematics had higher value in society though.

> It's more useful than GCSE. It's not more useful CV-wise, like qualification-wise. (Lee, Public Services)

A tension between the wide acceptance of GCSE mathematics in society and the usefulness of functional mathematics was evident in several focus group discussions. Although students had experiences of an alternative form of mathematics they were still subject to influences from society that prioritised the academic knowledge-based GCSE qualification and found these two views difficult to reconcile.

A synthesis of the findings shows evidence of five areas in students' images of mathematics:

- beliefs about the nature of mathematics;
- beliefs about the process of learning mathematics;
- beliefs about the purpose of learning mathematics;
- emotional responses to mathematics;
- attitude to learning mathematics.

This is less extensive than the range of categories identified by Sam and Ernest (2000) but it includes some similar elements.

Further analysis of these changes was carried out in cross-case comparisons between groups with strong positive images (5) and those with strong negative images (5). This led to the identification of some common features within the groups with the most pronounced changes in students' images of mathematics. One of these, evidenced through observation and student feedback, was the presentation of mathematics to students as relevant and useful 'tool for life'. This image was promoted through a teaching approach that focused on the use of meaningful real-life contexts or examples to make connections to students' personal lives or vocational interests. Students in these classes often commented that their experiences of learning mathematics were different from school.

The functional mathematics curriculum made this easier to achieve due to the emphasis on using and applying mathematics in a range of contexts. In the cases where there was little or no evidence of improved attitudes though, observations and student feedback indicated that contexts were less meaningful for students and there were less connections to their lives or vocational aspirations. Furthermore, students in these groups often found the teaching approaches similar to those they had experienced before in school.

Finally, the timescale for these changes in students' images of mathematics is worth noting. There was evidence from the card-sorting activities and discussions in the first focus group meetings (December) of changes in beliefs, attitudes and emotional responses. Evidence from the final focus group of the college year (June) then showed very little change from the first meetings. This suggests that most of the changes in students' images occurred within three months of entering college but that the new images formed by this point were then sustained through the year. It was expected that there would be some changes but these were more rapid than anticipated, with students' early experiences of mathematics in college being particularly influential. Positive attitudes were evidenced more extensively than expected in the student groups. After the early changes, the way in which attitudes stabilised was also surprising, indicating that there were consistent features of their experiences of mathematics in college that affected these.

Discussion

The images of mathematics evidenced in the study included a range of elements not dissimilar to those identified by Sam and Ernest (2000) and reflected many of the common features identified in public images of mathematics by other scholars (Furinghetti, 1993; Leder & Forgasz, 2003; Volmink, 1994). Students' images were built on memories of their prior learning of mathematics but were affected by both early and more recent experiences. The way in which contrasting experiences in college (compared to school) were capable of re-shaping existing images, even over a period of only a few months, suggests that students' images were capable of changing, with the acquisition of new memories continually reinforcing or replacing existing elements. As Presmeg (1997) and Ernest (2008) suggest, new experiences in a different social setting allowed images to be re-shaped and even transformed. There appears to be great potential to change students' images following their transition from school to vocational education in college but this is dependent on several factors that were highlighted in the study.

The transition to college provided an opportunity for positive changes in students' images of mathematics through exposure to an alternative, more applied mathematics curriculum. In classes where teachers embraced this curriculum and made use of the opportunities to present mathematics as a relevant and useful subject, students encountered contrasting learning experiences to those they had experienced in school. These contributed to the development of images of mathematics that were more positive. There are three aspects of their experiences in college that were particularly important in the development of these new images of mathematics: the curriculum, the teaching approach and the setting.

The mathematics curriculum that they encountered in college, functional skills mathematics, focused on the application of mathematics and the development of skills rather than knowledge acquisition. This gave teachers the opportunity to present mathematics as a subject that was connected to real life and work. In England, the history of qualifications with an emphasis on application has been fragmented and, although successive attempts have been made to develop skills-based qualifications suitable for students in vocational education, these have been relatively short-lived compared to the GCSE qualification (Dalby & Noyes, 2020). If views of mathematics are going to change in society, then widespread use of a mathematics qualification that focuses on application would appear to be one way in which entrenched negative attitudes in society might be influenced during students' journeys through education.

In student groups where positive images of mathematics were evidenced, teachers used the opportunity afforded by the functional mathematics curriculum to emphasise the relevance and usefulness of mathematics. This typically involved the use of familiar contexts and scenarios to demonstrate how mathematics was *connected* to students' personal lives and vocational studies. These were used in two ways. Contextualised problems were sometimes used to model the mathematics, or students were presented with examples of familiar situations in which mathematics was used, simply as illustrations.

The use of contextualised tasks has been problematic for various reasons (Beswick, 2011) but when used for the purpose of understanding the mathematics, its success relies on accurate representation of the mathematical structure in the given scenario. In Realistic Mathematics Education (RME) for example, the context used is described as needing to be 'meaningful' to students, i.e. a situation that they can imagine (Van den Heuvel-Panhuizen & Drijvers, 2001) but this may not necessarily be strongly connected to their lives and interests. Although this approach is effective in terms of understanding the mathematics (Dickinson & Hough, 2012; Laurens, Batlolona, Batlolona, & Leasa, 2017), the emphasis is on cognition rather than affect. If students' images are to become positive then affective elements also need to be addressed.

The use of mathematics in contexts relevant to students' lives, either as examples or in contextualised tasks, fulfil a different function by demonstrating the relevance and uncovering the hidden mathematics (Coben, 2002; Wedege, 2010) that they may have already encountered in their everyday lives or vocational practices. The identification of authentic contexts (Wiliam, 1997) is however a challenge, especially in England's FE colleges where student groups are not necessarily taught in vocational groups and common interests are therefore limited to their personal lives. Nevertheless, the use of relevant contexts addressed some of the negative aspects of students' views of mathematics and remains an important device to develop a different image of the subject.

As a result of their experiences of functional mathematics in college, rather than retaining a negative *separated* image of mathematics, some students developed *connected* images of mathematics with clear links to their lives and values. Differences in the mathematics curriculum and teaching approach between school and college were instrumental in facilitating these changes but students were also influenced by participation in new social situations and learning environments. This exposed them to new social images that affected their personal beliefs, attitudes and emotions, and allowed space for different connections to mathematics to develop. Independence and orientation to the workplace were becoming increasingly important for these students (Brannen & Nilsen, 2002; Côté & Bynner, 2008) and connections to practical workplace applications of mathematics resonated more strongly than in school. A different educational environment, in which students developed new values and identities, provided opportunities to create new images of mathematics that were connected to their aspirations. Furthermore, where connections were made between emerging work-related values and mathematics, students also reported an increased engagement with mathematics learning and gains in understanding.

There are two important implications here for teachers in colleges. Students' images of mathematics were not only affected by a different curriculum in college but also by the use of a different teaching approach by their mathematics teachers. Continuing with the same teaching approaches used in school was unhelpful to students with negative images since this reinforced existing beliefs and attitudes. To cultivate positive images, mathematics teachers needed to embrace the alternative curriculum and teach this in ways that emphasised the connections to students' lives and aspirations. Vocational teachers also have a part to play in the development of these connected images. As they help students prepare for the workplace, emphasising the importance of mathematics skills and highlighting where mathematics is used in work routines strengthens the connections.

Some of the key elements of students' images evidenced in the study show a close alignment to research findings concerning affect and these are worth considering in view of ongoing concerns about post-16 students' affective responses to mathematics (Noyes & Dalby, 2020). There was evidence of changes in attitudes, emotions and beliefs (McLeod, 1992) and, as highlighted by Zan et al (2006), anxiety about mathematics was common. A key finding, however, concerned how these attitudes, beliefs and emotional responses to learning mathematics changed over time. Rather than beliefs remaining fairly stable whilst attitudes and emotions were more transient (Wedege & Evans, 2006; McLeod, 1992), there was evidence of concurrent changes in beliefs, attitudes and emotions over a short period of time, suggesting the presence of fast-changing aspects of each element (Goldin, 2003; Hannula & Laakso, 2011). Importantly, if students' images of mathematics had become more positive by the end of their first term in college, a time period of less than three months, it was likely that this change would remain stable, at least until the end of the college year.

Comparisons to existing models suggest compatibility but also some differences. For example, the emotional responses of students were closely connected to prior experiences of learning mathematics (Hannula, 2002) but their attitudes and beliefs were also grounded in previous encounters with the subject. There was evidence of attitude being linked to engagement (Goldin et al., 2011) but emotions and beliefs were also entwined into student behaviour. In Goldin's 'engagement structure' students' beliefs are intertwined within cognitive and affective structures and explain "in-the-moment mathematical behaviour" (Goldin et al., 2011, p.558) but not a more sustained response, as shown with the vocational students in this study.

Evidence that it is possible to change students' images in college is a key finding of this study but the question of how to change the dominant image in society remains, especially in an education system where academic qualifications are the priority and vocational skills are a secondary consideration. Even students who understood the usefulness of functional mathematics were sometimes uncertain about the value of the qualification in comparison to GCSE because of the wider acceptance in society and 'gate-keeping' function of the qualification. The prioritisation of GCSE mathematics in current post-16 mathematics policy in England and a decline in the use of functional mathematics (Dalby & Noyes, 2020; Noyes, Dalby, & Smith, 2020) therefore present challenges to the development of positive images of mathematics in vocational education. Students are now more likely to experience the same mathematics that they studied at school, with limited opportunities for teachers to emphasis the relevance and usefulness than they did at the time of this study. Although a renewed commitment to the development of skills is welcome (DfE, 2021), students are still influenced by common images in society and these are likely to reflect the high value of academic qualifications for some time. Meanwhile, the emphasis in post-16 vocational education remains firmly on a mathematics qualification associated with a remote and abstract academic image of the subject.

Conclusions

This study of students' images of mathematics is largely exploratory. The approach used has limitations due to the reliance on self-reported beliefs and attitudes, and the relatively small sample size. These conclusions therefore focus on the images constructed by students in their discourse and the implications of these. A more detailed analysis of student attitudes using recognised measures of, for example, attitude and self-efficacy would be useful to build on the findings reported here. This could provide more detailed and robust quantitative data to examine the type and extent of attitude change. A longitudinal study, spanning the transition from school to college, could also provide more insight into how images are shaped and developed.

From this study, it can be concluded that the construct of a personal mental image provides a useful way to represent the set of beliefs, attitudes and emotions described by students in connection with their responses to mathematics in school and college. Although these images are grounded in memories of prior experiences, exposure to an alternative mathematics curriculum and different approach can have a significant and positive effect. There appear to be benefits, therefore, in providing contrasting learning experiences for students who have been disaffected with mathematics in school, to enable the construction of more positive images.

The potential of an alternative curriculum to have a positive impact on students' images and engagement has implications for the type of mathematics taught to students in vocational education and the teaching approaches used. Mathematics teachers are in an influential position to facilitate the development of positive images of mathematics but are constrained in England by a policy that focuses on achievement of the same GCSE qualification that students have taken and 'failed' in school.

In the transition from school to workplace, understanding how students' images of mathematics are formed may well provide a better understanding of how learning mathematics in vocational education can be instrumental in shifting long-standing negative images in society. However, widespread change is likely to be dependent on a change in the value attributed to skills-based qualifications by policy-makers and those within education, in order to create the conditions in which new images can develop.

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Adjusting to a Digital Environment as a Teacher of Adults Learning Mathematics

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Abstract

As more and more classroom and digital technologies are developed, the author has had to wrestle with how, and if, certain technologies should be employed in teaching a quantitative reasoning course for university students. Ten self-reflection questions capture the author's key decision-making factors in adjusting to a collaboration classroom environment from a traditional classroom. These self-reflection questions, organized by the Areas of Activity from the UK Professional Standards Framework for teaching in higher education, represent important decisions and potential adjustments that all teachers may want to consider as they reflect on their own teaching practice in the digital age. This article is based on a presentation given at the 26th annual conference of Adults Learning Mathematics held in Lund, Sweden in 2019.

Key words: mathematics, technology, adult learning, higher education

Rationale

There are particular challenges to teaching mathematics and especially so for teaching to adult learners who have already had experiences with mathematics classrooms. Their previous life and classroom experiences have led some students to have particular cognitive or affective issues that they bring with them as adults. So, I have always looked for the proverbial "silver bullet" that would be the key to successful teaching of this population. While I have come to learn that there is no single methodology, technique, policy, or style that works for all students (or all teachers), I do get excited about the search for ideas that will improve my effectiveness in helping students to learn. The explosion of digital devices and applications makes this a prime area for my search. But, through my practice, I have learned that there are numerous considerations when looking to incorporate digital technology in the classroom.

Context

I teach in the United States at a large public university that integrates the university and community college missions. There are approximately 40,000 students. All students seeking a bachelor's degree must complete a quantitative literacy (QL) requirement which consists of completing a specified mathematics course, depending on the area of study (the student's *major*). I eventually specialized in teaching Quantitative Reasoning which in some institutions might be named something like Math for Life, Math for Society, or Liberal Arts Mathematics. This course is the QL requirement for non-STEM majors. My students were studying dance, art, English, American sign language, graphic design, philosophy, etc. Most students probably would not have taken the course if there was no QL requirement. Many had previously taken at least one developmental (remedial) mathematics course that the institution offers to prepare students for college-level mathematics.

A few years ago, I observed a colleague using a “collaboration” classroom where approximately 30 students sat in pods of up to six people each. Each pod has its own monitor and white board. Students can connect to their monitors with a variety of their own devices. The pods are spread around the outside of the room and there is no traditional front to the room. There is an instructor station in the corner where any screen can be broadcast to all of the students’ monitors. I was intrigued so I sought out collaboration rooms for my classes, after receiving the requisite technology training. The training was only on using the technology, not methodology, so I quickly learned that I could not teach my Quantitative Reasoning course in the way I had become accustomed. I found myself rethinking everything about my teaching. With no front of the room, it forced me to present in a different way and take advantage of the pod seating. My focus became what I was going to have my students do together during class rather than what I was going to tell them. It was a lot of work to make the transition, but I was glad for the experience and requested those rooms to teach in, from then on. That experience made me consider the impact of technology on my teaching. I began to think about general considerations that myself and other faculty must make in the digital age given the ongoing technological innovations that have the potential to impact teaching and learning.

To organize my thinking and to comprehensively look at the act of teaching, I decided to use the five Areas of Activity from the UK Professional Standards Framework (Advance HE, 2018). Those five areas [bold added to indicate short names for each area] are:

- **Design** and plan learning activities and/or programmes of study;
- **Teach** and/or support learning;
- **Assess** and give feedback to learners;
- Develop effective **learning environments** and approaches to student support and guidance; and
- Engage in continuing **professional development** in subjects/disciplines, and their pedagogy, incorporating research, scholarship and the evaluation of professional practices.

For each of these five areas, I find that there are questions I must ask myself as I confront technological change and the potential to improve student learning. These questions are found below for each of the areas.

Design

With all the information that is available to students, I found myself thinking of the following question as I designed a course or planned a lesson:

Question #1. What should students do by hand versus what should they do by calculator, computer, mobile application, or online calculator?

For example, in a quantitative reasoning course with a financial unit, I could have my students calculate a monthly mortgage payment by hand with the help of a calculator. Or, I could have them find an online mortgage calculator, input data, and interpret the results. Which is more important? I ended up compromising and having my students do both. My rationale for having them do it by hand was that they should know how to use a calculator and that manipulating the formula would give them a better understanding of how the online calculator works and why the concept of exponential change is important. But, using an online mortgage calculator helps them with a life skill they may use in the future.

There are other aspects of mathematics for which question #1 applies. For example, should students: (a) calculate a unit price or know how to find and interpret the labelled unit price in a store, (b) construct a pie chart by hand or use spreadsheet software to create a chart, (c) convert units or use an app or online program (even as simple as typing the units to be converted into the Google search bar). The following statement from Boyle and Farreras (2015) gave me some pause:

> Changes in the use of technology today, especially in hand-held devices, may well translate into students today not memorizing the multiplication tables or being unaware of the process of multiplying two or more digit numbers. Educators' initial reaction is to assume that modern students are thus not 'learning' because they are not using the traditional method. As this study has shown, however, this conclusion needs to be examined very carefully. The fact that students do not learn the way that previous generations did, is not evidence for lack of learning, or any of the other dire conclusions that are often drawn. (p. 98)

When considering having students work by hand or using a digital tool the most important consideration I have found is the expected learning outcomes for my adult learners. Those outcomes should be developed while keeping in mind the Boyle and Farreras' (2015) quote in mind. The outcomes must be explicit and should drive the development of the course, including the incorporation of technology.

The second question in the design area is:

Question #2. Should I incorporate a particular new digital technology into my course design?

The answer depends on the expected student learning outcomes. Technology should support the teaching-learning process as directed by the outcomes. One should not look at a new technology as a solution looking for a problem. I once incorporated some technology without fully thinking it through in advance. It failed and I quickly abandoned it.

In addition to the learning outcomes, other considerations for adopting new technology in the design of a course include accessibility, cost, past performance, customization, and ease of use.

Teaching

The third question is in the teaching area:

Question #3. What is my role as a teacher and how should technology support or modify that role?

The answers to this question are highly personalized, depending on the instructor's characteristics as a teacher. There are metaphors for how one might see themselves in the classroom like boss, coach, docent, etc. There is also an issue of how much control an instructor needs. Does the instructor see themselves as operating a dictatorship, bureaucracy, or democracy? How structured/flexible is the instructor or how extroverted/introverted? These are just a few characteristics, but they can all be factors in how technology will be used in teaching.

A colleague of mine has changed all his classes to a flipped model. He quite heavily relies on digital technology to eliminate lectures during class time and maximize use of group projects. He seems quite successful at it. However, this does not work for me for several reasons including that I get an intrinsic value from teaching that I would not have in a flipped model. It works for my colleague but not for me. I do not believe there is one correct way to teach because we are all different. Faculty members need to decide what is best for them, and for their students, and make appropriate technological decisions.

Here is an additional question in the teaching area:

Question #4. What is my view of the students' role and how should technology support or modify that role?

Technology has changed a traditional model of the instructor imparting content to the students. Now, students have greater access to the content because of digital technology. Instead of being primarily recipients of content in class, should expectations be raised for students to find more of the content on their own? If so, this would require more emphasis on how to find and evaluate information. I have a car buying project where they compare hybrid and non-hybrid versions of the same car model. I give them very little information and require them to decide what they need and to go find it. To support this, I also have a small unit that I teach on efficient online searching.

Technology has also changed how students are able to interact with each other. Digital technology allows for greater collaboration. Is this collaboration an important part of students' educational experience? If so, then what tools are appropriate? But a tool, alone, is not enough. There is this caution by Borokhovski, et al. (2016):

> When educational practitioners strive to effectively achieve their instructional goals, simply relying on more interactive technological tools is not enough—special attention should be paid to how to maximize their potential by designing tasks and activities that would elevate interaction to the stature of collaboration. (p. 23)

Technology must go together with good instructional design. Again, expectations for students must be clearly articulated. For example, in a quantitative reasoning class, a learning outcome might be to solve an authentic, real-life problem. Another outcome could be working successfully in a team to collaborate and develop consensus. For the latter outcome, some form of digital technology would be appropriate.

Assessment

Regarding assessment, the key question is:

Question #5. Is the use of digital technology appropriate for assessing student work and providing feedback?

Some faculty get enamoured (seduced?) with publishers' online homework systems that automatically grade homework and provide hints and other help. Students can get immediate feedback on their answers. Some programs are including artificial intelligence to diagnose incorrect responses by students. Also, analytics can be provided to the teachers regarding which problems students are having the most trouble with. So, there are certain advantages to online systems but, as instructors, do we get the same sense as to where particular students are having trouble? Also, homework that is automatically graded means that there are only certain types of questions that can be asked because the answers have to be recognized as correct or incorrect. Faculty must sort out these issues for themselves. I have used online homework programs for students to practice procedural skills and then supplement that work with projects that I hand-grade.

Learning Environment

As I described in the introduction to this article, I have recently been using collaboration classrooms with students sitting in pods as groups. End-of-term student feedback indicates that the students very much enjoyed the experience and believed it helped their learning. Most became very close with their pod mates and worked well together on practice problems and group exercises. This shows that classroom furniture and digital technology can have an impact. Kramer (2017) stated:

> The creation of more Active Learning Classrooms is supported by the theory of architectural determinism, which in this case suggests that physical environments will affect the learning experiences of students.

> Various universities are implementing policies that shift traditional teaching away from lecture style (one-way teaching) to student-centered learning. This approach involves both active learning and collaborative learning practices, with Active Learning Classrooms serving as a catalyst. (p. 15)

For all types of classroom situations and technology, given the above, it is worthwhile for instructors to consider the following question:

Question #6. Can I use technology to enhance the students' classroom experience?

Consider what features of various technologies are important in helping students achieve learning outcomes but do not underestimate the role of classroom technology as simple as furniture, layout, and classroom design. Years ago, at a previous institution, there was an instructor I knew who preferred a traditional classroom with individual chairs with tablet arms. But one term he was scheduled in a room with long tables. When he found out his room assignment, he objected to that room because it did not allow him to move up and down the rows helping students. When offered to change rooms he decided to just go with what was originally scheduled. Near the end of the term, I asked him how his classes were. He said the classes were wonderful and that attendance was better than usual and so were the exam scores. I then asked him to what did he attribute the improvement. His response, to my surprise, was "It's the tables." His rationale was that the tables allowed students to help each other more and that resulted in a better learning environment in the classroom. So, years later, when my institution created the collaboration rooms, I took the opportunity to try something new which resulted in my classroom being a more effective learning community.

The next question may be a strong consideration for teaching adult students:

Question #7. To what degree do busy adult students need a physical classroom experience, given that digital technology can provide other ways for connecting with students and content?

My students tend to be quite busy between school, work, and other responsibilities. Digital technology can help relieve the time spent in commuting to school and offer flexibility on when the learning is accomplished. Remote or other forms of online learning can be quite effective. But, I also believe in the value of the classroom experience for adult learners and saw an example in the collaboration classroom that illustrated the value for an older student in the pod environment. During one term a few years ago, an older, non-traditional student was in a pod with four students who were right out of secondary school. He would joke about how little he knew compared to the younger students but also remarked on how beneficial it was for them to help him learn. Later in the term when we were covering home mortgages, I saw him at his pod's white board explaining concepts to them because he had actually gone through the loan process in buying a house. I went over and said something like, "Well, look at you teaching your pod mates." He gave the biggest smile and said it was great to be able to switch roles and help the young adults in his pod.

There are many options from the classroom to various digital technologies including learning management systems, cloud services, social media, and video conference sites. But, what is the trade-off? How important is the classroom experience through meeting regularly and interacting face-to-face? Do adult students need more structure or less?

Digital technology is so prevalent in many countries around the world that it is easy to forget that not all have access. Hence, the importance of considering the following:

Question #8. How accessible is any planned new technology and what can I require of my students?

As an example of studies showing a digital divide, Wilson, et al. (2019) measured digital inclusion in Australia. They concluded the following:

> The ADII [Australian Digital Inclusion Index] reveals that digital access, affordability and abilities continue to follow distinct geographic, social and socio-economic contours. In general, rural and regional

> Australians, older Australians and Australians with low levels of income, employment, and education are less digitally included than their compatriots. (p. 117)

Similarly, in my own country, here is a statement from Yu, et al. (2016):

> Using a representative sample of Americans over the age of 50 years, … Findings show that nearly half of respondents do not have regular Internet access. While the access divide in gender is reversed in favor of women, those who are socioculturally, economically, and physically disadvantaged are less likely to have reliable Internet access, … (conclusion, para. 1)

In most cases, we cannot assume that every one of our students will have internet access, devices, or needed software programs. The collaboration room though allowed the students to see various software programs like mortgage calculators and to visit and explore various websites to analyse quantitative information. Pod mates had various levels of computer expertise and were able to help each other learn. To further help with any potential digital divide issues, my institution provides free Microsoft 360 accounts for all students. There are also computer labs that students can use but I find that students are on campus only when they have classes in the two or three days that they come to campus. They usually have to get to work or pick up children from day-care right after their classes. So, even though the university provides what they need, it may not be accessible to all and I still needed to be prepared to make allowances for some students.

There are also potential issues with online resources that may lack accessibility for students with disabilities, although this has improved a lot. The pods were actually an advantage to one of my students who was sight-impaired. He loved the pod setup because he could sit right next to his pod's monitor and easily see his screen whereas he had difficulty often in traditional classrooms.

Professional Development

A teacher wanting to do what will work best for student learning must do some self-reflection on how flexible they are and how much time they are willing to spend examining digital technology use. How willing is an instructor to try something new, despite the learning curve?

Question #9. Am I comfortable in pursuing and using new technology for my teaching?

It takes time and effort to stay current. How committed is one to professional development regarding digital technology? That commitment requires self-reflection and continuous professional development. Seeing the possibilities for providing valuable learning experiences in the collaboration room, I was willing to put in the time to not only learn the technologies of the room and my institution's learning management system but to also alter my teaching style and methods. It was a considerable investment of my time and worth it, in my opinion. It was also valuable to work closely with a colleague who was ahead of me by a year in the use of the collaboration rooms.

The last question is about teachers becoming students themselves in a digital world:

Question #10. Can I take advantage of digital technology to improve my professional development opportunities?

Digital technology can help instructors to learn and there are a variety of means to communicate and collaborate with colleagues. One can follow various educators on social media, participate in online research forums, use cloud sharing services, belong to professional organizations, attend conferences/webinars, etc. Also, educational institutions have an obligation to encourage technological professional development through evaluation/reward systems and providing resources for training and personal development.

There is more I could have done to take advantage of some of the professional development activities available through technology. But, my primary method was to attend conferences of several mathematics learning organizations such as the annual conference for Adults Learning Mathematics which has now done a number of virtual seminars. I was always attracted to sessions involving technology, small-group learning, and teaching methodologies.

Conclusion

There will be continual innovations in classroom and digital technology in the future. We must be prepared, as instructors, to decide to what extent we will try new technologies and experiment with our teaching practices. A central point of this paper is that the establishment of expected student learning outcomes, good instructional design, and a willingness to adapt are critical when considering the use of technology. Digital tools should not be adopted because of a “wow” factor. Instead, the decision must be deliberate and intentional and in support of student learning. My experience with the collaboration room with its pods, brought much of the above to light for me. Making such a drastic change to the learning environment forced me to think about my role, students’ roles, learning outcomes, assessment, and even the value of the classroom. My hope is that my experience and self-reflection will be a source of reflection for other instructors.

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