Equity in Tertiary Mathematics: Imaging a Future

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Current economically driven reforms in higher education have demanded that educators develop teaching strategies that are sustainable within new contexts. Often these developments appear to be effective, but caution needs to be exercised as to which students are likely to benefit from, or be excluded from, participation and success in these evolving contexts. This paper identifies issues associated with developing equitable practices in tertiary mathematics within a context of reform including participation and retention; language; technology; gender issues and flexible learning.

Introduction

Current reforms in higher education are being guided by three key discourses – economic rationalism, massification of higher education, and post modernism. These discourses are embedded within a market ethos whereby students are seen as clients and education is a marketable commodity to be sold for profit. The discourses have serious implications for how teaching and learning are theorised and instituted. Economic rationalism has made a significant impact on the organisation and structure of pedagogy. There is increasing pressure to do more with less and to be held accountable for producing and documenting learning outcomes among the client group. This ethos has placed greater pressure on teaching staff to adopt practices which are pedagogically and economically lean. In concert with the economically-driven reforms is the expansion of the higher education sector in which access to tertiary education is no longer the domain of an elite few. The Dawkins reforms of the 80's has resulted in considerable expansion in the sector resulting in students gaining access to higher education with very different skills, knowledges and strengths than previous generations. Pedagogy and curriculum need to be developed in order to cater for the differing backgrounds of these students. The third discourse is that of postmodernism where it is recognised that structures and practices of the industrial age have been eroded through the development and extended use of technology. This has resulted in new ways of working and thinking. What is increasingly obvious is that students enter the tertiary sector with substantially different skills and knowledge than previous generations.

Within this context, it is increasingly important to consider the theme of this conference to "stimulate discussion on various responses to the problems faced by undergraduate mathematics instructors working with students who may vary widely in terms of their backgrounds, their level of mathematical preparation, their expectations of, and need for, mathematics courses."[1]. On this basis, I propose to raise issues critical to our considerations of how we can best manage our learning environments by being cognisant of our changing clientele and the contexts within which we work. In particular, I take as central, my focus on equity.

[1]http://www.sci.usq.edu.au/delta99/delta.htm

Theoretical Framework

In this paper, I use the writings of French sociologist, Pierre Bourdieu, to provide a theoretical framework within which to embed notions of equity in tertiary mathematics. Bourdieu has argued persuasively that students, as a consequence of their familial experiences and their later experiences within and beyond school, come to construct a sense self. This sense is referred to as habitus,[1], which in its most simple form can be seen to be the embodiment of culture. The habitus provides the lens through which students interpret the world and learn to act within the world. Bourdieu argues that the habitus predisposes people to think and act in particularised ways based on their previous experiences. For some students, their habitus may be akin to the practices and cultures embedded within a particular context - in this forum, tertiary mathematics. In contrast, other students may have had substantially different experiences and hence have come to construct a habitus which less congruent with the practices valued within higher education. For the former group/s of students, success is likely to come more easily than for the latter group. This latter group may have to undertake considerable reconstruction of the habitus in order that they are successful in their study. In considering how habitus frames the world for the students, it is necessary to consider such attributes of language use, tastes, consumption patterns and so forth. For students who come from some social and cultural groups where there is greater synergy between their familial habitus and the practices of education, then access to success is somewhat easier. For such groups of students, their cultural background as embodied in the habitus comes to be a form of capital which can then be exchanged for success. This is what Bourdieu refers to as cultural capital,[2]. Within this framework, it becomes necessary to consider: What practices in mathematics are likely to create difficulties for students and exclude them from participation and success in their study? This is the focus question of this paper.

A Word on Definitions: When considering equity, a number of definitions should be noted. Often equity and equality are conflated as being the same construct. However, they are considerably different and will be used in the following manner throughout this paper. Equity is defined as the unequal treatment of students with the intention of producing equal outcomes whereas equality is defined as the equal treatment of students with unequal outcomes. Initiatives in equity reforms have focused on various components of education. Some programs have focused on improving "access" where the aim has to been the provision of opportunities for incoming students. In contrast, other programs have focused on "participation" where the focus has been on the numbers of students actually enrolled in courses. These types of reforms have focused on the initial enrollments in courses, but these do not address the progress through courses. Two other considerations need to be made once students have entered courses of study. "Success" where the progression rate of students is defined as the proportion of study units passed within a particular course of study. The other measure of successful reforms involves "retention" where the proportion of students who re-enrol in a course of study is considered. Within all of these measures for implementing and evaluating reform, the notion of target groups are critical and these are seen to be the groups of people usually excluded from participation in tertiary study.

Participation and Retention

Trends in higher education indicate participation is skewed for some groups in particular. In their analysis of participation across the higher education sector, the Department of Education, Training and Youth Affairs (DETYA) illustrate patterns of enrolment as per Table 1.

Background of Student	**%age of population**	**% enrolment in Higher Ed'n.**
Indigenous	1.7	1.3
NESB	4.9	1.3
Rural	24.3	17.4
Isolated	4.5	1.8
Low SES	25	14.5

Table 1. Patterns of participation in Higher Education in 1997 Source: DETYA, [3].

For DETYA, low SES is defined as the lowest quartile of the population in relation to economic wealth. DETYA notes some concerns in participation patterns in recent years. The participation of isolated and low SES students has been declining over the past 6 years and is continuing to do so. Considering that these groups are considerably under-represented in the sector to commence with, the decline is of greater concern. Furthermore, the decline in the rural economy is expected to result in less students from these backgrounds in higher education, making them even further excluded from participation.

When considering equity in the context of tertiary mathematics, we need to consider the special needs of particular groups of people in our society. One of the more obvious and well-researched target groups is that of women. In part, this has been due to the impact the feminist movements and writers have had on the status of women within the society. As a consequence of the work and research undertaken across a number of sectors, there have been substantial changes in women's access, participation, retention and success. One of the outcomes of the many gender reforms has been the increasing participation of women in undergraduate mathematics. This has yet to transfer to postgraduate mathematics, but there are encouraging signs that there has been an increase in participation in this area of mathematics as well. However, the notion of gender as a singular variable denies the complexity of it as an equity issue as gender intersects with other social and cultural aspects of teaching and learning, participation and success. For example, studies at the secondary school level,[4], indicate that women from working-class backgrounds are less likely than their middle-class peers to participate in higher order mathematics, suggesting that gender as a singular variable is not a good indicator for participation and success. Similar interactions between gender with ethnicity and race should be considered.

Participation in Tertiary Mathematics

In surveying the literature on participation in tertiary mathematics, there were no readily available indicators for the various target groups. However participation and success rates in secondary school mathematics have been well documented, *eg.* [4], and there is overwhelming support to demonstrate that participation and success are clearly delineated along gender, geographical and social location lines. The implications of these research findings are that the cohorts of students who enrol in tertiary mathematics can be considered within two distinct groups - those who have the cultural capital to undertake further study in mathematics and will have greater chance of success in their study. The second cohort of students are those for whom mathematics represents a disparate discourse with which they have minimal resonance. In this latter cohort, success is more elusive and will require substantial support for the students to aid their progress through mathematics.

Arguably one of the most under-represented groups in tertiary education, and particularly mathematics, is that of indigenous students. In their study of indigenous students undertaking study of tertiary mathematics, Fraser, Malone and Taylor,[5], note that "only a handful of Aborigines ever complete higher education qualifications in science-related and mathematics-related fields"(p. 85) and claim that only 18% of indigenous students complete secondary school and even less take mathematics and science in their senior school studies.. These studies indicate a skewed distribution of students undertaking - or avoiding - further mathematics.

Retention

Participation is only part of the equation in tertiary mathematics. The other key component of the equation is retention. It is necessary to consider how many of the original intake of students remain in a particular course of study. Indeed, this is seen to be one of the potential criteria for quality teaching within the new guidelines for quality performance in teaching. However, as noted in The Australian (1999), there is now a disturbing trend whereby disadvantaged students are the ones most likely to discontinue their study in higher education. It is recognised that the cultural difference between the University and the background of the students represents a major obstacle for students to overcome if they are to become a part of the academy. More particularly for mathematics, retention may be further hindered due to economic reasons, whereby the funding mechanism introduced in 1997 which placed the mathematical sciences in the middle band for the Higher Education Contribution Scheme (HECS) funding has the potential for many already disadvantaged students to be further excluded from studying in the field due to the even greater costs. In these instances, it may be productive to consider the cultural and economic differences in students' backgrounds and how these are impacting on their capacity to remain in higher education. Closer analysis of the reasons for withdrawal needs to be undertaken and subsequent interventions undertaken.

Issues for Tertiary Mathematics

In the following sections, I discuss different practices within tertiary mathematics that need to be considered. A review of the literature in mathematics education reveals two distinct findings. First, there is very little literature in the area of tertiary mathematics teaching and learning. Second, that the literature on "good practice" in the teaching of mathematics has a focus on practices which may not be suitable for the large group teaching environments and pencil-and-paper assessments of the higher education sector, particularly in the current context where there is need to return to such practices

Language

Mathematics has often been considered the discipline least affected by language. Widely held perceptions of mathematics being language free suggest that all students, regardless of language background or competence, can have success in mathematics. This may be the case if only pure mathematical equations are considered. For example, posing tasks that require students to calculate operations with matrices or integrals are often in abstract forms devoid of much language. However, textbooks and teaching practices are heavily linguistic and instruction can not occur in a language vacuum. Conveying ideas, explanations, models, and so forth demand a use of language. Accordingly, it is not feasible to consider mathematics teaching and concepts without considering language. This is even more the case when problems are embedded into contexts. Such contexts provide a justification and application of the mathematics so that students are able to see the purpose of mathematics, yet the contexts complete with language can create difficulties for students. Students who are familiar with the language of instruction, in this case English, will be better positioned to understand the intricacies and complexities in instructions and explanations offered by teachers and texts. In contrast, for students for whom English is not their language of high competence, the chance to unpack the full meaning and implications of explanations is restricted, thus making access to the mathematics somewhat more elusive. A quick and simple analysis of textbook explanations indicate the complexity of language in explaining mathematics and the context of the problem.

When considering the notion of cultural capital, it is essential to consider the composite factor of language. There now exists a considerable literature on the role of language in mathematics teaching and learning, yet it is predominantly within a psychological framework. In contrast, I posit that the language background and competency in the language of instruction are key factors in effective teaching and learning. Where a student is competent in the language of instruction and at a level appropriate, the student is more likely to develop deep understandings of the mathematics. In contrast, where there are differences and gaps in the level of linguistic competence, then there is a reduced chance of success. Consequently, language background and level of competency in the language of instruction are forms of culture which can be exchanged for success. Within most Western contexts, there is now wide recognition that the language of instruction is that of middle-class English.

Two aspects of instructional English need to be considered. First is the language form itself. Mathematics is a highly specialised register with many words unique to it or words used in highly specific ways. There are many words used during instruction that can be problematic for students. For example, McGregor,[6], cites the difficulty with the use of prepositions such as *by*, *to*, *from*, when considering a statement about temperatures: *where the temperature fell by ... to ... from ...*. These "filler words" are small but significantly affect how meaning is established. When confronted with the technical aspects of mathematics, such as calculations, students with restricted language backgrounds may have some success. Similarly, the conciseness and specificity of the mathematics register makes the use of many words redundant. A typical text book example may be of the form:

$$\textit{draw a sketch of the given inequality}\colon\ 3y - x + 6 \geq 0.$$

A simple translation of the task indicates that the two words 'draw' and 'sketch' would be similar to one another so that the task seems to be repetitive. In the context of teaching, the statement is requiring the students to plot and then shade the equation. Students need to be able to translate the statement from its linguistic signifiers (the words and symbols) to what is actually signified (meant) by the statement. Unlike other forms of English where there are other words in the task that explain the task at hand, mathematics has developed an extremely concise and precise language, including the use of symbols to convey highly abstract and complex concepts. To develop deep understanding of the mathematics embedded in the language, students must be able to crack the code in order to develop meaning.

The second aspect is that of the communicative contexts where there is an expectation that concepts and ideas will be conveyed coherently from one participant to another. Such contexts include teaching situations and professional conversations where there is an expectation that there will be a dialogue between participants. Other communicative contexts include more formal and written forms such as projects or theses where there is a strong need to be conversant with academic/mathematical English. This is particularly the case for postgraduate studies where thesis writing is integral to the course.

It must also be recognised that at the undergraduate level, the capacity to read and comprehend mathematical texts is a complex process and made more difficult when English is not the language of familiarity. Often students entering higher education have relied on rote learning in order to pass examinations. This is commonly the case where they have not been able to 'crack the code' of mathematics texts. Whereas mathematicians may understand the mathematics embedded in the text, the student (potentially) relies on a mechanised process where they manipulate symbols in order to produce a response.

In considering the use of English as the medium of instruction and writing, it is critical to recognise the differences in register within the English language. Students whose first language may not use the middle-class register of formal educational contexts. Students from such backgrounds may have English as their first (and only) language, but it is of a different register to that of the educational context. As such, they are likely to encounter difficulties with the spoken texts during instruction along with the written texts of books and instructions. These students are often place at greater disadvantage as it is often assumed that their first language is English so that there are no problems with the language used in instructional contexts.

When considering language, it is essential that other factors are considered in concert with the language background of the students. For example, the success of many Asian students needs to be considered in concert with the value placed on mathematics and science in Asian cultures along with the social background of the parents and the level of language (and mathematics) acquisition in the first language,[7]. Just as with English-speaking families, the social background of the family influences the fluency in the middle-class language of instruction.

Technology

Increasingly the use of technology – such as computers, graphic calculators and web-based learning environments – is having a greater impact on how students learn, interact and represent mathematics. The support for this type of learning is often based in futuristic notions of learning where the computer is seen to be accessible to all and an essential component of the new societies in which we live.

Learning tools, such as graphics calculators have gained a strong foothold in teaching and learning as they free time up from tedious calculations and allow students to focus on the mathematics. However, there is also the need to consider who has access to these tools for learning. Just as literacy was the key to power in the pre-industrial age; and mathematics and science in the industrial age; many authors contend that technology is the key to power in the post-industrial age,[8]. In earlier historical periods, women and the working-classes were excluded from literacy and then mathematics. It can be argued that in these new times, the same groups of students (and people) are excluded from power through their lack of access to technology. It is now commonly expected that students will have access to a computer and graphic calculator in order to participate effectively in classes. In many universities, students are offered subsidised loans in order to ensure that they readily have access to computers. However, there is a need to stress a word of caution. While there is a recognition that not all students can afford access to their own personal computers, more subtle forms of denial of access can be observed. The rhetoric of providing common access laboratories, some with 24 hour access, would appear to lend support to the argument that all students will have access to computers and technology. However in many cases, students who are struggling economically in our subjects are compelled to sit in university computing laboratories until all hours of the evening in order to complete set tasks, and then to attend classes (and often work) the following day. Clearly, such students are at a distinct disadvantage from their more affluent peers who have access to a computer and programs in their own study environments.

Flexible Learning

In many universities, there is an emphasis on flexible learning. This means many things to many people. Broadly speaking, it can include intensive mode delivery; mixtures of distance learning and small, on-campus weekend schools (such as those offered by Central Queensland University); or web-based modules (such as Hubbard's "Click on to maths" Series available from QUT). These approaches represent a shift away from standard modes of delivery where the traditional lecture and workshops are the key mode of operation. In many cases, the rhetoric behind such practices is that they are flexible for students who are then able to balance their workload with other life commitments including work and families. Indeed, for some students, this is likely to be the case. However, there is also a need for caution and balance. Some groups of students who are unfamiliar with the context and culture of higher education are placed at a disadvantage. Traditionally these students are those for whom higher education has not been a common pathway within their familial circumstances and without sustained support for these students as they encounter new terrain, there is a greater chance of failure through the unfamiliarity with the demands and expectations of higher education. Indeed, in one university where there is a campus located in a low socio-economic region which is heavily reliant of web-based and flexible learning, the failure rate of students is significantly higher than would normally be expected for such a cohort of students. This indicates a need to be cognisant using alternative modes of delivery without due recognition of the potential difficulties experienced by some groups of students.

Peer Support Groups

The background experiences of students are foundational to their study programs. Many first year students are overwhelmed by their first semester (or year) at university. There is a substantial change from the very structured experiences of secondary school education, and in many cases, the workplace environments in which they may have worked prior to coming to university. One of the more disconcerting aspects of university life is the large lecture format and the restricted contact with teaching staff. Unlike the more supportive environments of secondary school, students are likely to feel a sense of isolation when they first enter university. For students who come to university from small communities and/or schools, the magnitude of the context is potentially overwhelming and disorientating.

Within the current constrained context, there has never been a greater demand for larger classes. This is contrasted with wide recognition of the value of small group teaching as an effective teaching strategy. Furthermore, many of the students entering higher education have come from cultural or geographical groups where there has been little interaction within large group contexts. For example, students from remote or geographically isolated areas are likely to have been in very small communities and schools. Similarly, immigrant students may have lived in smaller communities within larger cities. The support networks so critical to their continued learning are lacking in the large group context and hence place these groups of students at greater risk of marginalisation. Strategies need to be developed to support these groups of students. They need not be of the traditional, compulsory format. One strategy adopted by many indigenous programs is the development of support networks within the university. These vary from site to site, but are indicative of the need for and success of small support groups.

Gender-Inclusive Pedagogy

In considering the relationship between gender and tertiary mathematics, there has been success through the gender reform initiatives that have increased participation of women in undergraduate study of mathematics. However, this has not transferred to postgraduate study. Such a phenomenon is not unique to this discipline, but is found across the higher education field. What becomes critical in considering gender equity in tertiary mathematics is the qualitative aspects of pedagogy. Recognising that participation has increased, it is important to consider what the experiences of students are when they enter our classrooms. In her study of tertiary mathematics classes, Forgasz,[9], found that students rated their courses highly but women (and some men) noted that there was gender-based discrimination against the women in the courses. Such discrimination came from both male lecturers and male students who held gendered stereotypes of women in relation to the study of mathematics. Forgasz's study indicated that in her sample the women who continued with the study of mathematics needed to be "highly motivated and prepared to face and overcome the obstacles and adversity they may have to face" (p.198).

Conclusion: Mathematics in Crisis

In the preceding sections, I have highlighted some of the issues that will need to be considered in the context of equity in tertiary mathematics. In the current context of reforms where there is increasing pressure to be more accountable with higher workloads and less support, the need to consider the students who enter our classes has never been greater. Historically, education has gone in waves where there emphasis and support for learning have waxed and waned with the whims of politics. As we move into a new millennium, this is ever more the case. The focus on equity over the past two decades has brought little in the way of measurable success in the current context where expenditure must be evaluated against outcomes. Consequently, there is considerable pressure on education to produce outcomes or support will be discontinued.

For mathematics, there are strong indications that the discipline is in a period of crisis. It is increasingly difficult to attract students,[10] and many faculties and schools are closing down substantial components of their offerings. This further exacerbates the current context of higher education and as such there has been no greater need for mathematics educators to consider how to improve the access and retention rates of our students. As mathematics has become available to a wider range of students, it would appear that practices are needed which are sustainable and inclusive. This paper has raised some of the issues that need to be addressed in order that retention and course satisfaction rates remain high. Research agendas need to be developed in order that teaching and learning environments can be enhanced while recognising the constraints of economic reforms driving our work practices, moreover these must be cognisant of the needs of the students enrolled in our courses.

So what would a future for tertiary mathematics resemble? Clearly for the discipline to be remain viable and not become the modern-day Latin, then there is a need to make the discipline accessible to a greater diversity of students. Mathematics can no longer be the domain of the elite, but rather be more accessible to the masses. This means a serious reconsideration of how greater accessibility can be achieved. This requires a critical examination of the practices through which mathematics is conveyed to students. Language, technology and classroom practice hold considerable potential in this area. Students may need to be exposed to explicit practices that allow them to "crack the code" of mathematics and mathematics teaching.

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