Mathematics and the Construction of Feminine Gender Identity

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Females remain underrepresented in tertiary Mathematics Research has indicated that this is, in part, due to the way that mathematics is traditionally taught This paper reports the results of a participant observation intervention in the teaching of proportional thinking to Year 6 girls It was found that by taking account of their preferred learning styles with the provision of specific scaffolding and the use of integrated and authentic tasks most females enjoyed the tasks and developed a stronger disposition to study mathematics

Recent research into gender difference in mathematics achievement among middle school students indicates that differences were non existent (e g Amit, & Neria, 2002) Despite this females continue to be underrepresented in careers related to mathematics and tertiary studies in mathematics (Kort, 2001) Since mathematics provides a key element in understanding science and technology, without certain mathematical knowledge, avenues of development are closed (Keeves & Stacey, 1999) This has serious implications for equity issues and for the national economic well being (Murphy & Gibbs, 1996)

The disengagement of some females with mathematics begins early, but becomes more pronounced as they progress towards the middle school (Fennema, 1996) The reasons for this decline in females' attitudes towards mathematics are complex Boaler (1997) noted that the traditional method of teaching mathematics has the effect of alienating females who became disenchanted with pedagogic variables related to pace, closed approaches and competitive environments The research on what forms of pedagogy are most likely to address gender inclusive issues in mathematics learning has guidance from cognitive style research For example, Head (1996) compared males and females preferred learning styles on a number of dimensions He noted that male students tended to extract while girls preferred to embed Extraction is a mode of thinking that helps one to see a component in isolation, a style that is good for locating the component of a car that is malfunctioning Embedding is akin to a more holistic way of thinking, better attuned for considering how the change in one component of an ecosystem affects another Secondly, Head (1996) noted males tended to be more impulsive; having a willingness to take risks, and were happier to launch into practical work even though they did not know what they were doing In contrast, females were more reflective and felt inhibited from commencing the task, however, such deliberation is likely to pay off in skills where care is needed such as essay writing Thirdly, males attributed their success to their own efforts and failure to outside factors The reverse is true for females and this makes them especially susceptible to "learned helplessness " It was noted that the bland praise that females typically receive in mathematics classes may have come from good intentions, but the pedagogic outcomes were unfortunate Finally, males tended to work well in a competitive environment, while co-operative environments tended to suit girls better

The differences between the preferred learning styles of boys and girls are set against the deeper and persuasive issue of gender identity The construction of gender identity becomes more important as girls approach middle school and the time of adolescence (Cotterell, 1996) For girls at this time interactions with same sex peers is central to their development of self identity and expression of their individuality Further, girls have a particular relationship with cultural texts and cultural icons act to construct and shape what it means to be feminine At this time Bloustien (2003) has pointed out that relationships and body image become paramount, in fact the body can be seen as the site of enormous symbolic work and symbolic production The female body is to be slender, without obvious muscle, it should be physically attractive, is not sexually mature in that it lacks other secondary sex characteristics such as body fat and hair and it is always white (Bloustien, 2003) Bowler-Reyer (1999) has commented that the way women perceive their bodies has everything to do with how they perceive themselves Within this context the cultural icon of Barbie is significant, as noted by Pecora, (1999), Barbie is not just a doll, she is a plastic powerhouse It could be said that Barbie is a powerhouse in the construction of girls' identities

Norton (2004) reported that a significant portion of middle school female students developed negative attitudes towards the study of mathematics through integrated construction activity, and that they wanted specific learning scaffolding in order to help them make the links between construction and embedded mathematics Against this background, the aims of this study were to reflect upon how girls' engagement in mathematics discourse can impact upon their identity formation, specifically whether mathematics and engineering could be seen as consistent with feminine identity; what tasks and pedagogic devices can support girls' positive identities as users and creators of mathematical understandings

Method

The method was one of participatory collaborative action research (Kemmis & McTaggart, 2000) The researcher established a co-operative working relationship with the teachers and taught one 90 minute lesson each week in each of two classes over a 10 week term The subjects were 46 Year 6 female students and the classroom teachers, Annie (all names are pseudonyms) an experienced classroom teacher and Louise who was a first year teacher having recently completed her degree in primary teaching The study was carried out in a single sex, private school in metropolitan Brisbane

Instruments

The data sources included video-recordings, classroom observations and field notes of students' interactions with objects, peers and teachers, and classroom artefacts The students were interviewed about their views on technology, mathematics and science and explanations for design plans and construction features throughout the study While engaged with critical learning tasks the students worked in groups of three

Student perceptions related to the classroom learning environment dimensions: investigative nature of the classroom, enjoyment of learning activity, intention to undertaken further study, and intention to consider a career in the field were assessed using the modified TOSRA (Test of Science-Related Attitudes) instrument (Fraser, 1981) pre and post intervention

At the beginning and end of the study the students were tested for knowledge of proportional reasoning The pencil and paper test had 18 questions Some questions had simple and familiar contexts that could be solved with arithmetic thinking, including the construction of tables which can be done with repeated addition Other questions required a greater abstraction of the notion of proportion, and are not easily solved without a structural understanding of proportion While the tests results are reported to indicate any growth in knowledge, the focus of this paper is upon the students' attitudes to the activity and themselves as learners of mathematics, a manifestation of their sense of identity as users and creators of mathematical knowledge

Critical Tasks

It was decided to make the mathematics the focus of the study, and to adopt an integrated approach to planning in that *technology practice* (Investigation, ideation, production, evaluation - Queensland Studies Authority, 2003) and *working scientifically* (investigate, understand and communicate - Queensland School Curriculum Council, 1999) were part of a complete term plan for integrated mathematics Students worked through technology practice as a means to utilize the motivational potential of authentic construction in applying and exploring critical mathematics concepts To this end, rather than looking to identify the mathematics and science in activities, the concepts associated with fractions, rate and ratio (proportional thinking) were seen as central to technology practice, thus, activities were designed specifically to make mathematical understandings explicit To facilitate this process, the researcher identified the key prerequisite mathematical knowledge associated with proportional thinking and had weekly meetings with the two teachers to plan the teaching of fractions, decimals, percent, rate and ratio The part/whole notions of fractions, decimals and percent were compared and contrasted with the part:part notions of ratio

There were three critical learning activities, the first being a diluting investigation where part/whole and part:part notions of fractions and ratio were explored and linked The process of *working scientifically* was used, that is, fractions and ratio understanding were used to understand the colour changes associated with dilution and the phenomenon was communicated mathematically The second critical activity again used *working scientifically* in an investigation of Barbie The central task was to use mathematics to provide evidence as to whether Barbie was disproportionate when compared to their body dimensions Students developed methodologies including the use of fraction and ratio to determine if Barbie was anatomically similar to the students in the class They then constructed a cardboard cut out of Barbie in profile using the concept of scale such that the height of Barbie was equivalent to the mean height of students in the class In the final critical activity, students used the *technology practice* of investigation, ideation, production and evaluation to design and construct motorized vehicles to go fast and also to pull loads In each activity the students were encouraged to make their knowledge explicit and to make the links between various representations of multiplicative thinking that they had experienced The researcher and the teachers carefully prepared the students for each activity making sure they had the pre-requisite mathematics to undertake the tasks

Results

The mathematics tests, and the survey data was analyzed using repeated measure statistics Over the 10 week study the students made significant gains in their capacity to apply proportional thinking The pencil and paper test results are tabled below:

Table 1

Pre and Post-test Paired Results on Rate and Ratio Questions, Total 24 Marks

Test	N	Mean	SD
Maths pre-test	44	10 35	5 24
Maths post-test	44	16 17**	4 62

** significant at p<0 01

Additional qualitative analysis of test items and of student explanations of constructed artifacts was based on the structural relationships associated with proportion including identifying "within quality relationships" and "between quality relationships" as described by Lamon (1995, p 172), indicated that over half the students were developing understandings of proportion Earlier studies have indicated that the percentage of middle school students who can apply proportional reasoning including comparing ratios is about 20% (e g , Karplus, Pulos, & Stage, 1983) These results are included to demonstrate that most of the students made progress in their understandings of proportional thinking However, the focus of the findings presented in this section of the paper is upon students' perception of mathematics as being consistent with their gender identity

A significant shift in attitude on four dimensions of the modified TOSRA instrument can be noted (Table 2) The within-subject comparison of pre-test and post-test was statistically significant (F= 14 054; df=4; p<0 00, partial eta sq 991; 99%) indicating that the accumulated result of the four components of the attitude scale contributed to an overall shift in attitude The pre-test/post-test results for the separate dimensions are reported below

Table 2

Pre-test and Post-test Trial Results on Attitude Dimensions

	Mean	SD	N (df =35)	Partial Eta sq
Investigation			39	0 588
Pre-trial	3 220	0 481		
Post-trial	4 051**	0 602		
Enjoyment			39	0 405
Pre-trial	2 836	0 478		
Post-trial	3 313**	0 655		
Study Intention			39	0 230
Pre-trial	3 113	0 366		
Post-trial	3 423*	0 585		
Career Intention			39	0 345
Pre-trial	2 805	0 638		
Post-trial	3 231**	0 631		

** significant at p<0 01; * significant at p< 05

Clearly the attitudes of the students improved over the life of the study This was particularly the case for their description of the investigative nature of mathematics activity and enjoyment as indicated by the higher Partial Eta sq statistics

Student comments in both on the spot informal and formal interview settings support the evidence presented in Table 2 that overall there was a considerable improvement in attitude and provided indicators of why this may have been the case First, many students commented on the authenticity of the work and the enjoyment they experienced For example:

> Sam: I like the Barbie maths because it was enjoyable we were trying to figure out if the "perfect" Barbie was blown up to our size, would she look normal It was a fun way to learn how to do ratios

> Georgia: Yesterday we learnt all about ratio and we understood it more If Barbie was a real human she would be approximately as thin a cat The negative thing was that the people who made Barbie didn't make her in the right proportion

> Brodie: It was very interesting comparing Barbie to a human I never realised that she was so abnormal and how easy it was to tell!! It was great because now I understand ratio and find it easy to compare things I have written these three ratios, they are all the same (1:9, 2:18, 4:36)

> Georgina: Her waist is just too small for her body and her legs…I think if Barbie was alive she would be very sad and lonely because she just would not fit in with any of the others

> Lucinda: I liked the Lego, building the tractor, because I learnt how gears worked

The comments suggest these students found that mathematics could be authentic, useful, and fun and also they had at least a qualitative understanding of proportional thinking These comments contrasted to the way most of the students described their usual lessons For example:

> Alyssa: Usually it is just written on the board and we just write in our book, plus, times, divide and just writing them down in our maths books

> Chantelle: I thought it was really good that we could investigate and not just like we usually do, the teacher would just say O K , I'll write this on the board and you copy it down

Students also commented about the type of scaffolding afforded:

> Brodie: I like the way we worked on the white board and that way it was easier to understand it… Then if you wanted to make something go faster you could use it

> Sarah: If you just gave it to me and we had not talked it over or anything, I would be feeling O K , I don't really get this but, but since we talked about it, it as quite easy

> Gabrielle: I liked it because we were learning through the object instead of just board work

> Sophie: I don't think there is really anything that would make it better because it is fun and it has helped me understand pulleys

> Julie: If you wanted to make something go fast, you could use it (the understanding of ratio)

> Ruby: I reckon it was fun…We could go over it again and do some more work on it For me it was hard work The Lego was really fun

Some of the students made positive explicit reference to the lesson structure and the teaching of the prerequisite mathematics prior to engaging in construction activity or investigation Their comments indicated that they liked to have the mathematical tools to understand the phenomena prior to embarking on technology practice or working scientifically Ruby's comment above illustrates her desire to revise before leaving the task Clearly, these students wished to understand Analysis of video data of students working on their investigations and constructions indicated that in constructing and explaining their artifacts they made connections between the abstractions of mathematics and the artifact For example Laura was observed to count gears and scribble calculations in order to determine which gearing to use for a tractor That is, in explaining their artifacts they gained a better understanding of the mathematics For example, in her explanation of how the car operated (Figure 1), Brodie initially stated that the car would be fast with a small pulley attached to the motor When asked to explain why this ought to be so, she turned the motor several times counting the times the driver cog rotated compared to the number of times the follower cog rotated and concluded the car would actually go faster if the driver cog was larger in diameter

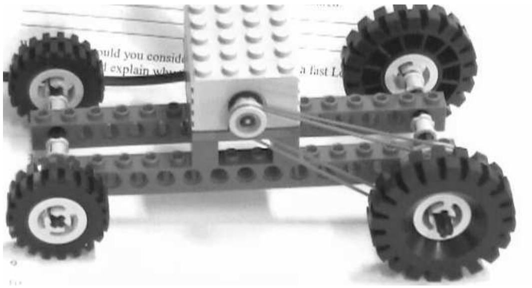

Figure 1 Misconceptions in fast car gearing

The students made consistent reference to the usefulness of mathematics, for example:

> Paige: I never knew that you need mathematics for like making cars and pulleys and every thing Now I think you would use mathematics in every job you might have

Student comments indicated that they found the tasks authentic and enjoyable and appreciated the forms of scaffolding offered Student statements supported the survey data in this regard

Discussion

The data presented in Table 1 demonstrate that most students made considerable gains in their understanding of proportional reasoning The attitude data (Table 2) show that, overall, most students' attitudes to mathematics improved Generally, attitudes are fairly stable (Thompson, 1992), thus to have so many students report more positive attitudes for a number of dimensions of mathematics is encouraging The survey data suggest that much of the change can be attributed to students' appreciation of the more investigative learning environment and also the enjoyment they found in the tasks This finding is supported by interview data

In order to cater for females' preference to think holistically (Head, 1996) the author implemented specific scaffolding Prerequisite tasks were completed such that the students had the mathematical tools for the modeling and construction activities In the lessons in which construction and modeling was not a feature, the students were supported in their learning of fractions, rate and ratio (multiplicative thinking) with the use of alternative models and materials A number of students commented specifically on this scaffolding, claiming it was useful because the mathematics associated with the critical activities made sense The students' comments referring to their need to have some understanding of the mathematical tools prior to commencement of construction is consistent with Head's (1996) finding that females generally did not like impulsive risk taking

The relationship between prerequisite mathematics and activity was complex The description of Brodie's learning related to her fast car indicated that, in attempting to explain her gearing, she was able to reflect upon and manipulate her car, count turns of the pulleys and develop her understanding of ratio Overall, the data support the notion that when students were given the whole picture, including opportunities to understand prerequisite knowledge (fractions, decimals, place value, percent, and the part:part dimension of ratio) and opportunities to tinker, the tasks were more understandable

Another, feature of the scaffolding was that the underpinning mathematics (proportional thinking) formed the basis of the activity sequences Frequently when attempting to teach mathematics via an authentic and integrated approach, the process has been to start with an interesting activity and begin to extract the mathematics out of it However, in this study the approach was to devise technology practices and scientific investigations in which specific mathematical concepts could be embedded In short, the specific mathematical outcomes were the starting point and remained the focus throughout the study In a previous study on the integrated teaching of mathematics, science and technology it was found that the mathematics involved in a construction task may well have come from a number of strands such as number, space and measurement, and at a number of levels and this became a source of discontent for a number of female students (Norton, 2004) However, in this study, rather than attempting to make a large number of different concepts explicit, the author and the teachers focused on number, in particular the multiplicative thinking associated with fractions, decimals and proportion This focus on a few critical mathematical ideas was well received by the students It was found that the students wanted to have the tools to understand the investigations and constructions, and given these mathematical tools they were highly motivated to make sense of the modeling and construction activities, a finding consistent with those of Boaler (1997) The approach gave the students opportunities to see the connections between the multiplicative nature of the number system, equivalent fractions, aspects of our standard measurement system and proportional thinking In doing so, the students were able to use their preference for embedding (Head, 1996)

Cotterell (1996) noted that the adolescence phase was critical for the construction of female identity In addition, Bloustien (2003) and Bowler-Reyer (1999) described this phase as a time when females were especially interested in the body Thus, in selecting critical activities, one that focused on “body form” was expected to be seen as relevant and authentic by many of the students The interview data confirmed that the Barbie study was seen as such and the students were enthusiastic in using the mathematical tools to investigate Barbie In fact, the discovery of Barbie’s abnormal proportionality may well have helped a number of students critically analyze the role that this cultural icon has upon the identity formation of young girls As one student noted, “Barbie would be sad and lonely because she just would not fit in ” Mathematics had been used as a tool to help this student develop a healthier understanding of normal body proportions and in this way what it means to be a normal female

The study adds to our knowledge on how to cater for the needs of female students It has indicated that with specific scaffolding, in well planned integrated sequences of study and specifically designed investigations and technology practices, female students may develop positive attitudes towards mathematics, a reflection of a more positive identity of themselves as users and creators of mathematical understandings In this instance, a large proportion of the students increased their beliefs that mathematics study and possibly a career in mathematics were consistent with their gender identity In conclusion, the study of mathematics in the way described in this paper can be used to help females to construct gender identities consistent with those occupations typically regarded as masculine domains This was indicated by their more positive inclination to undertake study and careers in sciences associated with engineering tasks exemplified in the study

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