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Students' Conflicting Attitudes Towards Games as a Vehicle for Learning Mathematics: A Methodological Dilemma

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Mathematics games are widely employed in school classrooms for such reasons as a reward for early finishers or to enhance students' attitude towards mathematics. During a four week period, a total of 222 Grade 5 and 6 (9 to 12 years old) children from Melbourne, Australia, were taught multiplication and division of decimal numbers using calculator games or rich mathematical activities. Likert scale surveys of the children's attitudes towards games as a vehicle for learning mathematics revealed unexpectedly high proportions of negative attitudes at the conclusion of the research. In contrast, student interview data revealed positive associations between games and mathematical learning. This paper reports on the methodological dilemma of resultant conflicting attitudinal data related to game-playing. Concerns arising from the divergence in the results are raised in this paper. Implications based on the experience of this study may inform educational researchers about future methodological choices involving attitudinal research.

Mathematical games are popular with teachers as alternatives to more traditional forms of repetitive practice, for many parts of the mathematics curriculum, and especially for arithmetical computation. The research literature, as well as popular commercial publishing, supports the idea that games can fire children's interest and motivation because students enjoy competition, challenge, and fun (Bragg, 2003; Bright, Harvey, & Wheeler, 1985; Ernest, 1986; Gough, 1999; Owens, 2005).

This research began by assuming that a novel pedagogical approach, such as game-playing, might have a positive effect on students' classroom engagement and attitudes towards mathematics. What is reported here is based on a larger study which explored games as a pedagogical approach to enhance mathematical learning (see Bragg, 2006). Games were examined in that larger study for their potential to promote mathematical learning, but that aspect is not reported in this paper. Surprisingly, triangulation of the data revealed conflicting attitudinal responses from the students about games. These attitudinal data were collected via Likert scales and student interviews. This paper focuses on the methodological difficulty of interpreting conflicting results and raises some possible explanations as to the contradictory nature of these data.

Background and Theoretical Framework

Attitudes

Motivating students in the classroom is a particular concern for educators because of society's generally accepted poor attitudes towards mathematical success (Kloosterman & Gorman, 1990). It is a minority of adults who will remember with fondness their own childhood experiences in mathematics classes. More so, people remember difficulties and an impenetrability associated with mathematics. The widespread dislike of mathematics is easily communicated from non-teacher adults to children.

Attitudes to mathematics curriculum and teaching have been widely researched (Leder, 1987; McLeod, 1992; Zan, Brown, Evans, & Hannula, 2006). The results of extensive research have shown that the field of educational research lacks one clear definition for attitude (Di Martino & Zan, 2001). For the purposes of this paper McLeod's (1992) definition of attitudes is adopted: "affective responses that involve positive or negative feelings of moderate intensity and reasonable stability" (p. 581). McLeod noted that attitudes develop with time and experience and are reasonably stable, so that hardened changes in students' attitudes may have a long-lasting effect.

When children commence school their attitude towards learning derives from their home environment (Lumsden, 1994). However, success or failure in the classroom impacts on these initial attitudes, and attitudes shaped by early school experience, in turn, impact on subsequent classroom situations (Lumsden, 1994; Reynolds & Walberg, 1992). Other factors affecting learning and attitude include motivation, the quality of instruction, time-on-task, and classroom conversations (Hammond & Vincent, 1998; Reynolds & Walberg, 1992). Students' learning and attitudes are also affected by interactions with peers (Fishbein & Ajzen, 1975; Reynolds & Walberg, 1992; Taylor, 1992). Positive and negative experiences of school activities produce learned responses which may then impact on students' attitudes as they get older, when positive attitudes towards mathematics appear to weaken (Dossey, Mullis, Lindquist, & Chambers, 1988). Awareness of these complex interacting factors informed the research in relation to the potential impact of games on students' attitudes.

Constructivism

This research used a constructivist paradigm to examine the ways students built on their cognitive structures through mathematical games. The games were selected to generate cognitive disequilibrium with the students' existing conceptual structures, requiring them to accommodate new conceptual understandings and potentially attaining cognitive equilibrium. Constructivism represents a way of conceptualising our understanding of how learning takes place. Following on from Piaget (1937), constructivism is an established theoretical framework for understanding these phenomena and indeed proved fruitful in this study. Future work may revisit this study from alternative theoretical perspectives such as socio-cultural theory.

Some writers have suggested that constructivism is based on a metaphor of carpentry (Ernest, 1996; Spivey, 1995). From this perspective, constructivism describes knowledge as an entity built upon previous knowledge; we construct and reconstruct knowledge to accommodate new understandings (Ernest, 1996; Spivey, 1995; von Glasersfeld, 1984). Learners come to *know* their world through their experiences, socio-negotiations and reflections. Upon engaging in a new experience, learners reorganise their conceptual framework to assimilate or accommodate this experience (von Glasersfeld, 1984). This is when learning takes place (Lerman, 1996), a process also captured by Piaget's notion of cognitive disequilibrium, where previous knowledge is challenged by unfamiliar or misunderstood experiences and moves towards cognitive equilibrium, as these experiences are reconceptualised and the knowledge has been constructed and accommodated (Simon, 1995).

This research focused on students building on their cognitive structures through mathematical games. The mathematical games were selected to provoke cognitive conflict while assisting the children to overcome the typical misconception found by researchers (see Greer, 1987; Tirosh & Graeber, 1990) related to multiplication and division of decimals, specifically, that multiplication always makes a bigger number, and division always makes a smaller number. Students' difficulties with decimals and decimal notation is well-documented (see Steinle, 2004, for a recently conducted large-scale longitudinal study on this topic). It was anticipated that addressing decimal misconceptions through the use of games would be a suitable pedagogical approach for provoking the necessary cognitive conflict to promote learning.

Methodology

The Participants and Intervention

The research was conducted with 222 Grade 5 and 6 students (9 to 12 year olds) from three primary schools. These schools were situated in a lower socio-economic area of Melbourne, Australia. The children participated in one of four experimental teaching programs over a four week period. Both students and schools have been assigned pseudonyms for the purposes of this research.

The four experimental teaching programs incorporated game-playing exclusively or mathematically-rich activities related to decimals. A class of students was designated to one experimental group and participated in this intervention for a four week period. Each group, which consisted of two grades, undertook two experimental teaching program sessions per week, for a total of eight sessions. Table 1 shows the variations in intervention for the four groups.

Three of the experimental groups engaged in games while one did not. The fourth group was the activities group which engaged in activities focused on the same mathematical concepts as the games, exploring multiplication and division of decimals. The activities were selected on the basis of their similarity in cognitive demand with the games for these students. They provided opportunities for further investigation of the same mathematical focus related to decimals and included the use of calculators in all sessions.

The rationale for the design of four experimental teaching groups was based on enabling the exploration and comparison of possible pedagogical differences that may occur when games are played for varying time allocations and under differing instructional conditions.

Table 1
Variations of Intervention for Participants

Experimental Group	Intervention	School
Game with discussion group (*n* = 44)	20 min game-playing 15 min focussed discussion	Burrard Primary Sproat Lake Primary
20-minute game group (*n* = 48)	20 min game-playing no focussed discussion	Burrard Primary Sproat Lake Primary
35-minute game group (*n* = 32)	35 min game-playing no focussed discussion	Burrard Primary Sproat Lake Primary
Activities group (*n* = 36)	35 min non-game activities discussion throughout lesson as required	Burrard Primary Alberni Primary

The Games

This paper reports on the methodological issues that arise from data that produce conflicting results. These data arose out of the methodological choices made to examine the use of games in the classroom to build on students' cognitive structures; therefore, it is important to understand the games employed in this study and the rationale for their inclusion.

Games focussing on the multiplication and division of decimals were selected because this was not an area addressed in the Year 5 and 6 curriculum. This concept is primarily addressed in Level 5 (Year 7 and 8) of the *Curriculum and Standards Framework II* (Board of Studies, 2000). It was, therefore, believed that the Year 5 and 6 students would have experienced little formal instruction in this area and hence would not be familiar with the concepts. As previous teacher instruction was more likely to be limited or non-apparent for the participants, the direct effect of the experimental teaching program on mathematical learning would have potentially been more evident. The potential for cognitive conflict was also higher with games that addressed mathematical concepts with which the participants had little prior experience. These selected games are described below.

Guestimate (Swan, 1996) is a calculator game based on multiplication of whole and decimal numbers. The aim of the game is to be the first player to *hit* the nominated target of 100.*** (* indicates decimal places in the number). The numbers to the right of the decimal point have no bearing on the target in this game. Therefore, answers of 100, 100.432, and 100.6 are all considered winning results. Player one begins by entering a two-digit number. Player two can *only* multiply this number so that the answer will hit the target of 100. The players take it in turn until one reaches the target. The students soon become aware that inputting an "easy" whole number such as 10 or 20 at the commencement of the game may result in losing a game rather quickly. Thus the inputting of decimal numbers is required early on in the game. *Guestimate* was also played using only division. In this version the students were to reach a target of 80.***.

Hone on the Range (Brannan, 1983) is also a calculator game and followed the same procedure as *Guestimate*. However, in *Hone on the Range* the players aim for a target in the range between two given numbers, for example, 750 and 780. At the commencement of the games the players decided on the target range. *Hone on the Range* was played using either only multiplication or division.

The selection of *Guestimate* and *Hone on the Range* was supported by their immediacy in promoting a complex challenge and producing cognitive conflict. Both games enabled the students to ponder within the first few turns how to reduce the value of a number greater than the target through the use of multiplication. These games thereby encouraged the students to question their prior understandings of multiplication. The support of a computational tool (calculator) that assisted problem-solving through trial and error also supported the choice of these games for the study.

Methods for Collecting the Data

Two forms of data collection are reported in this paper: for quantitative data, a five-point Likert attitude scale (administered three times: pre-, post- and delayed post-intervention); and for qualitative data, semi-structured student interviews (conducted post-intervention). This paper specially focuses on the Likert scale statement: "Maths games help me to learn maths" and the corresponding interview question: "Has there been a time during playing the games that you thought, 'Hey, I am learning this?' If so, tell me about it."

The Likert scale is a widely used scale in educational research for measuring attitude (Gay & Airasian, 2000). A Likert scale is a useful and time-efficient method of gaining insights into the attitudes of large numbers of students. Student interviewing was employed as it has the potential to provide further insights into the students' experience that may be overlooked in other forms of data collection, and can assist in developing a meaningful understanding of the climate of the mathematics classroom (Zevenbergen, 1998). Interviews supplemented and assisted in interpreting the quantitative information into the impact of game-playing on mathematical learning.

Other data were collected via achievement tests, and researcher observations. However, this paper focuses on the students' attitudes rather than on achievement and engagement and, more specifically, the issue of conflicting data.

As the researcher was expressly interested in the attitudes of the students towards games, only the data from the three game-playing groups are presented. The data from the children who completed the three attitude scales were analysed. Due to missing data in some of the scales, a total of 121 children's data was analysed. In the analysis, group differences were not considered noteworthy and therefore not reported. These data focus on the overall experience of all the game-playing students. Eighteen randomly-selected children were interviewed, six from each of the game-playing groups. These interview data are seen as broadly representative of the general views of the participating students, irrespective of the experimental teaching program they experienced.

Results and Analyses

Attitude Scales

Table 2 presents the frequency of responses to the rating scale for the Likert scale statement: "Maths games help me to learn maths" on the pre-intervention scale. As Table 2 shows, before the game-playing intervention, 75% of the children had a favourable (or strongly favourable) attitude to the view that playing mathematics games is beneficial for their learning of mathematics. This fits the widespread idea that mathematics games are educationally worthwhile; the children's views reflect those of their teachers. This response may also be due to students' positive prior experiences with mathematical games.

Table 2
Pre-intervention Attitude Scale Results for Game-Playing Students (n = 121)

Attitude Statement	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Maths games help me to learn maths	46	45	19	9	2

By contrast, Table 3 illustrates the shifts in the children's attitude immediately after the game-playing intervention period. The change column represents the difference on the Likert scales between the pre-intervention and the post-intervention. The students' pre-intervention results were subtracted from their post-intervention results to gain an indication of any shifts in attitudes.

Nearly 40% of the students in the game-playing groups showed zero shift in attitude between the pre-instructional period and immediately after it: through combining the totals in a positive direction it appears that 17% of students showed a positive change towards the view that playing mathematics games helped them learn mathematics, whereas 43% (a tally of totals from -1 to -4) made a negative change towards the view that games were not helpful. This response was not anticipated.

Table 3
Interval Changes (Pre-intervention and Post-intervention) in Responses to: Maths Games Help Me to Learn Maths (n = 121)

Change	Frequency	Percent %
-4	5	4.1
-3	6	5.0
-2	17	14.0
-1	24	19.8
0	48	39.7
1	15	12.4
2	6	5.0

Given these responses, some further investigation of the nature of the attitude changes was undertaken. Table 4 presents a crosstabulation of the pretest and posttest responses to the prompt, "Maths games help me to learn maths".

Table 4
Crosstabulation Results of Pretest and Posttest Statement: Maths Games Help Me to Learn Maths (n = 121)

		Posttest				
		SD	D	N	A	SA
	SD	2	0	0	0	0
	D	2	1	4	2	0
Pretest	N	1	5	4	5	4
	A	3	7	9	20	6
	SA	5	3	9	8	21

Note. SD = Strongly disagree; D = Disagree; N = Neutral; A = Agree; SA = Strongly Agree

This table elaborates some important aspects of the apparent negative changes in the students' perspectives and the potential of games to help students learn mathematics. The movement in the negative direction was predominantly from those students who were initially positive. Eighteen of the students who strongly agreed or agreed with the statement in the pretest strongly disagreed or disagreed in the posttest. Some such movement may be expected due to a natural effect of regressing to the middle, but even so, it is more marked than anticipated.

To provide an alternative perspective on the shifts in attitude, longer-term changes were examined through the delayed-instructional scale. Table 5 illustrates the shifts in the children's attitude 10 weeks after the teaching program period.

Table 5
Interval Changes (Pre-intervention and Delayed Post-intervention) in Responses to: Maths Games Help Me to Learn Maths (n = 121)

Change	Frequency	Percent %
-4	8	6.6
-3	8	6.6
-2	15	12.4
-1	28	23.2
0	45	37.2
1	13	10.7
2	3	2.5
3	1	0.8

Over 37% of the students did not shift in attitude over the whole 14-week period; only 14% made a positive change to the view that playing games was helpful; while almost 49% changed negatively to the view that the mathematics games did not help them to learn.

Strikingly, it appears that the experience of playing mathematical games as the main instructional activity resulted in less positive attitudes towards learning mathematics through the use of games. This was all the more surprising because during observations of game-playing the students seemed to enjoy the games and had also demonstrated a developing understanding of key concepts, as is described later in the student interviews.

Drawing on a constructivist framework some possible explanations for the negative trend in the attitude scales are:

- The games were addressing both content and process that were quite advanced for these students. This explanation supports Okazaki and Kaoyama's (2005) research which highlighted the difficulties of 5th grade children in learning division with decimals.
- The games provoked Piagetian disequilibration, for example, the early whole-number belief that multiplying always results in bigger number conflicts with the evidence of multiplying positive decimal fractions smaller than 1. The students may not have recognised that this disequilibrium was a part of the learning process and therefore responded adversely to this progression.

- Some children may have become bored with playing the same types of games twice a week over the four-week period. Even seemingly novel pedagogical approaches may become tedious when employed repeatedly.
- Some children who would otherwise enjoy playing easy mathematical games as a reward at the end of a traditional lesson may resent playing games addressing challenging concepts as the focus of the lesson.
- Some children who enjoy individual work and the intellectual stimulus of traditional classroom instruction may dislike the collective interactions and time-demand of game playing as an alternative medium for learning.
- Some children may find the process of answering questions on a Likert scale repetitive, and hence answered more negatively.

Student Interviews

One further explanation for the negative responses on the Likert scales is the possibility that the scales may not measure students' attitudes accurately. An ambiguous positive or negative dichotomy may result from the sole use of Likert scales as suggested by Di Martino and Zan (2003). Scales may be more accurately analysed when triangulated with other kinds of data, such as interviews. To gain deeper insight into students' perceptions of their learning during the game-playing sessions, students were asked the following interview question: "Has there been a time during playing the games that you thought, 'Hey, I am learning this?' If so, tell me about it."

All students interviewed were able to provide examples of learning during the game-playing sessions. This was in contrast to the negative impressions of learning through games derived for the scales which is discussed later in this paper. The responses students gave to the interview question, included: recounting the effect of key mathematical concepts addressed in the games; the benefits of using problem-solving strategies; and, the use of tools to assist learning. This was a satisfactory outcome as, according to the classroom teachers, the students lacked experience with articulating their learning after game-playing.

Several children referred to learning about the effect of multiplication and division of positive decimal fractions smaller than 1, and commented on related strategies they had used; for example, "Yeah, a couple of times, when I thought, 'Oh, this number gets it down to this and then that number will get it up higher'" (Andrea).

A number of children offered more detailed discussion of the problem-solving strategies used to assist their learning. For example, Frazer said:

> When I played the games I didn't know what it would do if I times it by a point, like just a point and a tenth, or just a whole number and a whole number and a tenth or hundreds or a thousandth. That's what I didn't know. When I experimented with it then I found that point 1 is 10 to the 100 or something. It

> goes lower than with a whole number and a whole number and a tenth or a hundredth ... and with just a whole number would go higher anyway. And, so that's how I learned how to times and what would happen. That's how I knew: that's how I got it first shot, because I learnt how to do it when I was experimenting.

When confronted with a difficult concept Frazer's initial Piagetian disequilibrium was overcome through the use of trial and error, which seems to have helped him develop an understanding of the effect of multiplying fractions (that is, positive fractions smaller than 1) and thus he achieved cognitive equilibrium. Frazer's teacher considered him to be a highly motivated and proficient mathematics student. However, similar understandings were also developed by those, like Katie, with less confidence who viewed themselves as poor mathematical thinkers. Katie had declared many times in the study that she was "hopeless at maths". It appears that using calculators in the games freed Katie to experiment, test theories, and build the key concepts. For example, Katie said:

> Oh when I figured out that I can actually bring it up and down without going, "Oh, how do I do that?" and sort of wondering without asking somebody, because you can try anything with a calculator. Which is good because you can always put it back, it's not like writing it. And you can sort of like trial, I can just keep trying: it just makes it easier without anybody watching you. Yeah, without everyone going "That's wrong"; got to rub it out now or keep it there because you know like every time in class you know I rub out the right answer sometimes. ... if you hear anyone coming up saying you can't put it like that you can just clear it and put it back in again and work it out more without writing it down. You're using your head.

Katie found support in the use of a computational tool such as a calculator which enabled her to explore numbers unassisted by her peers or teacher. The game's atmosphere of playing and fun appears to have been less threatening than the typical mathematics classroom environment for Katie, enabling her to engage openly in developing an understanding of mathematical content. Interestingly, Katie also recognised her use of mental computation in playing the game, rather than simply relying on the calculator to support the method of trial and error on all occasions.

As noted above, many students believed that games provided viable vehicles for the learning of mathematical concepts. In response to the following question, "Was there a particular time that you thought these maths games were fun? Tell me about it", over a third of the students related fun associated with mathematics games to an opportunity to learn a new mathematical concept. Three representative comments follow:

> Kevin: Yeah, at the very, very start. I like learning new things so that's why I was glad to be able to play this. I'd never ever timesed decimals or divided and I learned about what they do to a whole number.

Haydn: Yeah, like sometimes when you're got it up to the thing [target] when you won. And when you learned how to do something. Just say dividing and timesing, how to make it go higher and lower. Because I already know how to times and everything but I didn't know which one if you times it by that it goes higher and lower.

Mathis: I started to enjoy it a bit more because I liked division. I liked times better because I find it a bit easier. But at *Hone on the Range* I found division easier. Because, I think, we did division for a bit longer and I think I worked out how to do it, more than times table.

It is interesting that Kevin found the games to be fun "at the very, very start". Since he also mentioned a liking for learning new things, it is possible that Kevin lost interest in the game after he felt he had mastered the mathematical concepts addressed. For him, the fun derived from the game was in the challenge of learning a concept, not in the challenge of beating an opponent. Although Haydn enjoyed winning, he goes on to discuss the benefits of the game in his developing understanding of multiplication and division. It is this newly acquired knowledge that appears to have appealed to Haydn. Mathis' comment summarises many of the points made by the students. However, in contrast to many responses, Mathis found that division was easier than multiplication. Although the same amount of time was designated for multiplication and division versions of the game, Mathis' mastery of the concept may have led him to believe that he had spent more time playing the division game.

In summary, it appeared from the qualitative interview data, that the students felt comfortable with game-playing, they were actively involved in developing strategies for winning, their aspiration to win encouraged them to wrestle with mathematical concepts that were beyond the scope of the prescribed curriculum for their level and they were having fun learning new mathematical concepts. It could be argued that for some students the game-playing environment provided the scaffolding needed to bridge constructively their conceptual understandings.

Some of the students interviewed were able to voice and share the strategies they had developed; thereby highlighting their emerging understanding of the mathematical concepts they were exposed to during the games. It was also clear from some of the students' responses that they were still attempting to create meaning from the concepts addressed in the games: for them the new concepts were still a work-in-progress. From a constructivist perspective, disequilibrium was an important step towards engaging students in mathematical learning.

Discussion

The less than positive response displayed in the quantitative attitudinal scales towards games as a vehicle for learning contrasted markedly with the students' qualitative interview data which revealed episodes of mathematical learning during game-playing which was perceived as fun for some children. It also contrasted with the researcher's anecdotal observations and class teachers' impressions of students who voiced positive comments towards the games as a learning experience during the game-playing sessions. This contrast in data was puzzling and presented a great methodological challenge for this study which needed to be resolved or understood in some way. A series of explanations were developed to account for this discrepancy.

Firstly, students' attitudinal responses suggested that the students undervalued games as a learning tool. The children's previous familiarity with mathematics games as a pre-lesson warm-up activity or as a post-lesson reward may have undermined the effectiveness of games used as the main instructional focus (Bragg, 2006). Interestingly, research by Baker, Herman, and Yeh (1981) found a negative relationship between games employed as end-lesson rewards and the students' completion of class-work. Students presented poor quality work in a hurried effort to be rewarded with game-playing. It is possible that the students in this current study had previously had a similar experience of games being used as a reward, or as a warm-up activity. Games of this nature often comprise content familiar to the students and aimed at their current level of understanding. These games typically comprise a drill and practice formula which students may associate with "learning". In spite of the stated fun associated with learning new mathematical concepts, being confronted with more challenging tasks in the games in this study may have been perplexing for the students and in turn undermined their confidence in this pedagogical approach.

Secondly, attitude scale items may not be well understood by children at this level of schooling. A seemingly simple attitude scale item, such as "Maths games help me to learn maths", may not be well understood by children at this level of schooling. Students may have little understanding of what it means to "learn." Self-awareness, articulate reflection, and metacognition develop slowly through the early years of schooling. Students may not be explicitly aware that learning is occurring. Students are unlikely to have recognised that the cognitive conflict promoted through the game-playing caused the disequilibrium necessary from a constructivist perspective for learning to take place. The confusion associated with the mathematical concepts of the game may have caused the students to respond negatively towards the Likert scale item. In comparison to the interviews, students could recognise that while they may not fully understand the mathematical concepts, there were elements that were understood, and with which they could identify. The interviews may have provided the students with the time necessary to appreciate that some learning had taken place. Hence the students' ability to make a meaningful determination about whether or not playing mathematics games can help them learn is problematic. There is an assumption that students make the same meaning from the Likert scales as the researcher intends in regard to this terminology.

Thirdly, the choice of implementation of measuring tools may have also impacted on these data. The placement of the attitude scales on the front page of the achievement test may also have produced a negative attitude towards the games. Many students have performance-anxiety towards the completion of the achievement tests (McDonald, 2001). Therefore, completing the attitude scale, while anxiously anticipating the impending test, may have caused the students to respond negatively on the scales. The teachers did comment that the students found the achievement tests rather difficult to complete. This was in contrast to students in the pilot test. The students in the study had no prior experience with the mathematical items on the test in the pre-intervention attitude scale and may not have assumed that the test would be difficult given its association with an enjoyable activity such as games. However, the students may have recalled their difficulties with the achievement test items when completing the post- and delayed post-intervention attitude scales. When reading these attitudinal scale data it is necessary to do so in light of the possible effect of test anxiety as a result of the choice of placement of the scales.

In summary, there are a number of aspects to consider when contrasting data arises in research; in particular, how to account for and explain these data when attempting to build a picture of the situation under investigation. In this study the explanations put forth for this disjuncture were: the students' prior experience of games as a pedagogical approach; the students' understanding of the terminology in the statements on the measurement tool especially their understanding of their "learning"; and the design and execution of the attitude scale. Implications arising from these explanations are presented in the following section.

Conclusion

The paper described a research study that was designed to explore the capacity of mathematical games to develop students' cognitive structures. The paper has explored how conflicting results from this research can raise many complexities for research methodology. There are a number of implications arising from these complexities.

The usefulness of games as a tool for learning should be made more explicit to the children. Students appreciate and enjoy games that provide them with a positive learning experience (Bragg, 2006), therefore teachers and curriculum developers should clearly specify learning outcomes related to the games and reinforce their relevance to students. Students could also be encouraged to reflect on their learning during and after the game-playing experiences. Teacher-led discussions which draw out the educational benefit of games could be useful in promoting a positive attitude towards the use of games as a pedagogical tool. Allowing the students an opportunity to communicate the benefits of the game beyond the key mathematical concepts may draw the children's attention to the potential of games to provide a learning experience. Encouraging the use of mathematical games at home with the family, accompanied by a letter explaining the educational benefits of games, may also promote a positive response to games as an acceptable pedagogical tool. Teachers should be encouraged to support the use of games, but should be aware that they need to maximise the potential of games in the classroom to support students' reflective and articulated knowledge of their mathematical learning.

Researchers and students need a shared understanding of the terminology of attitudinal statements. It is evident from the data that adult understanding of concepts such as "learning" may not be similar to students' understanding. Therefore, researchers should be mindful of the terminology employed in attitude scales. It may be useful to have prior discussions with students about their understandings of the terminology potential employed in measures in order to develop a shared understanding.

Consideration should be made in the execution of measures, more specifically their placement in conjunction with possible stress-provoking tasks. Whilst it is acknowledged that an appropriate time to distribute attitudinal scales is a complex issue, certainly there are situations which are less suitable than others. Unfortunately, the students' difficulties with the test items were not realised until the conclusion of the study. However, this understanding of placement of scales is useful for future research.

In summary, in this study a dilemma arose when attempting to make sense of conflicting data. It appeared that game-playing negatively affected attitudes, as measured by the quantitative attitude scales. However, this was not necessarily the case in the qualitative interviews and other data sources. A number of explanations for the possible reasons for this conflict were presented and implications arising from these explanations were put forth. It is anticipated that the findings in this study may inform us as a profession about prospective methodological choices we make.

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