Gender differences in students' mathematics game playing

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ABSTRACT

The investigation monitored the digital game-playing behaviours of 428 primary-aged students (aged 10–12 years). Chi-square analysis revealed that boys tend to spend more time playing digital games than girls while boys and girls play quite different game genres. Subsequent analysis revealed statistically significant gender differences in terms of the types of mathematics-rich games students prefer to play. Girls preferred to play games that required problem solving, quantitative computations and the interpretation of graphs. Boys preferred games that required visual/spatial engagement. Given the fact that boys outperform girls on spatial tasks and mathematics assessment items that contain graphics, this study has implications for the development of students' mathematics sense making.

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1. Introduction

The connection between children's play and the development of mathematical thinking and understanding is not a new phenomenon. Childhood activities including play with water, blocks (Jarrell, 1998) and construction toys such as Lego (Lowrie, 2002), provide opportunities for game-play contexts which stimulate mathematical thinking. Provided these game-play opportunities are "embedded in cultural practices that make sense to the participants", meaningful learning can take place—even if the practices are in simulated forms (van Oers, 2010, p. 26). Recent technological advances, particularly in relation to visual and spatial stimuli, have extended the opportunities and possibilities of game playing. Indeed, a range of children's games that were previously only in a concrete (three-dimensional) form, are now reproduced in digital forms (e.g., puzzles, board games and sporting activities). To some extent, these activities require different forms of processing and thinking (Gee, 2007). In addition, some digital games go beyond the representational scope of more traditional games, with opportunities for dynamic representations of information increasingly available. Importantly, these digital-rich contexts present the opportunity for meaningful mathematics engagement both within the confines of the game and beyond—and consequently become a catalyst for meaning making (Lowrie, 2003). As such, 'new' technologies, and the patterns of individuals' social behaviour(s) have an influence on children's mathematics engagement. This investigation describes primary-aged students engagement in games-based technologies and considers the impact such technologies have on mathematics engagement.

2. Background of the study

To date, digital games tend to attract a predominately male audience, which not only has an impact on a potentially untapped market (Ziemek, 2006), but also affects girls' technology attitudes and experiences. At a stage when girls are disengaging with mathematics (Fennema, 1996), they are also electing not to spend as much time on two-dimensional and three-dimensional game environments (Ziemek, 2006). Since digital games have the potential to improve some kinds of visuospatial reasoning (Guven & Kosa, 2008), further research on the types of games students play is necessary.

An extensive body of literature has examined the performance differences between males and females on non-verbal or spatial tasks. Although performance differences are widely acknowledged (Linn & Petersen, 1985), the ongoing prevalence of such differences is far from stable. Spelke (2005), for example, indicated that the gap between the performance of boys and girls on visuospatial reasoning tasks had

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diminished in the past ten years. Nevertheless, boys tend to perform better on tasks that require mental rotations or when tasks encourage the manipulation of objects in the mind (Spelke, 2005). Such tasks are often required in digital game environments and are increasingly necessary in the interpretation of mathematics tasks (Lowrie & Logan, 2007). With respect to primary-aged students (aged 9–12 years) there are significant gender differences in favour of boys on mathematics tasks that contain number lines and maps (Lowrie & Diezmann, 2007, 2011).

There are a number of plausible reasons for performance differences of males and females on these mathematics tasks. Explanations include the confidence levels of girls (Forgasz, Leder, & Kaur, 2001); their attitudes toward mathematics (Forgasz, Leder, & Kloosterman, 2004); and the fact that boys tend to process rotation tasks more quickly than girls (Wiedenbauer & Jansen-Osmann, 2008). Other accounts include the view that boys' and girls' everyday experiences are different (Tracey, 1990); the age of students (Levine, Huttenlocher, Taylor, & Langrock, 1999); or a combination of life experiences and inferentially biological propensities (Halpern & Tan, 2001). In the pre-school years, it was found that very young children engage with digital environments in clearly gendered ways (Zevenbergen & Logan, 2008).

Primary-aged students, in particular, are exposed to much more graphically- and visually-rich mathematics tasks than ever before. The ability to decode representations such as graphs, diagrams and maps are essential to mathematics sense making (National Council of Teachers of Mathematics, 2000). At the same time, digital games are becoming much more graphically rich, with multiple forms of visual displays representing information on any given screen. The nexus between representation trends in mathematics and game playing is noteworthy since "computer-games experience and preference seems to serve as a mediator between gender and mental-rotation performance" (Quaiser-Pohl, Geiser, & Lehmann, 2006, p. 617). As Bananno and Kommers (2005) argued:

> while males excel on tasks that benefit from requiring new strategies, such as mental rotation ability, females tend to draw on memory of past algorithms or knowledge such as verbal fluency, rather than inventing new approaches. (p. 36)

In studies with older students, it seems that females prefer playing games that involve logic (Quaiser-Pohl et al., 2006) and games which promote skills such as perceptual speed and time skills (Ziemek, 2006). By contrast, males prefer games which are graphically sophisticated and often involve competitive traits (Hartmann, 2003). Similar trends were observed with children under five as they engaged in digital environments (Zevenbergen, 2007). This investigation goes beyond studies which describe game-playing preference by not only considering the specific features of the games students play but also determining the types of mathematics sense making accessed and promoted in the digital games students play.

The study, therefore, investigates primary-aged students' preference for playing specific types of digital games, with a focus on the mathematics sense making required to engage with some of the games. Specifically the study considers:

1. Whether there are gender differences in the amount of time primary-aged students spend playing digital games.
2. Whether there are differences in the type of game genre boys and girls elect to play at this age.
3. To what extent gender differences exist in relation to the type of mathematics sense making promoted in the games primary-aged students play.

3. Method

The project focused on the development and subsequent implementation of a *Digital Landscape* survey with primary school students. Data from the survey were analysed to address the three research questions of the study using the Statistical Package for the Social Sciences (SPSS for Windows 17.1).

3.1. Participants

The participants who took part in the survey were 426 (M = 201; F = 225) primary-aged students from two states in Australia. One cohort was from a rural inland city in New South Wales ($n = 240$) and the other an urban coastal city in Queensland ($n = 186$). The sample was purposively selected from a general expression of "participation interest" from schools in both catholic education and state systems. The participants were aged 10–12 years from Grades 5 and 6. The questionnaire was administered to all Grade 5 and 6 students at the respective schools ($n = 426$), with students completing the questionnaire at home once parental consent had been received.

3.2. Survey development

The survey was designed to describe the nature of student use of a range of entertainment-based digital games with specific reference to mathematics content. The survey sought information that would provide patterns of student behaviour in relation to preference for types of games consoles and software, duration and sequencing of game playing and the content and processes involved in playing the games. The survey used in this study was based on the British Educational Technologies and Communications Agency (BECTA, 2002) questionnaire on Young People's Use of ICT and adapted specifically for this study. The instrument contained three sections associated with digital hardware and software, game-playing habits and the learning principles of the games. The survey included 24 items in three forms: (1) a 3-point categorical format which sought to identify duration and sequencing of game play; (2) a 5-point Likert scale (in the form *frequently* through to *never*); and (3) short answer responses. Descriptive data were also collated and included students' grade level and gender. Examples of the three types of survey questions appear in the Appendix.

Before the survey was administered to students, the items were reviewed by two content experts outside of the research team. In addition, an earlier version of the instrument was trialled with a small cohort of students ($n = 23$). The central aim of the piloting process was to ensure readability and appropriateness, with this cohort also interviewed about the content and nature of the survey to ensure questions were valid. Based upon the feedback provided by the students and content experts, some of the items were removed or rephrased.

Table 1
Contingency table and chi-square analysis for time spent playing games by gender.

		Boys frequency (%)	Girls frequency (%)	Chi-square Df (2, 425)
No. of days per week	<1 day	44 (22)	73 (32)	$\chi^2 = 13.89, p < 0.01$
	1–3 days	57 (29)	80 (36)	
	>3 days	99 (49)	72 (32)	
No. of hours on school days	<1 h	119 (60)	155 (70)	$\chi^2 = 5.01, p > 0.05$
	Between 1 and 3 h	66 (33)	58 (26)	
	>3 days	14 (7)	9 (4)	
No. of hours on non-school days	<1 h	58 (29)	99 (44)	$\chi^2 = 22.20, p < 0.01$
	Between 1 and 3 h	74 (37)	90 (40)	
	>3 h	69 (34)	35 (16)	

Note: Missing data for the three survey questions are 1, 4 and 1 respectively.

4. Results and discussion

4.1. Time spent playing digital games

Three 2×3 contingency table analyses were conducted to determine the relationship between gender and time spent playing digital games. In terms of time spent playing games per week, the Fisher's Chi-square value $\chi^2 (2, 425) = 13.89, p < 0.01$ revealed a statistically significant relationship between gender and time spent playing games. Forty-nine percent of boys played digital games for more than three days per week (as opposed to 32% of girls) while only 22% of boys played games for less than 1 day per week. In relation to the days in which these games were played, there was no relationship between gender and game play on school days $\chi^2 (2, 425) = 5.01, p > 0.05$; however there was a statistically significant relationship between gender and game play on non-school days $\chi^2 (2, 425) = 22.20, p < 0.01$. Within the non-school day category, 34% of boys spent more than three hours playing games per day (girls 16%) while 44% of girls spent less than one hour playing games per non-school day (29% of boys, Table 1).

Of particular note in these analyses is the fact that there is no relationship between gender and hours of digital game play on schools days. Although boys tended to spend more time on game play on school days, it was on non-school days where the significant gender differences occurred.

4.2. Game type preference

A 2×6 contingency table analysis was conducted to determine the extent to which there was an association between gender and preference among six types of game genre. The Fisher's Chi-square value $\chi^2 (5, 367) = 61.6, p < 0.001$ was statistically significant at a $p = 0.05$ level and therefore there was relationship between gender and game genre. Boys were much more inclined to play games within the action category (25% for boys as opposed to 4% for girls) while girls preferred games classified as other (29% for girls and 7% for boys). Games within the 'Action' category included *Spyro* (Activision, 2008) and *Medal of Honour* (Electronic Arts, 1999), whilst games within the 'Other' category included *Brain Training* (Nintendo, 2006) and *Buzz!* (Sony Computer Entertainment Europe, 2005). In terms of descriptive data presented in Table 2, both boys and girls preferred to play 'Simulation' games than any other game genre with 42% and 45% respectively.

4.2.1. Mathematics ideas within digital games

An Exploratory Factor Analysis was conducted on the six survey questions constructed to determine preference for playing digital games which involved mathematics ideas and concepts and the regularity of using particular types of game consoles. This data reduction analysis was conducted before analysing the survey data to ensure the reliability of the subsequent univariate analysis (Hair, Anderson, Tatham, & Black, 1998). A factor analysis with varimax rotation produced two factors with eigenvalues greater than 1.00. Tabachnick and Fidell (2007) advised that caution needs to be taken when conducting factor analysis with a small number of items, however, the items loaded appropriately across the two factors. Moreover, both the Kaiser–Meyer–Olkin (KMO) test of Sampling Adequacy [KMO = 0.62 (greater than the recommended 0.5)]; and Bartlett's test of sphericity [$\chi^2 (15) = 382, p < 0.001$] indicated the appropriateness of factor analysis for reducing data for further analysis. The factor structure accounted for 59% of the variance and included attitude factors associated with the mathematics processes 36% and visual/spatial engagement 23%. The items and factor loadings for the six questions can be seen in Table 3.

Table 2
Contingency table and chi-square analysis for favourite computer game by gender.

Gender	What is your favourite computer game? Frequency (%)						
	Action	Adventure	Simulation	Strategy	Role playing	Other	Total
Boys	46 (25)	38 (21)	77 (42)	0 (0)	10 (5)	13 (7)	184 (100)
Girls	7 (4)	35 (19)	83 (45)	3 (2)	2 (1)	53 (29)	183 (100)
Total	53 (100)	73 (100)	160 (100)	3 (100)	12 (100)	66 (100)	

Chi Square = 61.6, $p < 0.001$.
Note: Data were analysed using pairwise procedures and thus missing cases for boys = 17 and girls = 42.

Table 3
Rotated factor matrix.

Item	1	2	Component
How often do the games you play require you to do maths algorithms or calculations?	0.83		Maths Curriculum
How often do the games you play require you to do maths problems?	0.81		Maths Curriculum
How often do they require you to read graphs?	0.75		Maths Curriculum
How often do you play fixed console games [e.g., Wii, Playstation, Xbox]?		0.82	Visual/spatial engagement
How often do you play handheld games [e.g., PSP, DS, Gameboy]?		0.71	Visual/spatial engagement
How often do they require you to read maps?		0.51	Visual/spatial engagement

The questionnaire items have high loadings with factors that make conceptual sense with all loadings >0.7 on a respective factor, apart from *How often do they require you to read maps?* The first factor consisted of items typically associated with strands in the mathematics curriculum (i.e., problem solving, number and measurement) while the second factor was restricted to the questions associated with visual and spatial engagement. It is unsurprising that the map question does not load on the same factor as the other mathematics curriculum items since teachers seldom promote mathematics concepts through spatial reasoning (Lowrie & Logan, 2007). In addition, many of the handheld and fixed console games involve high levels of visual and spatial representations further reinforcing the loading of the map item away from Factor 1 (see Table 3). Consequently, the two factors could be regarded as curriculum-based mathematics and visual/spatial engagement.

An Analysis of Variance (ANOVA) was then used to determine whether student attitudes by gender differed across the two factors generated from the data reduction technique. Thus, game playing preference of boys and girls were compared across the preference dimensions associated with (1) mathematics curriculum content; and (2) visual/spatial engagement. Table 4 shows the means and standard deviations by gender across the two preference dimensions. The scores were calculated by generating a mean score for the high-loading items for each of the two variables. Items were scored in the same direction such that a 5 indicated a student response of *frequently* whereas a 1 indicated a response of *never*.

ANOVAs revealed statistically significant differences across gender for both *mathematics curriculum* [$F(1, 373) = 11.92$, $p < 0.001$] and *visual/spatial engagement* [$F(1, 373) = 33.59$, $p < 0.001$] variables. With respect to the mathematics curriculum variable, the girls were more likely to play with digital games that required problem solving, algorithmic computations or the interpretation of graphs than boys. By contrast, boys were more likely to play games that involved the interpretation of maps and digital game playing more generally.

5. Conclusion and implications

Buckingham (2007) acknowledged that students in today's society are accessing technology in a variety of ways and with varying amounts of intensity, with access to technology increasingly disparate. Moreover, it is generally agreed that digital games are more likely to interest boys than girls—or at least that boys and girls will have different levels of investment in different types of games (Gee, 2007; Unlusoy, de Haan, Leseman, & van Kruistum, 2010). The present investigation highlighted distinct differences in the types of games boys and girls elect to play and begins to explain the influence game choice can have on students' mathematical engagement—particularly sense making in out-of-school contexts.

Boys, for example, tend to choose games that require higher levels of spatial reasoning. These games are often adventure games which have a journey-based storyline and require a range of visual and spatial reasoning skills in order to make decisions about direction, locations and sequencing. By contrast, girls tend to prefer to play digital games that require computational accuracy and logic-based problem solving.

There is an extensive body of literature (e.g., Lowrie & Diezmann, 2007, 2011) that shows that boys outperform girls on mathematics items that require the interpretation of spatial information—and particularly tasks that required the interpretation of map-based graphics. It was noteworthy that these studies revealed gender differences across tasks that required the interpretation of location and positional information but not on other forms of graphics tasks (e.g., graphics tasks that displayed graphs, pie charts and flow charts). The present investigation highlighted the fact that boys not only prefer to play digital games that require the interpretation of map-based graphics but that these games provide a catalyst for other forms of mathematics engagement and sense making. Consequently, these games foster another rich context for students to think mathematically—from both game playing and related-context perspectives.

There is a need, therefore, to develop spatially challenging games that have appeal for girls. The research literature suggests that girls enjoy in-depth stories and characters within game-playing contexts—particularly if there are opportunities for social interaction both on screen and with others (Inkpen et al., 1994; Murray & Kliman, 1999). Game playing story lines need to accommodate these social interaction elements however they should also promote sense making that requires the encoding and decoding of graphics through visuospatial thinking. Visual and spatial thinking is becoming increasingly important and relevant to mathematics, particularly in concept development (Lowrie & Diezmann, 2009), so increased exposure to such thinking should narrow the gap in terms of gender performance on mathematics tasks.

Table 4
Means and standard deviations for the mathematics and map variables by gender.

	N	Mathematics curriculum	Visual/spatial engagement
Boys	177	2.08 (0.93)	2.05 (0.55)
Girls	198	2.41 (0.92)	1.74 (0.51)

Note: Data analysed using pairwise procedure and thus missing cases for boys = 24 and girls = 27.

Appendix. Examples of the survey questions.

3-Point Likert scale item	On school days, how long do you spend playing electronic games each day?
	• Less than 1 h
	• Between 1 and 3 h
	• More than 3 h
5-Point Likert scale item	How often do the games you play require you to do maths algorithms or calculations?
	• Never
	• Rarely
	• Sometimes
	• Usually
	• Frequently
Short answer item	How many hours per week would you spend playing your favourite game?— hours per week

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