Multimedia: A Means of Improving Students' Engagement in Mathematics Classrooms?

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Despite the potential benefit of multimedia, there is currently little tangible evidence to support the view that multimedia is bringing about the required shift in the quality of education that it is intended to support. This study compared mathematics students in nine Years 8 to 12 classes that were frequently exposed to multimedia with seven Years 8 to 12 classes that were not. First, quantitative data were collected using students' self-reports on their engagement. Second, classroom observations and interviews with 10 students and three teachers were used to gather information that provided insights regarding students' perceptions of the use of multimedia in mathematics classes. The results found statistically significant differences between the two groups, with students who were frequently exposed to multimedia reporting more learning goal orientations, task value, self-efficacy and self-regulation than their counterparts who were not exposed to multimedia. Observation and interview data, collected to provide insights into the quantitative data, suggested that students who were in classes that were frequently exposed to multimedia were more likely to be autonomous and independent in their learning than their counterparts in classes who were not frequently exposed to multimedia. Further, exposure to multimedia was found to be differentially effective for male and female students. Statistically significant interactions were found between exposure to multimedia and gender for learning goal orientations, task value and self-efficacy with males reporting to be more engaged than females in classes that were frequently exposed to multimedia and less engaged than females in classes that were not frequently exposed to multimedia. The results offer potentially important insights into how students' exposure to multimedia could promote their engagement in mathematics classes.

KEY WORDS: adaptive learning engagement, motivation, multimedia, self-regulation

For more than a decade, researchers have highlighted the current crisis of disappointingly low student motivation and interest in mathematics and have, as a result, called for major reforms focused on engaging young people in mathematics learning (Anderson, Hamilton & Hattie, 2004; Attard, 2014a, 2013; Osborne & Dillon, 2008; Sjøberg & Schreiner, 2010). On the whole, the lack of motivation has been attributed to the inability of the mathematics curricula and classroom practices to ignite the interest of students to learn mathematics (Martin, Way, Bobis, Anderson, 2015; Zhu & Leung, 2011).

Since the development of the first computers as multimedia tools, educators have argued that multimedia could be used to support learning (Bork, 1980; Papert, 1980; Neo & Neo, 2009; Chapman & Wang, 2015). For today's generation, traditional face-to-face learning would appear to be less favourable to studying in an immersive digital classroom. The use of multimedia for student learning has been found to improve student engagement (Arroyo, Woolf, Burelson, Rai, Woolf, Burelson, Muldner, Rai & Tai, 2014); interest and motivation (Chang & Lehman, 2002; Chapman & Wang, 2015).

Although there is much research related to the importance of motivation on mathematics achievement, our review of literature indicates that there have been only a limited number of studies that have examined whether student exposure to multimedia in the classroom could increase student motivation and interest in mathematics (see for example, Squire, 2005; Williams & Jacobs, 2004). Although somewhat outdated, the results of these limited studies suggest that exposure to multimedia could make curricula based on real-world problems available to classrooms and provide tools that could excite students in their mathematics learning.

Despite the potential benefit of multimedia, there is currently little tangible evidence to support the view that multimedia is bringing about the shift required in student engagement. It is this dearth of literature that provided the impetus for this research. Therefore, the study reported in this article, which was part of a larger study (Chipangura, 2014), examined: 1) whether student engagement differed for those exposed to classes that included multimedia and those who were not; and 2) whether, in terms of students' self-reports of engagement, exposure to multimedia in mathematics classes was differentially effective for male and female students.

Background

This study, involving 430 students from Years 8 to 12, was carried out at a regional high school on the south coast of Western Australia. The majority of the students at this school were from a low socio-economic background. The Index of Community Socio-Educational Advantage (ICSEA), which uses the key attributes of a school's student population to enable meaningful comparisons to be made across schools (Australian Curriculum and Reporting Authority [ACARA], 2012), was 926 for this school. This index includes student-level data, including occupation and education level of parents or carers, and/or socio-economic characteristics of areas where students live. Although most schools have an ICSEA of between 900 and 1100, generally, schools with an ICSEA of less than 1000 are considered less advantaged, whilst those with an ICSEA above 1000 are considered to be more advantaged (ACARA, 2012).

The Information and Communication Technology (ICT) infrastructure that was being built into the school by the education department was aimed at facilitating a learning environment that allowed the integration of multimedia into the delivery of programs so that student achievement at all levels could be improved. Not only was this school convenient for the author to do the research (since the author was teaching at this school), but this school was considered typical because of the ICT that was being rolled out. However, at the time of this project, not all rooms at the school had been equipped with hardware and some rooms lacked infrastructure including Wi-Fi. Because of the low ICSEA at this school, very few students could afford to buy themselves mobile devices. Whereas each teacher was loaned a computer by the education department, students relied solely on the school supplied devices by the education department. Consequently, the teachers (and students) at this school could not always use multimedia devices in all their lessons and, for these reasons, there were some students who frequently used multimedia in most of their lessons while some did not.

Given the costs of ICT infrastructure that was being built at this school, the author's desire to improve student engagement in mathematics at this school and the dearth of literature that examined whether exposure to ICT in mathematics classes could result in any improvements in student's perceptions of their engagements, this study sought to investigate the impact students' exposure to multimedia had on students' perceptions of their engagement.

Multimedia in Mathematics Classes

When the term multimedia is employed within an educational context, reference is often made to the principle underpinning the cognitive theory of learning that a human brain is capable of processing and encoding simultaneous auditory and visual stimuli (Phan, 2011). Research has consistently indicated that text and language are better remembered if accompanied by visual information (Mayer, 2005; Phan, 2011). In the context of this study, and henceforth in this article, multimedia is considered to be an environment where students use any combination of hypertext, video and audio media formats in their learning. Computers, web-enabled or "smart" phones, portable devices (such as laptops, netbooks, iPods and iPads) are all considered to be self-contained, multimedia machines that include hypertext, buttons, video and audio in the working environment.

Multimedia has the capacity to bring a concept to life, therefore, multimedia technology has the potential to help students to see, hear and model concepts in their environment. Further, multimedia can provide opportunities for students to extend their experiences and to have immediate feedback throughout their explorations (Segal, Tversky, & Black, 2014; Moyer-Packenham & Bolyard, 2016). With multimedia, students are able to stop and explore, or repeat a process as often as they wish or go to another part of a program that offers a different kind of explanation, example, or function without limiting the progress of other students (Squire, 2005; Segal, Tversky, & Black, 2014). Multimedia can provide the means for teachers to differentiate student learning and to cater for the specific needs of students by implementing educational individualised programmes. The combination of video, text, sound, animation and graphics addresses many different learning styles simultaneously and, as such, allows teachers to provide instruction that meets the needs of students from different backgrounds and learning styles (Papastergiou, 2009; Moyer-Packenham & Westenskow, 2016; Paek, Hoffman & Black, 2016).

A major benefit of the use of multimedia in mathematics is the high interactivity of the student and the concepts, as well as the practical application of the skills learned (Orlando & Attard, 2016). Multimedia offers opportunities for problem solving in collaborative groups and the comparison of results, both of which have potential to assist students in the development of team skills and permits real time feedback that supports conversations (Orlando, & Attard, 2016).

Afari, Aldridge, Fraser and Khine (2013) noted that students not only relate positively to visual interactions, especially if there is a game-like atmosphere to the presentation, but also become more engaged in their tasks. Today, multimedia is viewed by many educators as a new and potentially powerful teaching medium. Some researchers have reported that student exposure to multimedia in the classroom could increase student motivation and interest in mathematics (Florian, 2004; Samson, 2010; Project Tomorrow, 2010; Dick, 2008). Recent research is beginning to show positive correlations between the use of technology and student engagement (Dick, 2008; Taylor & Parsons, 2011); however, there is little research that examines whether students' exposure to multimedia increases student engagement in mathematics and whether that exposure to multimedia is indeed differentially effective for male and female students in this subject. Therefore, this study is unique in that it sought to address this gap in the literature.

Student Engagement: Motivation and Self-Regulation

Failure at school is a concern for teachers, psychologists and parents. It is disconcerting when students, who are not less able than others, fail because they simply do not sufficiently engage in academic activities (Anderson et al., 2004). Theobald (2006) and Attard (2014b) stressed that stimulating students' engagement remains one of the greatest challenges for teachers. Osborne and Dillon (2008) and Sjøberg and Schreiner (2010) have called for major reforms focused on engaging all young people in mathematics learning.

Students who are engaged show sustained behavioural involvement in learning activities accompanied by positive emotional tone, enthusiasm, curiosity, and interest (Pintrich, 2003). They select tasks at the edge of their competencies (Bandura, 1986), initiate action when given the opportunity (Schunk & Pajares, 2005) and exert sustained intense effort and concentration in the implementation of learning tasks (Boekaerts & Cascallar, 2006). The opposite end of the continuum to engagement is disaffection (Nardi, 2016). Students who are disaffected are passive, do not try hard and give up easily in the face of challenges. They tend to be withdrawn from learning opportunities or even rebellious toward teachers and classmates (Neo & Neo, 2009).

Motivational beliefs and self-regulatory practices are pivotal to student engagement in the classroom (Velayutham, Aldridge & Fraser, 2011). The consensus amongst psychologists is that students' successful learning engagement in mathematics is primarily determined by their level of motivation and self-regulation (Boekaerts & Cascallar, 2006). Three constructs have been shown to consistently promote students' motivation in learning: learning goal orientation, task value, and self-efficacy (Lynch & Trujillo, 2011; Velayutham, Aldridge & Fraser, 2011). However, students must not only be motivated through assigning goals and values to the learning activity, but they must also self-regulate in order to stay focused and to handle the numerous distractions they face in the completion of a task. As the present research sought to examine whether students exposed to multimedia reported higher levels of learning goal orientation, task-value, self-efficacy and self-regulation than those who were not, these constructs are reviewed below.

Learning goal orientation refers to the purpose of developing competence and focuses on learning, understanding, and mastering tasks. Evidence from past research has indicated that students' learning goal orientation is likely to influence a range of positive learning outcomes including student achievement and problem solving strategies (Kaplan & Maehr, 2007; Parez, Costa & Corbi, 2012), positive emotions and persistence, positive social attitude towards others (Kaplan, 2004), effort (Pass & Abshire, 2015), persistence and employment of deep learning strategies (Kaplan & Midgley, 1997; Moyer-Packenham & Westenskow, 2016), and retention of information and self-efficacy (Kaplan & Maehr, 1999).

Task-value theory emphasises the critical role of academic task value beliefs in directing students' motivation to learn. There are four major aspects of task value, these being, attainment value (importance of the task), intrinsic value (enjoyment one gains from doing the task), utility value (usefulness of the task) and cost (Eccles & Wigfield, 2002). Students who are convinced that their learning activity is important, interesting and useful are inclined to expend more effort and persist longer in completing activities (Wolters & Rosenthal, 2000) and achieve better results in mathematics (Gasco & Villarroel, 2014; Phan, 2014). Schunk and Zimmerman (2007) reported that even when students lacked self-confidence in their ability to perform and/or achieve a task, they were still likely to initiate and maintain their efforts if they valued the learning activity.

Self-efficacy refers to a person's judgment about his or her capability to complete a task at a specified level of performance. Students who are efficacious are more likely to be self-regulating, strategic and metacognitive (Bandura, 1989). Further, efficacious students tend to be more willing to face difficult or challenging problems and exercise control over stress that could provoke anxiety (Bandura, 1993). Self-efficacy beliefs are considered to be powerful predictors of student achievement (Baanu, Oyelekan, & Olorundare, 2016; Høigaard, Kovac, Øverby, Haugen, 2015; Yüksel & Geban, 2016), the choices that students make, the effort that they expend, and their persistence in facing difficulties (Britner & Pajares, 2001).

Self-regulation in learning has been established as both an important outcome of the schooling process and a key determinant of students' academic success (Helle, Laakkonen, Tuijula & Vermunt, 2013). Self-regulated learning steers and directs students' cognitive and motivation processes to achieve learning goals. Researchers, Pintrich (2000) and Aldridge and Fraser (2011), agree that learning goal orientation, task value and self-efficacy, without self-regulation, are of limited value to students in stimulating their engagement. Effort regulation is the key element required for building students' learning skills as well as helping them to stay focused and to be able to handle the numerous distractions that they face in and out of the classroom. Our review of literature found no research that has examined the impact of exposure to multimedia on students' self-regulation. Therefore, this paper serves to address this research gap.

Gender Differences

Concern about student gender and educational attainment focuses mainly on the extent to which female and male students perform differently in different subjects. Gender differences in mathematics learning outcomes are not a new phenomenon (Forgasz & Rivera, 2012). Nationally and internationally, there has been much activity aimed at addressing gender inequities, including education policies (see for example, Australian Education Union's 2008, Policy on Sex Equity) and intervention programs (see for example, Vos, Astbury, Piers, Magnus, Heenan, & Stanley, 2006). Despite this activity, gender differences in mathematics learning continues to persist (Assude, Buteau & Forgasz, 2009; Forgasz & Rivera, 2012). International statistics continue to reveal that a greater proportion of male, rather than female students, choose to study the most demanding mathematics courses when they become optional (Forgasz & Rivera, 2012).

Gender differences tend to be more marked and manifested in the secondary school years. Watt (2004, 2008), in a longitudinal study involving 1,323 students spanning from grades seven to 11, reported that, even when students' intrinsic value of mathematics declined during adolescence, male students consistently maintained a higher intrinsic value for mathematics than female students. Wolf and Fraser (2008) echoed the same findings when they reported that students' views of mathematics generally became less positive as they progressed through the schooling system and that this trend was more magnified amongst girls. They noted that girls' and boys' self-confidence in mathematics begins to drop in early adolescence but drops more precipitously for girls than for boys.

Despite much research related to gender differences in mathematics education, there is a dearth of literature that examines whether students' exposure to multimedia in mathematics classes is differentially effective for male and female students. Little is known about the impact of exposure to multimedia on gender. This study is, therefore, distinct in that it addresses that gap in the literature.

Research Methods

As elucidated earlier, it is unclear whether exposure to multimedia has brought with it shifts in students' perceptions of their engagement in mathematics classes. Therefore, we sought to examine whether exposure to multimedia impacted on students' self-reports of their engagement in mathematics. Given that past literature suggests that gender differences exist in the way in which students learn mathematics (Forgasz & Rivera, 2012), it was considered prudent to examine not only whether student exposure to multimedia influenced their engagement but also whether these influences differed for male and female students.

Theoretical Framework

This study was driven by a post-positivistic view relying on multiple methods of research to ‘capture’ as much as possible the reality surrounding exposure to multimedia on students’ perceptions of engagement. As such, this study involved moving between different paradigms (Onwuegbuzie & Leech, 2004; Teddlie & Tashakkori, 2009).

The theoretical drive for the first phase was deductive (Lovat & Smith, 1991) with priority given to using quantitative research methods to gather and analyse quantitative data. The purpose of the first phase was to provide a global picture of the differences, if any, in students’ perceptions of their engagement in mathematics for students in classes exposed to multimedia when compared to those who were not. This phase provided the study with a snap shot of whether differences exist between students exposed to multimedia and those who were not in terms of students’ self-reports of their engagement.

In contrast, the second phase was inductive and drew on interpretivist and constructivist worldviews and involved the collection of data using observations and interviews, (Morse, 2003). The quantitative results obtained during the first phase were used as a springboard for the collection of qualitative data. The second phase sought to ‘capture’ and elaborate on the quantitative findings and to provide causal explanations of the differences. Essentially, the quantitative data served to provide the study with a general picture of the learning environment and, the second phase, served to provide more in-depth insights and causal explanations for the general quantitative results.

Sample

At the time of data collection, the school had a population of approximately 430 students enrolled in Years 8 to 12. Intact classes rather than sample populations of each group were used. Although all six of the mathematics teachers who were teaching at the school at the time of this study agreed to have the surveys administered to the students in their classrooms, only three consented to be observed and interviewed.

To increase the internal validity of our findings, and to provide a more representative sample, the entire school population of 430 students were invited to be involved in the study.

The 16 mathematics classes were divided into two naturally occurring groups: those classes that were frequently exposed to multimedia and those that were not. The following criteria were used to classify these classes in terms of whether they were frequently exposed to multimedia: 1) Students were required to have access to an interactive whiteboard in their classes (not all classrooms had them installed) and/or the students actively used multimedia devices in their learning – that is, students were provided with hands-on activities involving the use of multimedia devices in at least three of their four lessons per week, 2) if the teachers, in their instruction of mathematics content, used at least one multimedia device during instruction in every lesson and the students actively used multimedia gadgets in their learning in three or more of their four lessons per week. Selection of these classrooms was based on both the teachers’ notes and classroom observations conducted by the first author in each of the classes. Based on these criteria, nine of the 16 classes were considered to be frequently exposed to multimedia and the remaining seven classes were considered to be infrequently exposed to multimedia.

Of the 430 students enrolled at the school at the time of the study, 365 students (191 males and 174 females) consented and were present on the day of administration. The students’ ages ranged from 11 to 17 years. For each year group, based on previous year’s achievement level, classes were made up of students who were selected according to their achievement levels, namely, high, moderate and low achievers. The table below show the distribution of achievement levels for students exposed to multimedia and those who were not.

Table 1
Number *of Classes and Students' Achievement Level for each Sex in each group.*

		Achievement levels			
		High Achievers	Moderate Achievers	Low Achievers	Total
Frequent Multimedia	Classes	4	3	2	9
	Male	45	35	27	107
	Female	37	25	28	90
Infrequent exposure to Multimedia	Classes	1	2	4	7
	Male	22	16	46	84
	Female	10	22	52	84

Data Collection

This study involved a sequential explanatory mixed-method design that involved the collection of both quantitative and qualitative data (in that order). The qualitative data (which followed the collection and analysis of the quantitative data) was used to help to explain or elaborate on the quantitative results. This section describes the instruments used to collect the data.

Survey: Assessing Student Engagement

To assess student perceptions of their engagement in mathematics classes, a modified version of the original Students' Adaptive Learning Engagement in Science questionnaire (SALES), originally developed by Velayutham, Aldridge and Fraser (2011), was used. This questionnaire assesses key determinants of student engagement: motivation (involving three scales) and self-regulation. The items of the SALES were modified to make them suitable for use in mathematics classes and the survey was renamed Students' Adaptive Learning Engagement in Mathematics (SALEM). The survey has 32 items in four scales:

- Learning Goal Orientation, which assesses the degree to which students desire to develop skills and competences by mastering tasks;
- Task Value, which assesses the extent to which students find the task to be of value and personally relevant;
- Self-Efficacy, which assesses the degree to which students hold their beliefs or judgements about their capabilities to perform a specific task; and
- Self-Regulation which assesses the degree to which students meta-cognitively, motivationally and behaviourally participate in the learning process.

The SALEM was responded to using a five-point Likert scale of strongly disagree, disagree, not sure, agree and strongly agree. The SALEM's factor structure, internal consistency reliability and ability to differentiate between classrooms were examined and proved to support the reliability and validity of the SALEM when used with this sample of

356 students in 16 classes (See Chipangura, 2014, for more information regarding the reliability of the survey).

With the approval of the principal and the teachers, the SALEM was administered during regular class time. Students were excluded from the study if their parents did not provide consent, or if students were absent on the day of data collection.

Observations and Interviews

Observations of Classes. Three of the six mathematics teachers were willing for their classes to be observed. To allow meaningful comparisons one pair of classes, from the same grade level and taught by the same teacher was selected. Each pair of classes selected was comparative in terms of year level, student ability and, importantly, both classes were taught by the same teacher. This provided a total of 12, 60-minute classroom observations: four observations for each of the three teachers (two of which were frequently exposed to multimedia and two which were not). Each pair of classroom observations for each teacher was carried out during the same week, to ensure that the subject matter was similar for each observation. These observations were carried out over a 12-week period. All Observations were recorded as field notes that were later written up as narratives for comparison.

Interviews with Students and Teachers. Parental and student consent was gained from ten students who were to be interviewed and audio taped. To provide a sample that might, generally, represent both senior and junior high school students, the students were all selected from year 10. In all cases, students were selected from classes with moderate achievers. Six of the students were selected from classes exposed to multimedia (three male and three female) and four were selected from classes not frequently exposed to multimedia (two males and two females). The interviews were in-depth and semi-structured, lasting approximately 20 minutes each. The questions used to guide the interview were generated from the items in the SALEM and used to provide insights into the quantitative results. All interviews were audio-taped and transcribed verbatim for later analysis.

The three teachers whose classes were observed also consented to be interviewed. These interviews, generally held after each pair of observations, were semi-structured and based largely on observations regarding the students' engagement. The interviews, which lasted approximately 30 minutes, were recorded and transcribed verbatim.

Data Analysis

Phase 1: Analysing survey data. To examine whether student engagement (in terms of self-reports of motivation and self-regulation) differed for those exposed to multimedia and those who were not, the average item mean (scale mean divided by the number of items in each scale) and standard deviation was calculated for each SALEM scale. Using the individual as the unit of analysis, effect sizes (difference in means expressed in standard deviation units) were calculated to describe the magnitude of the differences between students exposed to multimedia and those who were not (as recommended by Thompson, 2002). To further examine whether the differences in student scores for the two groups (those who were exposed to multimedia and those who were not) were statistically significant, a one-way multivariate analysis of variance (MANOVA) was used. The set of four SALEM scales constituted the dependent variables whilst exposure to multimedia (frequently exposed and not frequently exposed) was the independent variable.

To investigate whether exposure to multimedia was differentially effective (in terms of student engagement) for male and female students, the sample of 365 students in 16 classes was used to examine the interactions (exposure to multimedia, gender, and exposure to multimedia by gender) for each engagement scale using a two-way multivariate analysis of variance (MANOVA). The dependent variables for the two-way MANOVA were the SALEM scales and the two independent variables were exposure to multimedia (frequent and infrequent) and student gender (male and female). Because the multivariate test, using Wilks' lambda criterion, yielded significant differences for the main effects and for the interaction, the univariate analysis of variance (ANOVA) was interpreted for each scale. The eta^2 statistics was calculated to provide an estimate of the strength of association for each effect (exposure to multimedia, gender and the interaction) for each scale.

Phase 2: Analysing the interview and observation data. Analysis of the qualitative data involved thematic analysis, in which the data was collated and condensed into succinct themes. The analysis of the qualitative information was guided by the Framework Approach to Data Analysis by Pope, Ziebland and Mays (2000). Five key stages were involved in the analysis of the interview data. The first involved, familiarisation, in which the researchers read and re-read the transcripts of the data noting recurrent themes and ideas. The second involved the development of a thematic framework that was guided by the motivation and self-regulation factors assessed in the survey. In the third stage, those aspects or portions of the data that corresponded to a particular theme were coded or indexed according to that theme. The fourth stage, charting, involved arranging the data according to the framework and under headings and subheadings to aid with the reporting. Finally, the mapping and interpretation stage, involved examining the key characteristics of the analysis in light of the quantitative data to determine causal explanations and links.

Results

Student Engagement in Classes Exposed to and Not Exposed to Multimedia

Self-reports of students' engagement (in terms of their motivation and self-regulation) were used to examine whether these were different for students in classes with and without exposure to multimedia. The average item means, reported in Table 2, indicate that, for all four engagement scales (Learning Goal Orientation, Task Value, Self-Efficacy and Self-Regulation), students in classes frequently exposed to multimedia scored higher than for their counterparts who were not. The effect sizes, calculated to provide a measure of the magnitude of the differences (reported in standard deviations) in students' self-reports of engagement between the two groups ranged from just over one (1.08) standard deviation to more than one and a half (1.56) standard deviations (see Table 2). According to Cohen (1992), these effect sizes can all be considered educationally significant and important.

For the one-way MANOVA, the multivariate test using Wilks' lambda criterion yielded significant differences, therefore, the univariate ANOVA was interpreted for each scale. The results, reported in the last column of Table 2, indicate that students in classes that were frequently exposed to multimedia scored statistically significantly higher (p<0.01) for all four SALEM scales than did students in classes not frequently exposed to multimedia.

Table 2.
Average Item Mean, Average Item Standard Deviation and Difference for Students in Classes Frequently Exposed *to and Not Frequently Exposed to Multimedia (Effect Size and One-Way MANOVA Results) for each SALEM scale, using the Individual as the Unit of Analysis.*

Scale	Average Item Mean [a]		Average Item Standard Deviation		Difference	
	Frequently Exposed	Not frequently Exposed	Frequently Exposed	Not frequently Exposed	Effect Size [b]	F
Learning Goal Orientation	4.24	3.25	0.49	0.77	1.53	220.58**
Task Value	3.87	2.94	0.58	0.61	1.56	222.70**
Self-Efficacy	3.86	3.18	0.57	0.68	1.08	109.47**
Self-Regulation	3.86	2.97	0.61	0.78	1.38	147.23**

Note. *p < .05 **p< .01

N= 197 students in 9 classes frequently exposed to multimedia and 168 students in 7 classes not frequently exposed to multimedia

[a] Average Item Means = Scale Score divided by the number of items in that scale

[b] Effect size (Cohen's d) is the difference in means expressed in standard deviation units

Cohen's $d = M_1 - M_2 / \sigma_{pooled}$ where $\sigma_{pooled} = \sqrt{[(\sigma_1^2 + \sigma_2^2) / 2]}$

The results of the qualitative data analysis generally supported these quantitative findings. Observations of the classes indicated that, in classes exposed to multimedia, students were more attentive and more engaged in their work than their counterparts who were not exposed to multimedia. To this end, one of the teachers commented: "Multimedia excites students' interest and curiosity as it brings mathematical problems to life for students of all abilities." [Teacher 1]. Interestingly, all three of the teachers agreed that, in classes where there were multimedia, they experienced less disruptions from students. In addition, students in classes frequently exposed to multimedia were found to be more enthusiastic about the tasks and less likely to be distracted. As one teacher commented: "Multimedia helps to keep students on task by keeping them away from distractions and the bad influence of others." [Teacher 2]. These results suggested that students' exposure to multimedia could provide the means to nurture more goal-oriented behaviours (*learning goal orientation*) and exert sustained intense effort and concentration in the implementation of their learning tasks (*self-regulation*) in mathematics.

Observations of the two groups indicated that the enthusiasm for the work displayed by students in those classes exposed to multimedia was greater than for those where there was no multimedia. Analysis of the data indicated that this engagement could be the result of the flexibility afforded by the use of multimedia. The observations indicated that, for those students in classes that were frequently exposed to multimedia, there was more flexibility in terms of the seating arrangements, speed at which students could progress with their work and the activities provided.

With respect to the seating arrangements, in classes exposed to multimedia, these tended to be more flexible than in classes where there was no multimedia. It would appear that this flexibility was afforded because the students were more engaged. As one teacher expressed:

> Seating plans are not necessary in this class [frequently exposed to multimedia] because students do not show tendencies of distraction and boredom. They are generally engrossed in their work when using multimedia. With this in mind, I don't really mind where or with whom the students sit. [Teacher 1]

A student commented on how this flexibility in the seating arrangement was positive in their view:

> I don't want to be a loner. I always sit next to my friends and we help one another whenever we have problems with our class work on our computers. We don't laugh at each other when we make mistakes and our teacher likes that too. [Student 1.3]

This theme also involved flexibility in terms of the speed at which students could complete their work. For those students in classes not exposed to multimedia, there appeared to be less flexibility in terms of the speed at which they could progress. It would appear that the flexibility of the lesson was made possible by the use of the multimedia. To this end, one of the teachers commented:

> One advantage of using multimedia is that my students can progress at different paces giving me the opportunity to individualise the needs of specific students and to implement individual educational programmes. In this way, one student's progress does not hinder another student's progress. [Teacher 2]

It is possible this ability to differentiate the programme using multimedia might have influenced students' perceptions of their ability to succeed in mathematics (*self-efficacy*).

Classroom observations also indicated that, in classes exposed to multimedia, the teachers were able to provide a wider range of activities to students. In these classes there was more evidence of activities that involved small groups, discussions and individual work (mostly involving consolidation activities). In contrast, the work provided to students not exposed to multimedia was comprised predominantly of work written on the white board or on handouts. Students who were exposed to multimedia generally agreed that this range of activities helped to keep them interested. One of the students commented:

> I always have something to do in this class [frequently exposed to multimedia]. I can log onto Mathletics, do 'Mr Farmer's 10 quick questions', do 'challenges' with a friend or if I want to do my work alone, I can log onto the 'Khan Academy' [an online programme that delivers free mathematics resources to students]. [Student 1.3]

The three teachers all felt because of the different activities available to them, they could incorporate activities that were likely to engage students in their learning. To this end, one of the teachers commented:

> …The advantage of using multimedia is that students are willing to spend more time and effort and persist longer towards completing their activities. I design my lessons for this class with multimedia in mind, to excite their interest and stimulate their love for the subject [Teacher 1].

These findings support the survey data, suggesting that students in classes with multimedia are more likely to persist longer (*self-regulation*) and perceive their learning as interesting (*task value*).

Differential Effectiveness of Exposure to Multimedia for Different Gender

The previous section reported the analysis of the differences between the two groups as a whole. This section specifically reports analysis used to investigate whether frequent exposure to multimedia was differentially effective for males and females. As the multivariate test using Wilks' lambda criterion yielded significant differences for one of the main effects and for the interaction, the univariate ANOVA was interpreted for each scale, the results for which are reported in Table 3.

Table 3
Two-Way MANOVA/ANOVA Results (F and Eta^2 statistic) for Exposure to Multimedia and Sex for each Scale of the SALEM.

	Two-Way ANOVA Results					
Scale	Exposure to Multimedia		Gender		Exposure to Multimedia x Gender	
	F	Eta^2	F	Eta^2	F	Eta^2
Learning Goal Orientation	222.44**	0.38	1.67	0.01	8.72**	0.02
Task Value	223.49**	0.38	0.07	0.00	12.24**	0.03
Self-Efficacy	108.58**	0.23	0.06	0.00	8.18**	0.02
Self-Regulation	145.53**	0.29	0.06	0.00	2.28	0.01

Note. *p< .05 **p< .01

N= 365 students in 16 classes.

Eta^2 represents the proportion of variance in a dependent variable explained by an independent variable.

As expected, the ANOVA results with control for gender, reported in Table 3, reflect the results of the previous one-way ANOVAs ignoring gender (refer to Table 2). The eta^2 statistics show that the amount of variance in scores accounted for by exposure to multimedia ranged from 0.23 to 0.38 for the scales. No significant differences were observed for ANOVA results with control for exposure to multimedia.

A statistically significant interaction (p<0.01) between exposure to multimedia-by-gender occurred for three of the four SALEM scales, namely, Learning Goal Orientation (see Figure 1), Task Value (see Figure 2) and Self-Efficacy (see Figure 3). Therefore, independent interpretation of exposure to multimedia by gender differences was only valid for Self-Regulation. For all three of these scales (Learning Goal Orientation, Task Value and Self-Efficacy) the students, regardless of gender, scored higher in classes that were exposed to multimedia than those students who were not exposed to multimedia. However, the interpretation for the interactions was that, in classes that were frequently exposed to multimedia, males perceived a greater sense of *learning goal orientation*, *task value* and *self-efficacy* than their female counterparts. Further, in classes not frequently exposed to multimedia, female students perceived a greater sense of *learning goal orientation*, *task value* and *self-efficacy* than their male counterparts.

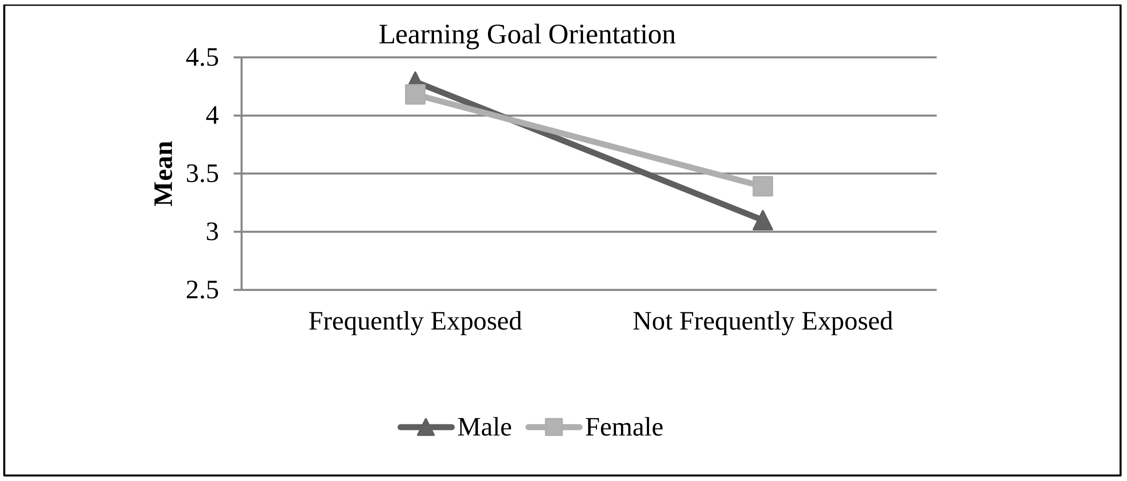

Figure 1 Interactions between exposure to multimedia and gender for Learning Goal Orientation

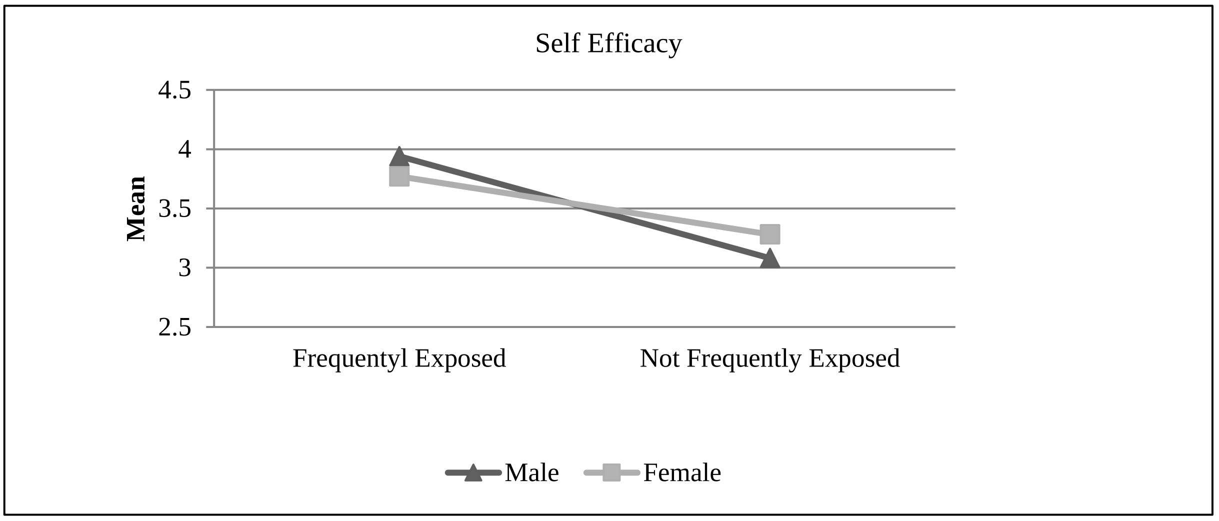

Figure 2 Interactions between exposure to multimedia and gender for Task-Value

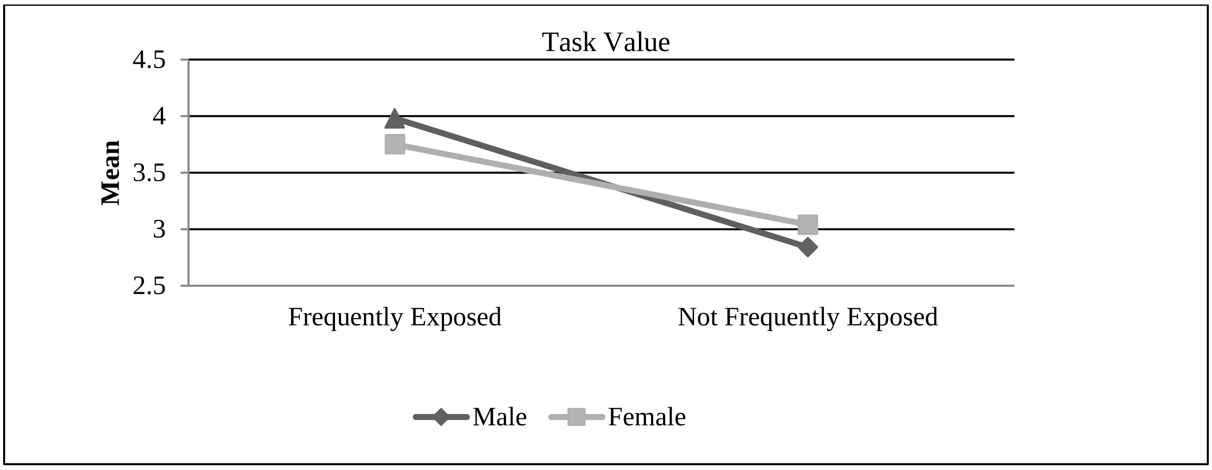

Figure 3 Interactions between exposure to multimedia and gender for Self-Efficacy

Discussion and Conclusion

The overarching aim of this article was to examine whether students' perceptions of engagement in mathematics differed for students who were frequently exposed to multimedia and those who were not, and if so, whether exposure to multimedia was indeed differentially effective for male and female students. The major findings and recommendations of the study are summarised below.

Differences for Students Frequently and Infrequently Exposed to Multimedia

Students in classes frequently exposed to multimedia scored statistically significantly higher on all four engagement (SALEM) scales than their counterparts who were infrequently exposed to multimedia. Further, based on qualitative findings, these results suggest that students perceived that they were more engaged in classes that involved multimedia. These findings add weight to past studies that have examined learning in settings that involve multimedia including, student enjoyment and engagement (Afari, Aldridge & Fraser, 2012, 2013; Florian, 2004; Segal, Tversky, & Black, 2014) student attentiveness (Samson, 2010); and motivation (Alexander & McKenzie, 1998; Samson, 2010).

These results corroborated numerous other studies that have examined multimedia in educational settings and found that multimedia had positive impacts on students' engagement. For example, Samson (2010) and Afari, Aldridge and Fraser (2012) reported that the use of computers in the classroom increased student motivation and interest. Pass and Abshire (2015) concluded that, rather than just completing tasks and being more committed to learn, multimedia impacted positively on students' motivation, their attitude towards their school work, and their behaviour in class.

Our study extends this past research by examining the engagement of students in mathematics classes in rural Western Australia. These findings are important given the curriculum efforts currently taking place in Australia and the large investment made in terms of ICT infrastructure. These findings support future interventions that specifically target the engagement of students in mathematics and that these interventions might include improving the availability of multimedia in mathematics classrooms.

Although it was beyond the scope of the present study, it is possible that students' engagement could be further enhanced by exposing students to different types of multimedia-involving tasks and activities. Therefore, it is recommended that future research examine whether different types of multimedia-involving activities enhance students' engagement in mathematics to differing degrees.

Differential Effectiveness for Male and Female Students

Statistically significant interactions were found between exposure to multimedia and gender for three of the four SALEM scales, namely Learning Goal Orientation, Task Value and Self-Efficacy. Interestingly, although students, regardless of gender, scored higher in classes that were frequently exposed to multimedia, in all cases, males were more engaged than females in classes that were frequently exposed to multimedia and less engaged than females in classes that were not frequently exposed to multimedia.

Our findings that males in classes that were frequently exposed to multimedia scored higher than their female counterparts in *learning goal orientation, task value* and *self-efficacy* is consistent with the findings of Assude, Buteau and Forgasz (2009). In their work, Assude, Buteau and Forgasz (2009) noted that in multimedia learning environments, males hold more functional beliefs about themselves as learners of mathematics than females do, and that female confidence in mathematics and in setting themselves goals remains a critical variable with respect to mathematics achievement levels and participation in mathematics.

Australian statistics continue to reveal that differences between male and female students tend to be more marked at high school, and are more clearly manifested in the middle school years with boys consistently maintaining a higher intrinsic value for mathematics than girls (Forgasz & Rivera, 2012; Wolf & Fraser, 2008). Therefore, examining the differential effectiveness of exposure to multimedia in terms of differences perceived by different gender, make it possible for policy makers to address these perceived differences in classes by using multimedia. However, given that both boys and girls in classes exposed to multimedia had consistently higher perceptions than their counterparts who were not (regardless of gender), it is recommended that schools consider the benefits of introducing multimedia to classes that are not currently exposed to multimedia on a frequent basis as a means of encouraging both boys and girls to participate in the learning process and to improve their perceptions of engagement in mathematics. This could be achieved through teacher professional developments courses targeting effective use of multimedia.

Limitations and Recommendations for Future Research

Given that the data for the present study was collected from students in one high school, generalising the results to other schools should be done with caution. It is recommended that future research, which replicates this study, involve a larger and wider sample of students from both rural and metropolitan schools.

Our selection of groups was based on the exposure of students to multimedia and did not take into consideration the quality of the activities or instruction (in terms of whether it was constructivist-oriented or otherwise) or student achievement. It is recommended, therefore, that future studies examine whether exposure to different types of multimedia and the quality of the programmes and activities provided through multimedia impacts on students' perceptions of engagement.

Due to the cross-sectional nature of this study, changes in students' perceptions of engagement over time were not tracked, it is recommended that, in the future, longitudinal studies be carried out to identify patterns of student perception of engagement over time and at different stages in high school.

Concluding Remarks

An important finding of the present study was that, in classes that were frequently exposed to multimedia, students reported statistically (p>.01) higher levels of student perception of engagement in mathematics learning than students in classes that were not frequently exposed to multimedia. These findings imply that schools and mathematics teachers wishing to improve students' engagement could consider involving the use of multimedia.

The knowledge that exposure to multimedia in mathematics has the potential to improve and, importantly, promote student engagement in mathematics learning, may provide schools with the impetus to involve multimedia as a means of promoting students to proactively regulate their own learning, particularly in high school where negative shifts in students' engagement have been shown to occur. In addition, it is hoped that these findings will encourage teachers to incorporate and model the use of multimedia in their learning environments as a means of engaging students in mathematics.

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