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‘New Directions for Traditional Lessons’: Can Handheld Game Consoles Enhance Mental Mathematics Skills?

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Abstract: This paper reports on a pilot study that compared the use of commercial off-the-shelf (COTS) handheld game consoles (HGCs) with traditional teaching methods to develop the automaticity of mathematical calculations and self-concept towards mathematics for year 4 students in two metropolitan schools. One class conducted daily sessions using the HGCs and the Dr Kawashima’s Brain Training software to enhance their mental maths skills while the comparison class engaged in mental maths lessons using more traditional classroom approaches. Students were assessed using standardised tests at the beginning and completion of the term and findings indicated that students who undertook the Brain Training pilot study using the HGCs showed significant improvement in both the speed and accuracy of their mathematical calculations and self-concept compared to students in the control school. An exploration of the intervention, discussion of methodology and the implications of the use of HGCs in the primary classroom are presented.

Introduction

Recent findings of the Review Panel of the National Numeracy Review Report (Commonwealth of Australia, 2008) highlighted that mathematics in Australia is at a critical juncture. The panel suggested that many Australian students are: (1) not learning the basics of mathematics, nor are they being equipped for further study or future employment, (2) not performing well relative to other countries, (3) part of a long tail of underachievement in international tests, and (4) part of pockets of low achievement that reflect socio-economic, geographical, cultural and racial/ethnic factors. Professor Gordon Stanley, Chairman of the Review Panel, suggested part of the reason for the poor performance of Australian students is that mathematics “is not generally perceived as a popular subject among young people” (p.1), nor is it “recognised as an easy subject to learn or to teach (p.1)”. While much emphasis in recent times has been placed on lifting literacy levels of primary aged students, numeracy has been somewhat neglected in Australian schools (Commonwealth of Australia, 2003). Further, Garcia, Jiminez and Hess (2006) point out that it is not easy to identifying students who have difficulties with mathematics because struggling with mathematics is considered ‘normal’ and therefore problems in this area are more socially acceptable than literacy difficulties.

The authors of this paper consider engagement to be a significant factor in student achievement. Lack of engagement is increasingly identified with poor student performance in schools (Greenwood, Horton & Utley, 2002); without it there is little possibility that students will make the classroom gains expected of them (Bulgren & Carta, 1992). The authors are therefore interested in pedagogies that engage students as well as factors that interfere with

engagement. One factor that impacts on students' ability to engage with a learning experience is anxiety and Gargiulo and Metcalf (2010) suggest that many students experience anxiety with mathematics which blocks initial learning and makes transferral of skills difficult. Cavanagh (2007) also highlights that this emotional response hinders working memory and subsequently the ability to recall basic facts. Anxiety is not restricted to those in primary school settings; Sharman and Christian (1999), in their exploration of self-concept among college students, suggest poor attitude "plagues [sic] learners at every level of schooling". While some level of anxiety may be beneficial in engaging students (Csikszentmihalyi, 1991), consistent negative feelings towards mathematics produces what Tobias (1976) refers to as the 'I can't syndrome'. Similar to the 'Matthew Effect' described by Stanovich (1986) in relation to reading, children who struggle with mathematics avoid it and therefore become poorer at these skills through lack of practice.

Automaticity of basic computations, such as tables, is considered important for students' mathematical achievement as information processing theory highlights that, without direct retrieval of basic facts, students experience difficulty performing more complex tasks (Woodward, 2006). Whitehurst (2003) suggests that one way around this is to ensure components of the problem solving tasks become "routine and over-learned" (para 31) which requires practice. If students do not develop fluent retrieval of basic facts, there is evidence that this limits the development of higher order mathematical skills (Ball, Ferrini-Mundy, Kilpatrick, Milgram, Schmid & Schaar, 2005).

Whereas enhancing automaticity is highly relevant, the development of these skills amongst today's students is difficult. Teachers tend to be focussed on developing 'number sense' (Van de Walle, 2003), and are not prepared to devote the time traditionally afforded to rote learning. Indeed, researchers such as Isaacs and Carroll (1999) question the value of rote learning, suggesting that students develop natural strategies if given the opportunity. Furthermore, rote learning is often perceived by teachers as not engaging for students and they increasingly refer to the 'crowded curriculum' whereby effective instructional time is at a premium. Further, students' poor self-concept pertaining to their ability to perform basic mathematical functions can create anxiety and resistance to practicing these skills. Hence the researchers' interest in exploring classroom pedagogy that not only engages students', improves their automaticity of mathematical facts, and enhances their self-concept but does this effectively and efficiently.

Enhanced self-concept, defined herein as "broadly based individual beliefs about self in physical, social and academic domains" (McInerney & McInerney, 2006, p. 577), is considered important for learners because there is a reciprocal relationship between this and achievement (Wang, 2007). Craven, Marsh and Burnett (2003) unpack this reciprocity further by highlighting that better student achievement leads to improvements in self-concept and, in turn, positive self-concept increases student achievement, which further improves self-concept.

Enhancing self-concept towards mathematics

The pathway towards improved self-concept in mathematics is complex. Craven, Marsh and Burnett (2003) refer to attempts within research to enhance self-concept in school settings as "typically employed ad hoc, idiosyncratic interventions that are not based on current theory and research, and are not systematically evaluated" (p. 119). Hattie (1992), in a meta-analysis of enhancing self-concept, suggested that much of this research relied on classroom teacher interventions that, according to research, were shown to be ineffective in this regard. On the other hand, engaging students on the basis of choice and interest is

accepted as enhancing the self-belief of learners that they are capable of achieving more positive outcomes in a subject (Margolis & McCabe, 2006; Pintrick & Shunk, 2002). Tomlinson and Dimersky-Allan (2000) also posit that instruction should be focused on interests, readiness and learning styles.

Prensky (2001) reminds us that students will learn better when instruction is presented in a stimulating, motivating and fun way and, for today's students, this often involves the use of ICT. As game-based digital technology is very popular with the current generation of students (Selwyn, Potter & Cranmer, 2008), the researchers of the study reported here believed that utilizing it would tap into pre-existing interests. Burnett (1997c) found that while the strategic intervention of teachers has a slight influence on student self-concept, the impact of significant others in providing positive affirmations was high. It is surmised that feedback provided by someone who is trusted and meaningful to a student enhances self-concept. Students occupied in meaningful and engaging activities, such as specific ICT, provides the classroom climate that affords teachers opportunities to connect and affirm students (Pierce, 1991). These types of activities can also offer the opportunity for students to support and affirm the work of their peers. In addition, many Commercial Off-The-Shelf (COTS) programs include an ongoing narration that provides performance feedback and affirmation (Oblinger, 2004) vital in establishing both engagement and aspects of flow (Csikszentmihalyi, 1991). Therefore, a more positive direction to enhancing self-concept appears to be cognitively oriented interventions, designed to realign students' thinking towards more positive self-affirmation (Hattie, 1992).

Engaging all students: A games-based approach

Universal design for learning has gained the reputation, in recent times, as an approach that enables the engagement of all learners (Gargulio & Metcalf, 2007). Fundamental to this approach is learning opportunities that focus on multiple means of representation, engagement and expression. Games-based technology provides the opportunity for students to engage with the content through different modalities, an important measure in ensuring all students are engaged in learning experiences (Ashman & Elkins, 2009). Furthermore, ICT interventions that are designed to enhance student interest rather than disseminate information (Jonassen, Carr & Yuen, 1998; Roschell, Pea, Hoadley, Gordin, & Means, 2002) have been shown to be effective in engaging students.

Fetherston (2007) hypothesises that children in Australian schools in the 21st century are so familiar with ICT that classrooms without access to popular technology appear strange and 'serve to distance them from the school as a place where they belong' (p.317). Prensky (2001) established the term 'digital native' to describe this generation of students' connection with ICT, and highlights that using digital technology is something that has always existed for them. A recent survey of 612 British primary students found that 47% of the student's favourite use of ICT at home was playing games or using game consoles (Selwyn et al., 2008); therefore it could be argued that using COTS ICT in measured and thoughtful ways in the classroom is likely to provide a stimulating environment for today's students. Further encouragement for the use of popular ICT in the classroom comes from a growing appreciation, particularly within primary school settings, that ICT is a "cross-curricular priority" (Selwyn et al., 2008, p.920). Downes (2002) presents this clear message for today's schools: 'educators cannot continue to ignore the discontinuity between the learning affordances of the computer and the traditional pedagogies of classrooms' (p.31-32).

The research reported on here sought to explore how ICT could be used to engage students with a key aspect of mathematical competency, automaticity of basic computations

such as tables. The assumption underlying this approach is that, while drill and practice may achieve the same outcomes, ICT would be more motivating for students. This research was closely aligned to the work of Miller and Robertson (2009) in that it sought to investigate whether the use of the popular Hand-held Games Console (HGC) *Nintendo DS* with *Dr. Kawashima's Brain Training* could be used to simultaneously improve students' mental computational skills, engagement and self-concept towards mathematics. The *Dr. Kawashima's Brain Training* game is based on Kawashima's research at Tōhoku University in Japan into the effect of mental agility tasks on slowing the cognitive deterioration of people as they age (Kawashima et al., 2005). While the premise of *Dr. Kawashima's Brain Training* is that cognitive exercise can improve blood flow to the brain enhancing storage and recall of information, the reason for selecting this game for the research was the prevalence of games involving the rapid recall of mathematical facts. It was decided to use this technology in a small-scale, pre-post controlled trial study aimed at investigating any changes in students' mental computation skills and mathematical self-concept.

Method

This study compares the use of COTS handheld game consoles (HGCs) with traditional methods of teaching automaticity and accuracy of mental maths skills in two year 4 classrooms over a ten-week period. Self-concept towards this subject area was also measured for both groups pre and post intervention. The intervention and control classes were selected on the basis of their age and location in the same socio-economic area. In the initial intervention period, school A used the handheld game console (HGC) *Nintendo DS* with the *Dr. Kawashima's Brain Training* game, while school B acted as the non-treatment control group, maintaining their current program in mental mathematics.

Participants and Context

Fifty-nine year 4/5 children (aged 9-10) from a middle to lower socio-economic demographic in the Perth metropolitan area were involved in the study. These schools were selected due to the researchers' prior contact with the intervention school as well as the schools' proximity to the researchers' university and to each other. The study took place in term 2 of a four year term within the students' regular classroom and with the same teacher they commenced the year with.

Instruments

The study incorporated both quantitative and qualitative methods of data collection, including interviews and standardized assessments. The Westwood *One Minute Test of Basic Number Facts* was used to measure numeracy skills and a survey was administered to assess children's self-concept pertaining to maths. Additional data was collected in the form of video footage of students using the HGCs and interviews with students, teachers and parents at regular intervals over the course of the 10 week intervention. This qualitative data provided additional information on the impact of the intervention.

The *One Minute Test of Basic Number Facts* was developed by Westwood in 1987 and is a norm-referenced assessment consisting of four 33-item tests, one for each of the basic maths functions (+, -, \times and \div), with a test-retest reliability of .88 to .92 according to sub-test (Westwood, 2003). As the name suggests, students have one minute in which to complete the

33 questions for each function.

The self-concept scale was developed by the researchers for this age group based on the Gourgey's (1982) *Mathematical Self-Concept* scale. The original 27-item scale, which contained both positively and negatively worded questions was developed by Gourgey to use with adults and had an Alpha reliability co-efficient of .96. In the version used for this study, the language of the scale was simplified and the possible responses reduced to a three-point scale true/ false/ or sometimes, on 25 items to make it more appropriate for the participants. It was not possible to assess the reliability of this scale prior to administration; however, using Cronbach's alpha on the self-concept scales administered both pre and post intervention the alpha was determined to be .8, indicating that the scale is reliable.

Procedure

Discussions were held with the two teachers and a visit made to each class using the HGCs prior to the intervention to explain the purpose of the study and each school's involvement. It was important that the classroom teacher in school A was aware that the intervention was to be student centred and that the teacher's role was a supervisory one. This teacher was also given a *Nintendo DS* console with the *Dr. Kawashima's Brain Training* game prior to commencement of the term so that he could familiarize himself with the console and the game.

The teacher of the control group was instructed not to make any changes to the approach she was currently using for mental maths only to ensure that they undertook 20 minutes of mental maths instruction each day. In the interest of fairness, the control school was given the opportunity to use the HGCs and software in the following term. Preliminary data suggests that positive results occurred from the control group usage of the HGCs and these will be reported in subsequent papers.

Children from both schools were administered the pre-tests at the end of the term prior to commencement of the intervention; post-test data was collected in the final week of the term. Students were encouraged to test their brain age, a function of the game, as an additional form of motivation but this data was not analysed due to the lack of data validating the game's brain age test. The intervention period was 10 weeks, the length of a standard school term in Western Australia. Qualitative data was collected from children and teachers prior to the commencement of the intervention and over the course of the term. This article reports the quantitative data including interviews and video observations.

Weekly visits to both schools by a research assistant enabled monitoring of the teacher's engagement with the HGC intervention program in school A and the practices of the teacher in the control group in School B.

Results

In order to determine whether the two groups differed in their ability in basic number facts at the start of the project, a one-way between groups ANOVA was conducted on the pre-trial scores for the two classes. The results indicated that the pre-trial scores for the two groups did not differ significantly on these measures: total score, $F(1, 57) = 0.289, p = 0.593$.

Mean scores were then calculated for answers correct at pre- and post-trial, and paired samples *t*-tests applied to the data. Effect sizes were also calculated, using Pearson's correlation coefficient *r* as there was little discrepancy between group sizes (Field, 2009). While the non-treatment group made some gains in maths accuracy and speed, these were not

significant and the effect size was small, pre-trial ($M = 57.96, SE = 5.33$) post-trial ($M = 59.93, SE = 6.44$), $t = -.66, p > 0.05, r = .13$. On the other hand, the HGC group made significant improvements in their maths scores with a large effect size, pre-trial ($M = 48.66, SE = 2.91$) post-trial ($M = 76.07, SE = 6.77$), $t = -5.166, p < 0.001, r = .69$. It is worth noting, however, that there is a significant increase in the standard deviation for the group using the HGCs suggesting that, while there is an overall increase in performance, some students are making much greater gains than others. The findings are summarised in Table 1.

School	Condition	N	Mean score		Sig	Effect size (r)
			Pre/post (SD)	Change		
A	HGC	29	48.66 (15.67)	+27.41	$p < .001$.69
			76.07 (36.46)			
B	No treatment	27	57.96 (27.67)	+1.97	ns*	.13
			59.93 (33.47)			

*($p > 0.05$)

Table 1: Results for Mathematics Test

In addition to the students' mathematical performance, the researchers were interested in whether children's self-concept towards mathematics was influenced by their use of the HGCs. As the self-concept data was not normally distributed, a Kruskal-Wallis test was conducted to determine if there was a significant difference between the classes on these measures at pre-trial. This test indicated that there was no significant difference between groups on their pre-trial self-concept, $\chi^2(1, N=56) = .312, p > .05$. A Wilcoxon signed-rank test was then conducted to determine if there had been a change in self-concept post-trial. There was a significant improvement in children's self-concept towards maths in the intervention group, $z = -3.373, p < .05$, but there was no significant difference in the non-intervention groups self-concept towards maths, $z = -.747, p > .05$. These findings are summarized in Table 2.

School	Condition	N	Mean score		Sig	Effect size (r)
			Pre/post (SD)	Change		
a	HGC	29	58.17 (8.48)	+4.25	$p < .001$	-0.66
			62.42 (7.23)			
b	No treatment	27	59.85 (7.78)	-.68	ns*	-0.14
			59.17 (9.01)			

*($p > 0.05$).

Table 2: Mathematics Self-Concept Scale

It was evident in the observation data that many of the boys in the intervention group engaged with the game in a competitive way and, as such, the researchers were interested to determine if there were any significant differences between boys and girls on the pre and post scores for maths and self-concept. A paired sample t -test applied to the data indicated that the levels of significance were identical for boys and girls on the pre and post maths test, $p = 0.003$; however, the standard deviation for the boys was greater, indicating that there was greater diversity in their maths performance. Whereas there was a significant difference in

boys and girls post-trial self-concept, the girls results reached a higher level of significance, $p = .008$, than the boys, $p = .034$. These findings are summarized in Table 3.

School	Condition	N	Mean score				
			Pre/post (SD)	Change	Sig	Effect size (r)	
A	HGC Female	16	46.25 (10.81)	+ 21.13	$p < 0.01$	0.68	
			69.38 (28.65)				
	Self-concept	16	55.37 (7.16)	+ 5.7	$p < 0.01$	-0.71	
			61.07 (9.98)				
	Male	13	51.62 (20.23)	+32.69	$p < 0.01$	0.73	
			84.31 (44.08)				
	Self-concept	13	61.61 (8.97)	+2.39	$p > 0.05$	-0.61	
			64.00 (7.51)				
	B	No treatment Female	15	52.60 (21.52)	+1.07	ns*	0.06
				53.67 (30.86)			
		Self-concept	15	57.93 (8.14)	-0.46	ns*	-0.08
				57.47 (8.29)			
Male		12	64.67 (33.65)	+3.08	ns*	0.33	
			67.75 (36.27)				
Self-concept		12	62.25 (6.89)	-0.87	ns*	-0.27	
			61.38 (9.74)				

*($p > 0.05$)

Table 3: Gender differences on pre and post measures

Video footage, observations and interviews were undertaken as a way of verifying and elaborating on the self-concept and performance data. Initial interviews were conducted prior to the commencement of the term with the teacher and three randomly selected parents and students of the class who would be working with the HGCs. The interview with the teacher sort to ascertain his attitude to using the HGCs in the classroom and the outcomes he anticipated from using the HGCs in his classroom. The parents were asked questions pertaining to their attitude to using the HGCs in class, what their child currently does outside of school to develop their maths skills, their child's attitude to maths generally and what they anticipated the outcomes of using the HGCs would be. Students were interviewed about their attitude to maths and using the HGCs to do maths, their attitude to maths and what they expect to learn from using the HGCs. The teacher and the same parents and students were also interviewed in week five and week nine of the term. These interviews included questions about attitudes to using the HGCs, attitudes to maths and the students' progress.

Video footage of the whole class mental maths sessions were also recorded for the intervention and the control classes of three occasions, the start, middle and end of the term. In addition, the research assistant observed the class using the HGCs once a week for the 10 week term and the control class in weeks three, five, seven and nine.

Analysis of video footage and observational data highlighted that the level of engagement when students were using the HGCs was high. The type of interactions that students were observed engaged in while using the HGCs was coded *post priori* into four categories: *assisting*, *sharing*, *engaging* and *non-specific*. *Assisting* was used to refer to the interactions where one student was assisting another with the operation of the HGCs; *sharing* describes situations where students shared their progress with the teacher and their peers, often in the form of high scores; *engaging* was used to identify the time when students were engaged in using the HGCs on their own and; *non-specific* was used as a category for all other interactions such as off-task behaviour and conversations not related to the use of the HGCs. An overall estimate of the time students spent on each of these categories was obtained by amalgamating and averaging the coding data from the video footage and the classroom observations. This data indicated that students were, on average, *engaged* for 65% of the 20 minute session with only 10% of the time being spent in *non-specific* activities. Of the remaining time, approximately 15% was spent on *sharing* and 10% on *assisting*.

Unequal observational periods make direct comparisons with the control group difficult; however, there appeared to be a more time spent on non-specific activities and less time completing the mental mathematics activities in the control classroom. Further, in the control classroom, assisting also included copying answers from their peers. Less time on the mental mathematics activities in the control classroom could, in part, be attributed to the time it took for students to be ready to start the lesson. As the teacher in the class using the HGCs identified when interviewed: *"They're coming in, they're getting ready, they're setting themselves up, so basically when the time starts most of them are ready to go ahead."*

The responses from interviews with teachers, students and, parents of the class using the HGCs were predominantly positive about the use of the HGCs and the outcomes for students. Typical of the students' response to using the HGCs for maths, one student responded that *"It's lots of fun ...every morning I get up early [to come to school]"*. Another student suggested that they *"feel more confident"* when using the HGC. While another said *"I think I have improved from it and made my brain think...It makes me faster [in completing maths problems]"*. The following parent responses confirmed their child's increased engagement with mathematics when using the HGCs: *"He has obviously missed some basic concepts along the way and now it's just clicking it in"*. While another parent suggested that *"they should be used in every school on everyday for confidence and the kids really enjoy it."* The teacher observed that the use of HGCs improved the students' concentration and performance: *"It certainly requires intense concentration and I can see the benefit of using that concentration every day."* *"There has definitely been an improvement that I can see without referring to their scores on the test"*. Overall, the response from those in the intervention group was overwhelmingly positive about the process and outcomes of using the HGCs.

Discussion

Despite the growing appreciation for the use of ICT in schools, until recently, games technology was considered counterproductive for school-aged children because schools could not compete with the ICT available for home usage resulting in disappointment and frustration amongst students (Selwyn, et al., 2008). However, in recent times, Miller and

Robertson (2009) have found embedding commercial off-the-shelf (COTS) ICT into classroom curricula has realised highly encouraging outcomes and the findings of this study are consistent with those of Miller and Robertson (2009).

In the study reported here students in the intervention group made significant gains in speed and accuracy of basic number facts and self-concept towards mathematics. It is, however, important to acknowledge the limitations that exist in a small-scale study such as this. Firstly, because of the numbers of students involved, the influence of the individual teacher cannot be discounted. Although a research assistant visited both classrooms regularly to ensure the methodology was adhered to, the extent to which the teacher in the intervention group influenced the goals and expectations of his students requires further consideration as teachers' actions have a significant impact on student achievement (Marzano, Pickering & Pollock, 2001). Secondly, it is difficult to make generalisations about how the use of HGCs will impact on the performance of all students when working with a small sample size. It is evident from the increase in the standard deviation post intervention that some students' performance increased considerable while others did not. To evaluate the use of HGCs for all students it is necessary to determine what factors influenced this variability in performance.

Additionally, there are other factors that potentially enhance mathematical skill development over a term: access to programs designed to enhance mathematical automaticity were readily available via the internet to all students; some students may have had access to personal HGCs and *Brain Training* software during this period; and individual commitment to developing faster times could have been a factor. Further, as with Miller and Robertson's (2009) study, the expectations were that the comparison class would apply consistent and appropriate rigour to their mental maths approach; however, observations revealed that the approaches used were not always systematic and thorough. It was observed that students in the control class were often required to complete worksheets on number patterns during this time rather than work directly on automaticity. As such, a degree of caution is necessary when evaluating the results of the comparison class. It does, however, highlight the inconsistencies in approaches teachers perceive as constituting mental maths instruction which is an important consideration on light of Swan's (2007) suggestion that, for fluency of times tables recognition to be developed, a strategic approach to instruction is required.

Whereas all classroom intervention results must be viewed with some scepticism, the authors of this research are confident that the structures employed and the COTS HGCs used in the intervention class were largely responsible for the impressive effect sizes established. One of the reasons for this confidence is that the teacher influence in the intervention class was minimised by the HGC itself. This generation of students are familiar with the types of interfaces used by gaming technologies and little time was required for students to start using the program effectively. Student engagement was clearly evident in video footage and the motivation to increase speed and accuracy was often raised by students, parents and the teacher in interviews. Further, the 'slippage factor' (Gersten, Baker & Lloyd, 2001), which is an inherent difficulty in classroom intervention research, wherein the researcher visualisation and the classroom realisation of the classroom processes do not meet, was not apparent in the intervention class.

Undoubtedly there is novelty value in using HGCs in the classroom and the researchers saw this as a positive factor in terms of engagement. Ke (2008) cautions that students may be distracted by computer games in the classroom and not achieve learning goals; however, the *Brain Training* software utilized in this study addressed this concern with its clear focus on learning goals that are well connected to the development of automaticity in number facts. Essentially this is drill and practice presented in a format that is familiar to students of this generation. In addition the tightly structured nature of the *Brain Training* software appears to maintain students' focus on the learning objective and its combination of

anxiety, challenge and reward in appropriate ratios is the type of learning environment that induces flow-type outcomes (Csikszentmihalyi, 1990).

It is worth noting that the improved mathematical skills resulting from this intervention appeared to be not only as a result of student engagement, but additionally because of the teachers' confidence that the HGC could achieve the research goals, namely enhancing automaticity and self-concept towards mathematics. Much of the research into implementing game technology in the classroom has identified teacher resistance as a key factor (Cuban, 1996; Levin & Wadmany, 2008); teachers often lack confidence in their ability to use the technology, however, the students' familiarity with the HGCs and the game meant that they did not require the teacher's support. Therefore, teacher resistance was not apparent within this study. The HGC's portability, ease of use and set mathematical game format were assumed to be factors that made their use more appealing to the teacher. In fact, the teacher commented on the benefits of their portability when students were able to use the HGCs while in transit to an excursion; thus maintaining the consistency of intervention required.

Conclusion

The Review Panel of the National Numeracy Review Report (Commonwealth of Australia, 2008) expressed concerns over the poor numeracy skills of Australian students and the social and economic impact that results from this. As highlighted earlier, lack of fluency in the retrieval of basic facts may limit the development of higher order mathematical skills (Ball, Ferrini-Mundy, Kilpatrick, Milgram, Schmid & Schaar, 2005); subsequently, research such as this, focussed on developing automaticity, continues to be relevant (Woodward, 2006). Furthermore, Professor Gordon Stanley, Chairman of the Review Panel, suggested that mathematics was not a popular subject for students; however the enthusiasm observed when students were using the HGCs would imply that, with engaging delivery, this need not be the case. It became evident throughout this pilot study that the students were not only highly engaged when using the HGCs but appeared to support each other, rather than reaching out to their classroom teacher. These types of collaborations enhance mathematical understanding (Book, Bond, Sparrow & Swan, 2004) and have been described by middle primary school students as being important in an 'ideal' maths classroom (O'Shea, 2009).

There are a number of considerations for subsequent studies in this field including larger scale studies across different contexts to establish the generalisability of these finding. Also, in a classroom where students are engaged and empowered to support each other's learning, the role of the classroom teacher requires consideration. Further research exploring such directions should be encouraged during this decade if we are to maximise the effectiveness of technology such as HGCs.

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