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ORIGINAL ARTICLE

The effect of mathematical games on on-task behaviours in the primary classroom

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Abstract A challenge for primary classroom teachers is to maintain students' engagement with learning tasks while catering for their diverse needs, capabilities and interests. Multiple pedagogical approaches are employed to promote on-task behaviours in the mathematics classroom. There is a general assumption by educators that games ignite children's on-task behaviours, but there is little systemically researched empirical data to support this claim. This paper compares students' on-task behaviours during non-digital game-playing lessons compared with non-game-playing lessons. Six randomly selected grade 5 and 6 students (9–12 year olds) were observed during ten mathematics lessons. A total of 2,100 observations were recorded via an observational schedule and analysed by comparing the percentage of exhibited behaviours. The study found the children spent 93 % of the class-time exhibiting on-task engagement during the game-playing lessons compared with 72 % during the non-game-playing lessons. The game-playing lessons also promoted greater incidents of student talk related to the mathematical task (34 %) compared with the non-game-playing lessons (11 %). These results support the argument that games serve to increase students' time-on-task in mathematics lessons. Therefore, it is contended that use of games explicitly addressing the mathematical content being taught in a classroom is one way to increase engagement and, in turn, potential for learning.

Keywords Games · On-task behaviour · Engagement · Decimals · Mathematics Pedagogical approaches · Calculators

The use of games in primary mathematics classrooms

Many teachers of mathematics feel that games add to students' enjoyment as well as their learning of mathematics (Bragg 2012). It is common for teachers to accredit

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game playing with adding variety, positive affective factors and social dynamics as well as cognitive engagement, and these beliefs are also supported by research. For example, after studying the impact of games use in her doctoral studies, Pintér (2010) concluded that:

> Playing games is not only fun, but students can learn more effectively through activities and participation rather than passive instruction since they are usually better motivated and more active in reaching their goals. Games provide a visual representation of problems through manipulative operations in a social context. They can increase students' knowledge, and, in addition, they influence their cognitive and social development (p. 74).

Research findings generally support the use of mathematical games to engage students' interests in mathematics (Cai et al. 2009), encourage positive attitudes (Bragg 2007), develop problem-solving skills (Pintér 2010) and promote mathematical learning (Siegler and Ramani 2008). However, the position is not clear because teachers often hesitate to employ games to promote learning (Onslow 1990), and in fact, Baker et al. (1981) found that including games during lessons as a reward for early completion of tasks had a negative effect on learning. Little research has been undertaken to determine whether students' engagement in games actually increases their on-task engagement in comparison with other pedagogical approaches. Thus the focus of the doctoral research reported in this paper.

This paper presents some evidence for the argument that games increase students' on-task behaviours in mathematics lessons. While it does not explore the relationship between the on-task behaviours and learning, there appears to be a positive link between game playing, learning and on-task behaviours (Caldwell et al. 1982). So it is assumed that an increase in on-task behaviour has the potential to promote an increase in learning.

The effects of using digital games, particularly speed and accuracy exercises and simulations, have been well researched (e.g. Habgood and Ainsworth 2011; Rodrogo 2010; Shaffer et al. 2005). However, despite the recent influx of digital games, non-digital mathematical games continue to have a place in primary classrooms and are commonly played. Primary students' time-on-task when playing non-digital games was the focus of this study.

Literature review

The key aspects of mathematical game playing that are have been researched are learning through games—including both teachers' rationales for game use and benefits claimed by researchers—and the notion of ‘time-on-task’.

Learning through games

Davies (1995) provided a comprehensive list of the benefits of game playing claimed by researchers in a summary of the literature available at the time, encapsulating the teachers' beliefs as:

- Provision of meaningful situations for the application of mathematical skills and knowledge;
- Motivation and enjoyment;
- The development of positive attitudes towards mathematics;
- Increased interaction between children, opportunities to test intuitive ideas and problem-solving strategies
- Opportunities for children to operate at different levels of thinking and hence to learn from each other;
- Children's thinking becoming apparent through actions and decisions made during a game, which is useful for diagnostic assessment;
- The provision of interactive tasks for both school and home; and
- The facilitation of children working independently of the teacher (p. 12).

Teachers who have been interviewed by researchers since that time have provided many reasons for including games in mathematics lessons: for enjoyment (Booker 1996), for motivation and engagement (Bragg 2003; Provenzo 1991), for disguising and encouraging drill and practice (Lim-Teo 1991), for the development of social skills (Ernest 1986; Oritz 2003) and as a warm-up activity or reward (Bragg 2006a).

There are sound empirical foundations for teachers to hold these positive beliefs. Lim-Teo (1991) classified mathematical games as being either for drill and practice, concept reinforcement, application of mathematical knowledge and/or fun; he found that well-structured games in each of these categories can lead to engaging mathematical investigations and strong concept formation. Other researchers have shown the potential of games to engage children in both skills-based play and higher-level mathematical thinking (Gerdes 2001; Saifer 2010) and have noted opportunities for logical thinking (Higgins 2000) and mathematical abstraction (Avraamidou and Monaghan 2009), as well as the enhancement of specific spatial skills (Amorim 2003). Other positive factors that have been noted include the impact of mathematical games on content knowledge. Bright, Harvey and Wheeler's (1983, 1985) large study of 44 classes of Year 5 to 10 students found that the use of mathematical games can have a positive cognitive impact. The research of Bragg (2006b, c) supported this finding. In 2007, Bragg's study revealed positive gains in affective factors and student motivation in primary-aged students, as did the work of Sullivan et al. (2009). Onslow's (1990) study of 12 to 14-year-old students demonstrated how games encourage overcoming of conceptual obstacles and has potential as an instructional tool. Game playing has also revealed the potential to further develop problem-solving heuristics (Kraus 1982; Pintér 2010).

There has also been research on the effects of specific types of games on process skills, such as by Asplin et al. (2006) who showed how extensive use of a card game resulted in improved mathematical verbalisation and mental strategies, as well as students' problem-solving experimentation with number combinations. Gerdes (2001) demonstrated how the use of a particular game resulted in the development of problem-solving, communication and reasoning skills as well as engagement with specific content such as line and rotational symmetry, direction and square numbers.

Generally, then, both teachers' reasons for use of mathematical games in primary classrooms and research findings do support the use of games. But do they result in students being more engaged with the mathematical tasks?

Students' time on-task engagement

Time-on-task is one measure of engagement with learning activities because time-on-task beliefs and research are based on the premise that 'if one works hard and spends more time-on-task, it is more likely that a goal can be achieved' (Guillaume and Khachikian 2011, p. 251). Generally time-on-task can be measured when students are appearing to be working on a set task—or not engaged with the task. Although components of engagement are hard to observe, time-on-task is assumed to reflect relatively positive behavioural, affective and cognitive components (Caraway et al. 2003). Caraway, et al. (2003) noted that it reflects students' commitment to learning and to successful academic performance.

In the study of Skinner et al. (2002) on children with behavioural problems, on-task behaviour was defined as the children having their heads bent down over the page. Multiple observers recorded on-task behaviour every 5 s. The number of times a student was observed to be on-task was expressed as a percentage of the number of times the student was observed. Skinner et al.'s method of using 'momentary time sampling' (Skinner et al. 2002, p. 652) for studying learners and their procedure for data analysis were adapted for and employed in this study (see below), and during game playing 'on-task' behaviours included taking a turn, observing an opponent's play, recording a move or discussing the game with a peer (Bragg 2006b).

Measuring time-on-task engagement is not by any means a new idea. In a review of relevant literature from the 1970s, Brophy (1988) concluded that increased time spent on learning activities is likely to result in increased learning, provided that the learning activities are designed effectively and implemented by a competent teacher. Brophy suggested that teachers should promote a classroom management system that seeks to maximise student engagement in worthwhile academic activities. Through measuring time-on-task, Brophy (1988) found that teacher preparedness and lessons that have continuity and impact assist in maintaining the students' academic engagement. In fact, since the early 1970s there had been a range of research indicating the positive effect of time on-task on mathematical learning (Brady et al. 1977; Caldwell, et al. 1982; Fisher et al. 1978; Good and Beckerman 1978; Louw et al. 2008; Ramsey et al. 2010) and features of instructional settings such as the group size and types of supervision, e.g. teacher-directed compared with independent student work (Brady, et al. 1977; Fisher, et al. 1978). A key study had been undertaken by Leach and Tunnecliffe (1984) who compared the impact on learning mathematics of two time-related factors—time allocated for mathematics and pupil time-on-task—with the influence of two context variables, aptitude and socioeconomic status. They found that the time variables accounted for significantly more variance in achievement than the context variables and that students' time-on-task had a greater influence than allocated time.

Measuring time-on-task faded in popularity as a research technique after the 1980s as qualitative research gained more credence, but there was still ample focus on on-task behaviours, affective factors such as motivation, and student engagement. Recently, the term 'engagement' has become popular as a research focus, perhaps because it enables researchers to examine affective factors as well as the range of academic uses that students make of their time.

Studies of students using technology (e.g. Louw et al. 2008) saw reemergence of the notion of time-on-task as researchers measured engagement using an on-task screen-time focus. Computers could be used to record time-on-task by individual users. For instance, Louw et al. (2008) researched the delivery of the mathematics curriculum in South Africa via a software programme and concluded that 'the more time learners spent on using the software to study mathematics, the more improvement they showed from 1 year to the next in their performance in the subject' (p. 49).

The notion of time-on-task has been criticised by some mathematics educators because 'cognitive engagement is qualitatively different from time-on-task or student participation' (Helme and Clarke 2001, p. 138). Peterson and Swing (1982), in a study of 72 fifth-grade students, employed a stimulated-recall technique which showed videoed segments of children in class to prompt a recall of their thinking at that moment in time. They noted that students exhibiting on-task behaviours are not necessarily cognitively engaged in the task. They contended there is a difference in the quality and appropriateness of children's thinking that takes place that cannot be measured through observations of on- and off-task behaviours. In fact, when Lannie and Martens (2008) trained fifth-grade pupils to self-monitor their own time-on-task by indicating whether they were on-task when a tone sounded, their findings showed that some students engage at deeper levels and are more productive regardless of time-on-task. Thus the drawback of observing only on-task behaviours is that we are not aware of the cognitive engagement taking place at any particular time.

However, much of recent research on 'engagement' still includes observation of individual pupils' time spent focussed on set tasks. For instance, Jolivette et al. (2001), Kern et al. (2001) and Ramsey et al. (2010) all linked variety and students' choice of task sequence to time-on-task and hence to task completion in mathematics classrooms. Middleton (1995) noted that children's perception that the games were 'fun' may have been the stimulus for the increased engagement that he noted in game-playing lessons. In a study involving 13,043 children in the first years of schooling, Bodovski and Farkas (2007) found that the time primary students spent on-task in mathematics correlated with achievement for all students, but that higher-achieving students are further advantaged because of their higher levels of academic engagement. Another relevant study was undertaken by Ramsey et al. (2010) using duration records with adolescents, finding that having a choice of mathematical tasks increased time-on-task, task completion and student performance.

When examining the results of TIMSS tests, Bos and Kuiper (1999) equated time-on-task with effective learning time, ruing the fact that no data were gathered for this important and 'potentially effective educational factor' (p. 164). However, the American Educational Research Association (2007) unpacked the notion of learning time with a descriptive hierarchy:

> Researchers generally distinguish sharply between Allocated Time—the time on the school calendar for a given content area—and Academic Learning Time—the amount of time students are working on rigorous tasks at the appropriate level of difficulty for them. Mediating these is student engagement—the time students are paying attention. However, the rate of engagement is influenced by how well-structured the teaching is with respect to individual students (p. 2).

In summary, while the notion has been contested, been interpreted variously and waned as a research approach over the years, time-on-task is still very frequently listed as a vital element of effective mathematics teaching and learning (e.g. Pegg et al. 2007; Seegers et al. 2002; Singh and Al-Fadhli 2011; Thoonen et al. 2011). It is acknowledged that a level of cognitive engagement may be difficult to access through observations of students in on-task behaviours, but it is more likely that students are engaged cognitively when they are exhibiting on-task behaviours than when they are not. Therefore, examining pedagogical approaches that increase the potential for on-task behaviours is worthwhile.

Methodology

The same children, working with the same teacher, were observed while playing mathematical games and while engaging in other mathematics tasks. Details of the participants, games, non-game lessons, lesson structures, structured observation methods and researcher recorded anecdotal notes follow.

The participants

A manageable number of six children were selected due to the intensive nature of assessing and recording behaviours via an observation schedule. Trials of the observation schedule indicated that six was the optimum number of participants whose behaviours could be systematically observed accurately by one observer. The same six students were observed for their on- and off-task behaviours during eight game-playing lessons and two non-game-playing lessons.

The six 9–12-year-old children were randomly selected from a composite grade 5/6 class (the usual arrangement in the region's primary schools) in a lower socioeconomic area of suburban Melbourne. These children were part of a larger group of 222 students from three schools who engaged in a game-playing experimental teaching programme over the course of 4 weeks (see Bragg 2006b).

The established seating arrangement was maintained during the game-playing interventions so as not to disrupt the normal flow of the classroom. The six students selected for detailed observation were in three pairs: two pairs of female and one pair of male students. A large number of structured observations (2,100) of these students were made over approximately 7 h of classroom lessons.

During all ten observed lessons, Mr. Ruby (a pseudonym), the teacher of all lessons, was constantly roving and monitoring the children's progress, asking probing questions and assessing the students' work. These teacher actions were perceived by Mr. Ruby as a strategy to encourage the students to exhibit on-task behaviours.

The game and non-game activities

Games were selected that incorporated both simple and complex mathematical challenges. The selected games were *Guestimate* (Swan 1996) and *Hone on the Range* (Brannan 1983). These games focus on the multiplication and division of decimals. They were selected specifically because students had experienced little formal instruction in this area and the games were likely to cause cognitive conflict

(Bragg 2007). The conflict would be with students' existing belief that if you multiply a number the result is always larger and if you divide a number the result is always smaller. From a constructivist perspective, cognitive conflict is necessary for learning to take place (Duit 1995). While these carefully chosen games were selected to promote cognitive conflict, this paper does not compare games likely to promote cognitive conflict with other games. What is presented is the time-on-task during the playing of the particular, selected games in comparison with non-game sessions. However, some incidents of cognitive conflict were observed and are reported herein.

Guestimate is a game played on a calculator. The object of the game is to multiply the number in the calculator to reach the target between and including 100 and 101. For example answers of 100, 100.432 or 100.6 are considered winning results. Player one commences the game by entering a two-digit number. Player two is required to multiply this number by another number to reach the target. Each player takes turns to reach the target. Guestimate was also played in this study using *only* division, with students needing to reach a target such as 80.

Hone on the Range is another game played using a calculator. It is similar to Guestimate in that players aim for a target between two selected numbers, for example, 750 and 780. At the start, the players decide on the target range. The selected range can increase or decrease the complexity of the challenge. Hone on the Range was played first using only multiplication, then in a later lesson, using only division.

When playing these games, the best possible option might be apparent immediately. On other occasions, the player might need to select from a range of alternatives, to consider what strategies to employ, to consider how to work within the game rules or perhaps negotiate to change them, or to anticipate the effects of their choice on their opponent.

The non-game-playing lessons The classroom teacher, Mr. Ruby, had been requested to demonstrate non-game-playing mathematics lessons that typically he would conduct. The teacher acknowledged that he was conscious of being observed and therefore spent more time and effort than usual in developing lessons that he believed demonstrated good mathematics teaching. These lessons still fulfilled their purpose in terms of this study by providing an alternative to game-playing sessions and being conducted by the same teacher. On several informal occasions outside of the experimental teaching programme period, I witnessed Mr. Ruby's teaching style and his high level of engagement with the students. I judged Mr. Ruby's teaching approach during my formal observations to be consistent with those during my informal observations.

The two non-game-playing lessons selected by the teacher were based on data and mental computation. The data lesson included reading and interpreting various graphs created by the teacher. The students were provided with a number of labelled graphs and answered a series of questions about them. Afterwards, the students created graphs to exchange with their partner to answer the same questions. The second lesson involved articulating and sharing mental computation strategies employed to obtain selected targeted numbers using the four operations. For example, a target number was 75 and the students were to create inventive ways to reach that number, such as $400 \div 10 + 35$. The students recorded their approaches and shared them with the class.

Lesson structure

Each lesson ran for 35 min, and observations were made from the commencement of the lesson until packing-up time at its conclusion. The rationale for the particular lesson structure for each of the game-playing lessons was to create a learning environment that encouraged the students to reflect upon their responses, discuss strategies and raise any difficulties that occurred during game playing. Table 1, adapted from Hammond and Vincent (1998), presents the structure of these lessons.

On a record sheet, the students noted each turn and the result of entering that number. During the lessons, the teacher moved from one pair of students to another, assessing their mathematical understandings and reviewing their record sheets, or discussing their decisions in the game. For example, the teacher asked students, ‘Why did you select this number to reach the target?’ ‘If I entered 0.5/0.1/0.2/0.99 into the calculator now, what would the calculator display?’ ‘What have you learned about multiplication/division through playing this game?’ ‘What have you noticed happens when you multiply/divide a number by less than 1?’

During the whole-class discussion, the teacher encouraged students to share the strategies they had developed to reach the target. The teacher also asked the above questions during this sharing period. The students were encouraged to utilise the strategies forwarded by their peers when resuming play.

Structured researcher observations

Classrooms are multifaceted social situations. In this study, it was intended that observation would assist in developing a nuanced picture of the students' behaviour within the social context of the classroom. The researcher took on the role of a non-participant observer, watching the students and recording events as they occurred. The researcher had visited and observed the classroom on several occasions prior to the structured observations, so the students were familiar with the researcher and her

Table 1 Structure for the game-playing lessons

Lesson structure	Time
Set up game	5min
Play game with teacher roving	10min
Assist students to access the task, observe mathematical strategies	
Whole-class discussion focused on the game	5min
Teacher and students articulate strategies employed and their usefulness	
Play game and teacher roving	10min
Assist students to access the task, observe mathematical strategies	
Whole-class reflection and discussion focused on the game	10min
Teacher assists students to reflect on their learning	
Pack up	5min

Adapted from Hammond and Vincent (1998)

presence in the classroom. The researcher communicated with the students before and after the ten observed lessons but did not communicate with them during the lessons.

The observation schedule

A simple observation schedule, with symbols used to note off- or on-task behaviours (see Table 2) at 1-min intervals, was used to gather and compare the data on the participating students' behaviour when in mathematics game-playing lessons and non-game-playing lessons. Table 2 presents the behaviours coded on the observation schedule for game-playing lessons.

The employment of a coding system ensured a measure of objectivity and neutrality (Hitchcock and Hughes 1989) and required no inference from the observer. Before the data were gathered, decisions about what would be categorised as on- or off-task were made. The coding system shown in Table 2 was trialled and refined for accuracy and usefulness prior to its adoption for data collection. The trials were undertaken in ten other lessons conducted by the same teacher, Mr. Ruby, to assess the accuracy of the coding system to detect classroom behaviours and determine the number of observed lessons required to generate an accurate picture of the classroom. The minor variation of the observed behaviours between lessons indicated that the observation of two non-gaming playing lessons would produce an adequate snapshot of typical mathematics lessons for the purpose of comparison with game-playing lessons.

This schedule was used for each student, each minute during eight game-playing lessons and two non-game-playing mathematics lessons. Observations began when play commenced during the game-playing lessons and continued until the teacher indicated that the students pack up. In non-game-playing lessons, the observations commenced once the students started seatwork and continued until pack-up time (35-min duration). An audiotape was recorded with a beeping noise at 1-min intervals for 35 min, with the researcher listening to the tape with a single headphone in one ear during the observation periods so as not to disturb the children. Each time the researcher heard the beep, all six of the participating students were scanned and their behaviours were recorded. The researcher recorded a numeric code in each child's column in the row that corresponded with the time at which the observation was made. In total, there were 2,100 observed ‘incidents’.

Table 2 Coding system for observations of game-playing lessons

Code	Behaviour
	On-task
1	Taking a turn of the game
2	Observing/waiting
3	Listening
4	Student talk
5	Writing
6	Off-task

The students' behaviours during the game-playing lessons were found to be easily identifiable as one of the six behaviours listed in Table 2. The first behaviour of ‘taking a turn of the game’ was indicated by a student having his or her head bent over a calculator, keying in numbers. Whilst this occurred, their partner would usually be observing the other player and waiting to enter their own number. This was coded as ‘observing/waiting’.

In all cases, the observer was able to hear the conversations of the children and was therefore able to ascertain the context of the discussion. Anecdotal notes of the students' conversations were recorded. A student was coded as exhibiting ‘listening’ or ‘student talk’ when the competitors were discussing an aspect of the game, the coding for each of the students depending on their role in the discussion at the time. If the children were not talking or listening but not engaged in discussion relevant to the game, they were coded as ‘off-task’. The category of ‘listening’ also included listening to the teacher during whole-class discussion or to their partner during the game. ‘Student talk’ also applied to a student who was actively participating in the whole-class discussion by adding to the commentary, or who was discussing the game with their partner.

Following the method of Skinner et al. (2002), ‘off-task’ behaviour was behaviour that indicated that the student was not engaged in the task at hand, not exhibiting one of the other behaviours on the schedule, or if talking or listening about non-task matters.

The coding system was employed for the non-game-playing lessons in a slightly modified version, in which the first category, ‘taking a turn of the game’, was replaced by a category called ‘organising’. This category referred to times during non-game-playing lessons when children were requested to retrieve their exercise books and pencils or move to another part of the room, but the observation period did not include setting up at the beginning or packing up at the end of the session.

Anecdotal observations

Anecdotal researcher observations were made during the observed sessions and informal conversations noted during the intervention period. These observations highlighted events that happened during the session that were considered potentially significant and provided a general impression of the classroom environment as well as perceived student and teacher attitudes. To limit the researcher's potential loss of memory recall over time, anecdotal notes were written up more fully on the day of the observation.

Analysis

The statistical computer programme, *Statistical Package for the Social Sciences* (SPSS) was employed to collate and analyse the data gathered from the observation schedule. The data were combined for all six students. On-task behaviours coded as 1, 2 3, 4 and 5 (see Table 2) were grouped and classified as ‘on-task’ behaviours. Observations of on-task behaviours were calculated as a percentage of the total number of observations. Some of the researcher's recorded anecdotal notes are woven into the results and discussion below.

Results of the observations

The purpose of the study was to compare the incidence and types of on-task behaviour of students during lessons in which different pedagogical (game and non-game) approaches were employed. Initially a comparison is made between the game-playing and non-game-playing lessons below in terms of the percentage of behaviours on-task. The types of on-task behaviours are then described for both pedagogical approaches.

Comparison of on-task behaviours

All on- and off-task behaviours were tallied to provide a total number of observations. The percentages of observed on- and off-task behaviours were then calculated. Table 3 presents the percentages of on- and off-task behaviours for game-playing lessons compared with non-game-playing lessons.

Clearly, the children exhibited a higher level of on-task behaviours during the game-playing lessons. During the observation lessons the researcher had judged informally that the children were marginally more on-task during the game-playing lessons than during the non-game-playing mathematics lessons, and during informal discussions Mr. Ruby expressed the opinion that the majority of the children were on-task for a large proportion of the time during both the game-playing and non-game-playing mathematics lessons. Hence, the difference in the on-task behaviours between the two types of pedagogical approaches was a surprising outcome.

Comparison of types of behaviours

Figure 1 shows the incidence of each of the six types of behaviour in game playing compared with non-game-playing lessons. The behaviours ‘organising’ and ‘taking turn’ were not exhibited in both types of lessons so these data are not paired for comparison in this figure.

Figure 1 shows a more even distribution of behaviour types during game-playing lessons compared with non-game-playing lessons. Interestingly, the greatest difference between the game-playing and non-game-playing lessons is in the incidence of off-task behaviour.

During the game-playing lessons, the percentage of on-task incidence ranged from a low of 11 % for observing/waiting, to a high of 25 % for writing/recording. In over 20 % of the observed occurrences, the students were engaged in taking a turn of the game. The students were more engaged in communicating with their partner or teacher during the game-playing lessons than in non-game-playing lessons, 35 % of students' time during game-playing lessons was spent either by talking (15 %) or by

Table 3 Incidence of on-task behaviour observations during classroom lessons

Behaviour	Type of lesson	Percentage of observations
On-task	Game playing	93
	Non-game playing	72

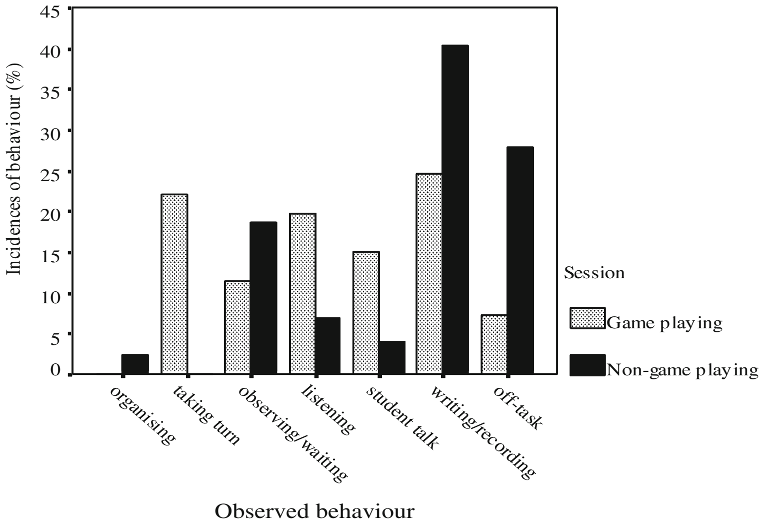

Fig. 1 Percentage incidence of observed behaviours for game-playing and non-game-playing lessons

listening (20 %) compared with 11 % in total in the non-game-playing lessons. The researcher observed that the student conversations during these lessons were all directly related to the games.

When students were engaged in non-game-playing lessons, their behaviours tended to cluster around two on-task behaviours: writing/recording (40 % of observed behaviours) and observing/waiting (19 % of observed behaviours). During the non-game-playing lessons students did not engage in a great deal of peer discussion (4 % of the incidences involved talking while 7 % were spent listening), as compared with 15 % and 19 % respectively in the game-playing lessons.

Students were observed during times of peer discussion providing helpful advice and immediate feedback to their partners during the game-playing lessons, although this type of assistance was witnessed only occasionally during the non-game sessions. An example of assistance during a game is that when queried on her choice of multiplying 177.43 by 0.6 by her partner, one student responded, ‘I worked out timesing by 0.5 is the same as saying half the number. Halving 177.43 won't be 100. So I tried timesing by 0.6 to make the number [product] just a bit more than half. It was pretty close to 100.’ This student went on to explain the benchmarks she had established for herself to play the game effectively, ‘See timesing by 0.25 is the same as a quarter. 0.1 is the same as a tenth of the number and 0.2 is like a fifth. I then try to guess near those numbers to hit the target.’ During the whole-class discussion, this student later shared her strategy, which the teacher recorded on the board. It was noted that a number of students also personally recorded this information on their record sheets as a reference. At the whole-class sharing opportunity at the end of the lesson, the teacher inquired if any of the students had used a strategy that had been shared earlier, and approximately a third of the students acknowledged that they had employed this strategy.

It should be noted that the category of ‘listening’ incorporated listening to the teacher as well as to peers because, as required in the game-playing lesson structure, the whole class engaged in 15 min of teacher-facilitated discussion of game strategies during each of the game-playing lessons. Within the whole-class discussion time, Mr. Ruby invited the students to share anything new they had learnt as a result of playing the game. One of the six students observed in this study offered the following finding to the class after previously sharing it with her partner ‘When you multiply the number by a number over one, like eight, the answer is bigger. To make the answer smaller you have to multiply the number by a decimal, like zero point two.’ This comment revealed a development of the student's understanding of multiplication beyond the simplistic notion of numbers becoming larger through multiplication.

At times, the students suggested an appropriate number to enter into the calculator to assist their confused partner. On a number of occasions students were witnessed attempting to explain to their bewildered partner why inputting a particular number did not give the expected result; for example, why multiplying 102 by 0.1 did not result in an answer close to 100 as anticipated, but rather a much smaller number. Another student during the whole-class discussion provided an example of new understandings of the relationship between dividing and multiplying numbers less than one as a result of game playing, ‘Dividing a number is the opposite of multiplying. So if you divide a number by a decimal, zero point something, your answer is always going to be bigger. You are finding out how many really little pieces are in that number. That's why the answer is bigger than what you started with.’

There was a considerable difference in the incidence of ‘writing/recording’: 25 % in the game-playing lessons compared with 40 % in non-game-playing lessons. From the researcher's experience, 25 % is high for a game-playing lesson as few commonly played games require any writing or recording, but during the game-playing lessons in this study the teacher had asked the students to reflect on each turn and keep a record for assessment purposes. This may account for the relatively high incidence of ‘writing/recording’. However, writing/recording was not the focus of the game-playing lessons and the incidence of this behaviour was still lower than in the non-game-playing lessons.

The energy level seemed more elevated in the classroom when students were playing games. The students appeared interested and engaged in the games. I noted that there was a ‘buzz in the air’, the children seemed excited about trying to reach the targets set by the game. Many children were discussing the results of each turn, whether their attempt was perceived to be successful or not. During informal discussion with the classroom teacher, he indicated that the children appeared to be having fun, and were challenged by the mathematical concepts addressed in the games. One of the observed students enjoyed the challenge that the games offered and provided the following comment in the whole-class discussion, ‘I like *Guestimate* more than *Hone on the Range*. It is fun. It is harder to get to 100 than a range of numbers. I like a challenge more than taking the easy way out.’

Discussion

The main aim of this research was to determine whether there was a difference in the time spent on-task during game playing compared with non-game-playing lessons. The study also sought to explore the types of behaviours exhibited during game playing in order to gain an insight into the types of behaviours that game playing promotes. This section discusses the level of on-task behaviours and the behaviours recorded on the observational schedule and anecdotally during the game-playing and non-game-playing lessons.

The observations demonstrated higher levels of time-on-task in the game-playing lessons. The non-game-playing lessons were carefully planned, well presented and employed a variety of non-traditional pedagogical approaches to engage the students. The students did appear to be engaged during the non-game-playing lessons, but not as engaged as in the game-playing lessons.

One possible explanation for the high level of engagement witnessed in the game-playing lessons was the 'fun' the games afforded the players. The children's perception that the games were 'fun' may have been the impetus for students to engage in the game-playing lessons more readily than the non-game-playing lessons (Middleton 1995).

It is important to note that student talk overheard was all considered to be an on-task behaviour and discussion is part of the learning design in the context of game playing. Although student talk is often considered off-task behaviour and built out of the learning design in other contexts, it is considered a legitimate aspect of the nature of game playing. Peer communication is a desirable outcome because, as social constructivism's theory of discourse emphasises, meaning is dynamic and constructed through a process of communication (Spivey 1995). Game playing can be a valuable teaching approach because with carefully selected games it can promote dialogue between peers that is specifically concerned with the construction of mathematical knowledge.

The children in game-playing lessons were witnessed to be encouraging others with non-verbal and verbal cues. Peers may take on the role of the teacher, especially in examples of peer-tutoring, where one student who is grappling with the mathematical content of an activity is assisted by another student who has mastered and demonstrated an understanding of that concept. The capable student works through the activity with their partner whilst monitoring and providing feedback on their partner's progress. Thus students assisted each other in overcoming their cognitive conflict. The challenge that the cognitive conflict posed may have encouraged the students to engage with the games as they attempted to make sense of this new information. The peer-tutoring may also contribute to an increase in time-on-task, as students are not waiting on the teacher to respond to their difficulties.

A positive aspect of peer feedback for a struggling student is its near anonymity. A student experiencing difficulties may feel more comfortable asking a trusted peer for assistance rather than calling on the teacher. However, non-disclosure of difficulties to the teacher may not be beneficial for a student in the longer term.

The most passive on-task behaviour observed was 'observing/waiting'. In the game-playing lessons, students spent the least proportion of time (12 %) exhibiting this behaviour, compared with 19 % of the time in the non-game-playing lessons. Games promote behaviours which require engagement with the task. The students were observed taking a turn of the game for 22 % of the time. On many occasions whilst one student was taking a turn, their opponent would record their previous move or talk to them about the game (15 %). These findings support the view that games are valuable for encouraging mathematical discussion (see Ernest 1986; Oldfield 1991) and engagement with the task.

Conclusion

It is clear from the data presented that the observed students exhibited a higher incidence of on-task behaviours during game-playing mathematics lessons than they did during non-game-playing lessons. As increased on-task behaviour is regarded as having a direct positive influence on mathematical learning (Brophy 1988), it can be concluded that a game-playing environment is a pedagogical approach that has the potential to promote student learning. It is not suggested that the amount of on-task behaviour is the only factor affecting learning. However the findings of this study support Brophy's (1988) early finding that more time spent on-task provides a greater opportunity to promote effective learning.

The relationship between the on-task behaviours and learning requires further research to clarify this connection. Further exploration of the types of behaviour exhibited by students playing different types of games could provide deeper insight into the value of game-playing lessons. The games in this current study required the students to record the results of each turn, so it would also be worth investigating whether removing this recording from the game-playing scenario would promote more or less discussion.

It is acknowledged that this study had its limitations, namely the small number of children observed and the attempt to compare game-playing lessons with 'typical' mathematics lessons. More 'typical' lessons might have occurred if there had been more of a shared understanding between the teacher and researcher concerning the purpose of the observations.

If one of the aims of teaching is for students to engage with the mathematical content by optimising their time-on-task, then it appears that game-playing is a useful pedagogical tool. However, teachers should be vigilant not to choose games that merely keep the children busy or entertained, but to carefully select games that possess an explicit mathematical objective.

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