Do Primary School Teachers Prefer Digital or Non-Digital Games to Support Mathematics Instruction?

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In this paper we explored primary school teachers preference for different game modes to support mathematics teaching and learning. Eighty-four teachers played digital and non-digital addition and subtraction games that were functionally equivalent during professional learning workshops. Most teachers indicated that they would be more likely to use the non-digital mode; despite more mixed views around perceived effectiveness for supporting learning and anticipated student preferences. Key reasons as to why teachers tended to prefer non-digital or digital games are examined.

The majority of primary school teachers use games in the majority of their mathematics lessons to support instruction (Russo et al., 2021). Accordingly, playing mathematical games has received substantial interest in the research and practitioner literature, partially because games are viewed as an effective pedagogy for making mathematics education more engaging for students, particularly in the primary school years (Bragg, 2012; Bright et al., 1985; Russo et al., 2021). In addition to facilitating engagement with mathematics, *non-digital games* have been associated with many positive cognitive and affective outcomes, including but not limited to: promoting mathematical reasoning (McFeeters & Palfy, 2018); supporting mathematics achievement (Kamii et al., 2005); reducing anxiety in learning mathematics (Alanazi, 2020); developing students' growth mindset (White & McCoy, 2019); and encouraging active learning, cooperation, and interactivity (Ernest, 1986). Moreover, studies focussed on using *digital games* to support mathematics instruction for primary-aged students have also revealed many cognitive and affective benefits, including mastery of number facts (Abdullah et al., 2012), improved attitudes towards learning mathematics (Miller & Robertson, 2011), and enhanced mathematical self-efficacy (Hung et al., 2014).

Despite evidence that they generate similar educational outcomes when used to support mathematics instruction, there are at least two differences between digital and non-digital games that are worth noting. First, non-digital games often incorporate physical activity, sometimes outside the mathematics classroom (e.g., Bahrami et al., 2012; Cichy et al., 2020), which tends to not be the case for digital games. Secondly, digital games involve students interfacing in an environment that has been principally "regarded as an entertainment medium" (Cojocariu & Boghian, 2014, p. 641), whereas non-digital games tend to involve repurposing educational resources and mathematical representations as game objects e.g., fraction walls (Clarke & Roche, 2010); and number lines, (Bofferding, 2014).

Generally, research into the effectiveness of mathematical games has focussed on one particular mode of game, either digital or non-digital, and compared playing games in this mode with non-game activities (e.g., Abdullah et al., 2012; Bragg, 2012; Kamii et al., 2005; Miller & Robertson, 2011). Indeed, we could not identify any studies that directly compared playing digital games to support mathematics learning with playing non-digital games. In addition, existing research into mathematical games has tended to focus on the impact of games on student outcomes, with fewer studies concerning themselves with how teachers use games in classrooms to support mathematics instruction (Russo et al., 2021). Consequently, substantial gaps exist in the literature, both with regards to research that aims to directly compare and contrast digital and non-digital games in mathematics education, as well as studies that examine the issue of how and why teachers choose to use particular games.

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Background to the Current Study

We recently undertook a questionnaire asking primary school teachers if they preferred, and were more inclined to use, digital games or non-digital games to support mathematics instruction, and the reasons for these preferences (Russo et al., in press). It is important to note that the questionnaire asked about these teachers' general game mode preferences, rather than asking them to compare a specific non-digital and digital game. Teachers reported that they were three times more likely to use a non-digital game in a whole-class setting compared with a digital game, and five times more likely in a small-group setting. Moreover, most teachers indicated they preferred using non-digital games (59% whole class setting; 70% small group setting), with only a small number of teachers indicating a preference for digital games (6% whole class setting; 5% small group setting). The remaining participants had no general preference for a particular game mode (35% whole class setting; 25% small group setting).

When asked to elaborate on the reasons why they were more likely to use, and preferred, non-digital games, teachers tended to put forward pedagogical reasons first and foremost. This included elements such as non-digital games' enhanced capacity to promote collaboration and communication, that non-digital games could be more easily adapted by the teacher to suit the learning needs of students, and that non-digital games afforded the students opportunities to engage with manipulatives and concrete materials that would support their mathematics learning. Teachers also indicated that it was easier to monitor and assess students when they were engaged in a non-digital game, and that they valued the fact that choosing to use non-digital games rather than a digital game reduced the amount of screen time students were exposed to (Russo et al., in press).

However, in addition to these pedagogical and assessment related reasons for preferring non-digital games, some teacher participants indicated that this preference was driven by specific barriers to utilising digital games. Although some of these barriers were related to technology usage in the classroom more generally (e.g., a lack of expertise in technology, lack of access to reliable technology), others related to digital mathematical games in particular. For instance, some teachers described a lack of awareness of what they would deem to be high quality/suitable 'digital' games, which they juxtaposed with their deep knowledge and familiarity with non-digital games. As one teacher stated: "I found it is hard to find games online which match what you are trying to teach the kids" (Participant #120); whilst another indicated: "My own knowledge of good mathematical games tends towards non-digital" (Participant #190) (see also Russo et al., in press).

Reflecting on these findings, we speculated that it was at least possible that a lack of awareness of what teachers determined to be high quality digital games was the principal reason that teachers preferred non-digital games, effectively because they were not comparing 'like with like'. The contention is that this lack of awareness might be interacting with pedagogical factors to determine their preferences. For example, a teacher who states that "often the answer is required with little knowledge of strategy or understanding in online games" (Participant #12) is unlikely to view digital games as supporting effective collaboration and communication (Russo et al., in press). Consequently, we decided it would be valuable to explore the issue of game mode preference in a workshop context, where the barrier to being able to access high quality digital games was removed and the digital and non-digital modes of the game being compared were 'functionally equivalent'. The general research question guiding the current study can be stated as: Do primary school teachers prefer digital or non-digital games to support mathematics instruction? Our two sub-questions included:

- What preference, if any, do primary school teachers have for a particular game mode (digital versus non-digital) to support mathematics instruction, in the context of comparing two functionally equivalent games?

- To the extent that they exist, what are the reasons for these preferences?

Before proceeding, it is worth noting that, in this context, we use the term 'functionally equivalent' to refer to the fact that the digital and non-digital mode of the game were equivalent in important ways including: the specific mathematical concept(s) in focus; the game objective; the rules that governed game play; and the types of mathematical representations used within the game. This functional equivalence was a direct result of the two digital games being designed to be digitised versions of the non-digital games Get Out of My House and Part-Whole Triangles (Russo, 2020), as part of the ABC GOAT Maths Suite (Gervasoni & Russo, 2023).

Method

Participants and Procedure

Eighty-four primary school teachers from five Victorian schools participated in one of a series of school-based professional learning workshops with the first author, where they were given an opportunity to play three pairs of non-digital and digital games focussed on addition and subtraction concepts. For each pair of games, the digital game was explained and played (approx. 10 minutes), followed by the corresponding non-digital game (approx. 10 minutes).

After playing each pair of games, teachers were then invited to complete a pen and paper questionnaire to reflect on their experiences. For each game pair, participants were presented with three forced-choice items with a corresponding open-response item where they were asked to 'please explain their response'. The forced-choice items were each presented on a five-point scale. See Table 1, Table 2 and Table 3 for details about both the items and response options.

Following these workshops, the questionnaire data was subsequently entered into a spreadsheet program (Microsoft Excel v. 6.2.14) in preparation for analysis. Note that, although teachers played three pairs of games (six games in total) during these workshops, only two of these pairs (Pair 1: *Get Out of My House* and *Goat Crashers*; Pair 2: *Goat Squad* and *Part-Whole Triangles*) can be clearly described as 'functionally equivalent'. It is these comparisons that form the focus of the current study. Note that readers interested in learning about the precise mechanics of these digital games can read about (and play) these games through the ABC website: https://www.abc.net.au/education/topic-goat-maths/102180130.

Approach to Data Analysis

In order to address the first research question, quantitative data were imported into SPSS Statistics, v. 26 for analysis. This enabled differences between teachers' preferences and usage of functionally equivalent digital and non-digital games to be explored. In addition to the presentation of descriptive statistics, a series of one-sample t-tests were undertaken to compare the obtained mean values regarding teacher views about game mode with expected results if, on average, teachers did not have game mode preferences (reference mean score = 3.0).

By contrast, the second research question focussing on the reasons for these preferences involved analysing the open-response items qualitatively. Specifically, for each question (which one do students prefer, which one is more effective for learning, and which one are you more likely to use) the teacher's open responses were sorted into whether they had preferred (a lot or somewhat) Get Out of My House or Goat Crashers or whether they preferred each game equally. Note that only the qualitative analysis of the Get Out of My House and Goat Crashers comparison is included, as time constraints towards the end of three of the workshops meant that participants were not afforded adequate opportunity to respond to the final open-ended item inviting them to explain their preference for either Part-Whole Triangles or Goat Squad.

The written responses to the three questions were each analysed separately using qualitative line-by-line coding as outlined by Braun and Clarke (2012). The following stages were conducted: familiarisation with the data; generating initial themes; merging responses that can

be accommodated into a single theme; defining and naming themes; and producing a table with illustrative quotes for each theme. For brevity, the data from each table that described teachers' explanations for choosing Goat Crashers or Get Out of My House were combined and are synthesised in Tables 4 and 5 respectively. Illustrative quotes that elaborate the definition for each theme are provided. Note that some responses were coded to more than one theme. Hence the sum of the *n* values may be greater than the number of responses (*n*). For example, when responding to: Which game would you be more likely to use with students in a primary school classroom, Participant A11 (who selected Get Out of My House) wrote "Easier to set up and more monitorable." This response was assigned to two themes *Easier to set up* and *Easier to monitor students* (see Table 4).

Results and Discussion

The first research question was focussed on the extent to which primary school teachers indicated a preference for a particular game mode (digital versus non-digital) to support mathematics instruction, in the context of comparing two functionally equivalent games. This involved teachers' comparing each pair of games along three dimensions: which mode they thought students would prefer playing; which mode they thought was more effective for supporting mathematics learning; and which mode they would be more inclined to use in the classroom with students. Results of these comparisons are detailed in Table 1, Table 2 and Table 3 respectively and are summarised below. Note that, within these tables, Pair 1 refers to Get Out of My House (non-digital) and Goat Crashers (digital), whilst Pair 2 refers to Part-Whole Triangles (non-digital) and Goat Squad (digital).

Table 1

Question: Which Game do you Think Students Would Prefer Playing?

Teachers' response option (percentage of respondents)	**Pair 1 (*n*=84)**	**Pair 2 (*n*=81)**
(1) Students would strongly prefer [Non-Digital Game]	12%	21%
(2) Students would somewhat prefer [Non-Digital Game]	15%	30%
(3) Students would like them the same	40%	28%
(4) Students would somewhat prefer [Digital Game]	23%	15%
(5) Students would strongly prefer [Digital Game]	10%	6%
Mean score (*SD*)	3.0 (1.1)	2.6 (1.2)

Overall, there was partial evidence that teachers anticipated students would prefer playing non-digital games. Specifically, while teachers, on average, anticipated that students would prefer playing Part-Whole Triangles to Goat Squad, $t(80) = -3.44$, $p < 0.01$, a one-way *t*-test using "Students would like them the same" (3.0) as the reference value revealed that, on average, teachers did not anticipate that students would prefer Get Out of My House to Goat Crashers, $t(83) = 0.19$, $p > 0.05$. Indeed, Table 1 indicates that around half of primary teachers thought that students would prefer Part-Whole Triangles (51%), compared with less than one-quarter anticipating that students would prefer the digital equivalent Goat Squad (21%). By contrast, there was comparatively little difference between the number of teachers who thought that students would prefer Get Out of My House (27%) compared with Goat Crashers (33%).

Similarly, there was only partial evidence that teachers believed that the non-digital mode of the game would be more effective for supporting mathematical learning than the digital mode. Again, while a one-way *t*-test using "They are both equally effective for supporting maths learning" (3.0) as the reference value indicated that, on average, teachers believed Part-Whole Triangles was more effective than Goat Squad $t(81) = -4.65$, $p<0.01$, there was no significant difference in perceived effectiveness when comparing Get Out of My House with Goat Crashers, $t(83) = -1.51$, $p > 0.05$. Whereas Table 2 indicates that most teachers (54%)

thought that Get Out of My House and Goat Crashers were equally effective for supporting student learning, only just over one-third of teachers (39%) held this view when comparing Part-Whole Triangles to Goat Squad.

Table 2

Question: Which Game do you Think is More Effective for Supporting Student Maths Learning?

Teachers' response option (percentage of respondents)	**Pair 1 (*n*=84)**	**Pair 2 (*n*=82)**
(1) [Non-Digital Game] is a lot more effective for supporting maths learning	10%	20%
(2) [Non-Digital Game] is somewhat more effective for supporting maths learning	19%	29%
(3) They are both equally effective for supporting maths learning	54%	39%
(4) [Digital Game] is somewhat more effective for supporting maths learning	13%	9%
(5) [Digital Game] is a lot more effective for supporting maths learning	5%	4%
Mean score (*SD*)	2.9 (0.9)	2.5 (1.0)

Contrasting somewhat with the data revealed in Tables 1 and 2, there was clear evidence that teachers believed they would be more likely to use the non-digital game mode of the game with students in the future. Specifically, using "I would be equally likely to use either game" (3.0) as the reference value, teachers indicated they were more likely to use both Part-Whole Triangles, $t(80) = -6.99$, $p < 0.01$, and Get Out of My House $t(82) = -3.19$, $p < 0.01$. Table 3 confirms that teachers were substantially more inclined to report having a strong preference for using the non-digital games (38% Part-Whole Triangles; 22% Get Out of My House) compared with their digital counterparts (2% Goat Squad; 6% Goat Crashers).

Table 3

Question: Which Would you be More Likely to use With Students in a Primary School Classroom?

Teachers' response option (percentage of respondents)	**Pair 1 (*n*=83)**	**Pair 2 (*n*=81)**
(1) I would be a lot more likely to use [Non-Digital Game]	22%	38%
(2) I would be somewhat more likely to use [Non-Digital Game]	16%	21%
(3) I would be equally likely to use either game	48%	31%
(4) I would be somewhat more likely to use [Digital Game]	8%	7%
(5) I would be a lot more likely to use [Digital Game]	6%	2%
Mean score (*SD*)	2.6 (1.1)	2.2 (1.1)

To summarise, teachers were far more likely to indicate interest in using the non-digital mode of a game with students back in their classrooms after playing both functionally equivalent modes in a workshop setting. This is despite the fact that their views about whether the non-digital game was more effective for supporting learning, or would be preferred by students, appeared to depend at least somewhat on the specific pair of games being compared. It is worth noting that such preferences for non-digital games are consistent with prior research inquiring into primary school teachers existing practice (Russo et al., in press).

In juxtaposing the two digital games, it was apparent that teachers viewed Goat Crashers more favourably than Goat Squad. Potential reasons for this might include the comparative richness of their respective digital landscapes in drawing students into the game world, and perceived opportunities to support mathematical thinking. Regarding this latter point, it is worth noting that Goat Crashers allowed students to choose an operation to construct an incomplete number sentence, and then provided immediate feedback to students about whether or not they are correct (e.g., an incorrect response brings up the prompt, "Think again: Is there another way to work out the problem?"). By contrast, Goat Squad only provided feedback once students had

correctly placed three numbers that shared a part-part-whole relationship in the appropriate box (e.g., 3, 4, 7), and did not make connections back to number sentences.

The second research question was concerned with examining the reasons teachers provided for these preferences and was limited to comparing Goat Crashers with Get Out of My House. Results of the thematic analysis are presented in Tables 4 and 5. Note that explanations for neutral responses are not presented in this paper due to space constraints, however the most frequently provided explanation for a neutral response could be coded to the theme *Prefer both equally as they are similar in content or serve the same purpose* (e.g., "It is really the exact same game, so they are equally effective", Participant A42). Most remaining neutral responses could be coded to a second theme of *Prefer both equally but for different reasons* (e.g., "Students would like Get Out of My House as they could physically throw the opponents counter off the board. Likewise, the digital mode would appeal to students because of the animation, sound, as well as using a computer … Different formats appeal to different students to support their maths learning", Participant A39).

As indicated by Table 4, comfortably the most common reason provided for preferring Goat Crashers was the reported richness of the digital landscape to draw students into the game; that is, sound effects, graphics, movement, characters and storyline. This explanation resonates with the notion that digital games involve players interfacing in an environment that has been principally constructed to entertain (Cojocariu & Boghian, 2014).

Table 4

Teachers' Preferences for 'Goat Crashers' Including Their Beliefs Around Student Preferences, Effectiveness for Learning, and Their Likelihood to Use

Main themes	Response (*n*=52)	Illustrative quotes
Sound effects, graphics, move–ment, characters, & storyline	23	A3—Children would enjoy the sounds effects and graphics
More engaging "fun"	10	A8—It is more stimulating and engaging being an online game
Preference for digital games	8	A12—[I prefer] the tech aspect
Easier to set up	6	A32—Less preparation, easier access
Multiplayer/Group work	6	A36—Accessible for small groups to share and discuss
Feedback	5	A4—Goat Crashers gives instant feedback for students. If they're playing in pairs and get the answer wrong, in Get Out of My House they may not necessarily realise

By contrast, the most frequently offered reason for preferring Get Out of My House related to its hands-on nature and opportunity to utilise concrete materials (see Table 5). Other notable reasons included opportunities for interaction and discourse, and the potential to modify the game for different learners. Indeed, these three most frequently offered explanations for preferring Get Out of My House resonated with teachers' pedagogical reasons for preferring non-digital games in general as gleaned from previous research, namely: better for promoting collaboration, interaction, and communication; more 'hands-on' and opportunities to use manipulatives; and easily adapted/ differentiated (Russo et al., in press).

The notion that a comparative advantage of Get Out of My House is its 'modifiability' is particularly noteworthy and perhaps somewhat surprising, given that teachers were shown multiple versions of Goat Crashers in addition to the addition and subtraction mode that they played. This included versions to support multiplication and division fact practice with various target multiples, and a more cognitively demanding version that involved the choice of using any operation.

Table 5

Teachers' Preferences for 'Get Out of My House' Including Their Beliefs Around Student Preferences, Effectiveness for Learning, and Their Likelihood to Use

Main themes	Response (*n*=83)	Illustrative quotes
Use of materials/ Hands-on	20	A1—The rolling of the dice and the counters I see the students really engaging with
More interaction and discourse	14	B28—It provided opportunity for collaboration and exchange of emotions between players
Easier to modify, adapt or differentiate	12	A20—There are multiple ways you can play the game (i.e., more counters, multiplication, sight words)
More engaging "fun"	11	A30—Students would enjoy saying 'get out of my house' and having a laugh
Disadvantages of digital games	10	A14—Cognitive overload in the Goat Crashers game; noises detract from application of mathematical skill
Suitability for age group	10	A40—Easier for younger students. A29—[Suitable] for older students
Easier to set up	8	A15—Materials are on hand in the classroom. Quicker than getting out devices and logging on
Easier to monitor students	7	A5—Has ability for the teacher to monitor student progress better, so as to be able to scaffold students if needed
More opportunities for challenging maths work	6	A43—GOMH gives children more opportunity to think about their equations, decide on an operation, write it down if needed. More skills involved than the digital version

Consequently, it appears that teachers valued the capacity to adapt and modify Get Out of My House in highly specific ways to support students, rather than merely having access to pre-set variations. Interestingly, the idea that a given mode of the game was more engaging from a student perspective, or easier to setup, emerged as a reason for preferring both the digital and non-digital modes. Moreover, while some teachers preferred Goat Crashers specifically because they preferred using digital games, other teachers indicated a preference for Get Out of My House precisely because they perceived digital games to have specific disadvantages, such as the potential for cognitive overload.

Conclusions

Although research has revealed similar cognitive and affective benefits to using non-digital and digital games in the primary mathematics classroom, previous studies have tended to not consider teacher views concerning the types of games they prefer to utilise to support instruction. The current study supports our recent finding that most teachers prefer using non-digital games over digital games, principally for pedagogical reasons (Russo et al., in press). That these preferences were revealed even in a context where the non-digital and digital modes of the game were functionally equivalent is noteworthy. It suggests that teachers' tendency to prefer non-digital games is not principally driven by issues such as a lack of access to high-quality digital games. Future research should consider conducting classroom-based quasi-experimental and/or observational studies to examine whether the comparative pedagogical benefits of playing non-digital games anticipated by teachers are actually borne out in practice. Moreover, such research should examine the extent to which these benefits are moderated by factors such as the teacher's digital literacy, as well as their beliefs about digital technology.

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