DIGITAL GAMES: CREATING NEW OPPORTUNITIES FOR MATHEMATICS LEARNING

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Drawing on the work of James Gee in literacy, we apply his contemporary approach to not only the knowledge systems of mathematics but also the processes by which school mathematics can be learned through the digital games environment. Using a number of games, and young people working these games, we propose that there are novel ways to learn not only many of the concepts that are integral to school mathematics, but such concepts can be learned in ways that are deep. The games environment offers an engaging environment that is substantially different from that experienced in formal school settings. We suggest that many of the principles that underpin the games environment may create new opportunities for teaching and learning that will (re)engage learners and learning of school mathematics.

Most social and education commentators concur that the digital age has impacted significantly on society, education, and young people. Terms such as millenials, digital natives, Gen Y, and nexters are just a few that have been coined to try to capture the very different generations that are emerging into schools and work and whose lives have been significantly shaped by a plethora of digital technologies. While there is a significant literature on this generation in terms of the values and their impact on the workplace, less is documented in terms of learners and learning, particularly in mathematics.

In the area of literacy, Gee has been a leader in reshaping thinking about this generation in terms of their learning preferences, which have been shaped by their exposure to digital games, but also his critical analysis of the learning environment per se. In his comprehensive analysis of the learning principles that underpin the games environment, Gee suggests that many of these principles are missing from school learning environments. These design principles raise pedagogical issues for teachers and systems. Not only do these principles engage learners for extended periods of time in the games themselves, they are also creating environments that stimulate the gamer, create genuine scaffolding to enable the gamer to successfully transition through the game, and create opportunities for success. Sadly, many of these characteristics are absent from school pedagogy. Controversially, Gee proposes that for many of the digital natives entering contemporary classrooms, immersion in these games environments has created new opportunities for new forms of learning. While there may be some space for challenging this position through arguing that games are generally played by adolescents, in a study of preschool children (3-5 year olds) (Zevenbergen & Logan, 2008) found that more 95% of preschool children had access to computers, generally outside the preschool setting. These computers were providing opportunities for engaging in literacy and numeracy activities that were not possible for previous generations. For example, not having fine motor skills to create letters is no longer an obstacle in the computer environment where children were able to recognise letters and create them via the keyboard. Parents also reported that many of the children accessed games on the computer—approximately 80% of the children playing games, with some differences in genders (with more boys playing the games than girls).

Gee (2003) has proposed a number of principles that underpin the games environment that work to engage gamers in the game but through these principles they learn to play the game and experience success. Some of the more poignant principles for learning environments include:

- *Active learning principle:* All aspects of the game environment are established to encourage active and critical learning;
- *Committed learning principle:* Gamers participate in extended engagement so that they feel commitment to the game in a world that they find compelling;
- *Achievement principle:* There are intrinsic rewards for each level of the game to recognise the achievements of the gamer;
- *Amplification of input principle:* For little input, the gamer receives considerable outputs
- *"Regime of competence" principle:* The gamer operates within, but at the outer edge, of his/her level of competence so that there is both safety and challenge;
- *Multiple routes principle:* There are many ways to solve the game, each of which caters for the strengths and interests of the gamer;
- *Intuitive knowledge principle:* Knowledge built up through playing the game is valued and honoured among participants;
- *Discovery principle:* Very little overt knowledge is given, as most knowledge is acquired through experimentation and discovery;
- *Concentrated sample principle:* Early in the game, gamers experience a concentration of signs that they practise, developing proficiencies for later in the game; and
- *Transfer principle:* Support is given to practise skills and knowledge that are then transferred to later problems.

In this environment, learning is seen as hard but fair since gamers can see that while unable to pass a particular skill that they will come to learn it and it will be needed for later in the game. Learning is within the confines of the game, so failure is not public but is intrinsic to the learning process.

When it is clear that young people learn in this type of environment, and engage in it for considerable amounts of time, educators may need to pose critical questions regarding school learning environments and their relevance to digital natives.

New forms of mathematics learning

Lowrie (2005) noted in his numerous studies of young children engaging with Pokemon, that this environment created significant different opportunities for engaging with spatial concepts. Unlike traditional teaching of spatial mapping where the map is represented in a two-dimensional space and contained to the page, the Pokemon environment creates opportunities to “go beyond the seen” to visualise the worlds beyond what is observed on the screen. He found that children created images of the world beyond what they could observe. Being able to create such images was essential to the success of the game since it enabled players to plan their pathways through the world/s being represented in the game. Furthermore, Lowrie found that in this environment, the players also had to create three-dimensional visualisations so more complex representations were essential. This visualisation process is significantly more complex and demanding than the activities that are typically part of the school mathematics experience for 8 year olds.

At the other end of schooling, Jorgensen (Zevenbergen) has studied the numeracy practices in contemporary workplaces as undertaken by a range of young workers. In these studies she reported that there are emerging new numeracies that have been shaped by radically different workplaces than in the past. These workplaces have been significantly shaped by new technologies. For example, in the Jorgensen (2010) study of retail assistants, the technologies of shopping are quite different from old practices. In contemporary shopping, the cash register not only tallies prices but also acts as a stock control device. Many older people bemoan the numeracy of young people but many of the practices of contemporary retail demand that operators undertake particular processes so that human error is eliminated. For example, in many restaurants, costs are not entered but the register has the menu items listed so that the operator enters foodstuffs rather than prices. This may seem to ‘downskill’ workers but the owner-operator needs to have information to enable more profitable ways of working. By knowing sales of the period of day or week or month, owners are better able to plan their sales to create more sales of popular products and to eliminate wastage. Thus, not only has the nature of work been radically altered by technologies, but young people approach their work in different ways.

It is in this changing context, where new forms of numeracy are being created by these environments, that we sought to better understand the potential for learners of mathematics. The conservative practices that sometimes appear to be immovable in school mathematics (Gutierrez, 1998) may be enhanced by better understanding the potential of the games environment to create engaging contexts for learning many mathematical concepts and processes. To this end, we posed the question: What learnings are made possible for primary school children through the use of digital games?

Method

The method we adopted in this research is unique as it is constrained by a number of key factors. First is the researchers’ limited knowledge (and skills) in the gaming environment. For researchers who are one or two generations removed from the game environment, we are not immersed in the culture of gaming and the ways in which the environment shapes actions and beliefs, so this limits our capacity to engage with the games environment in a naturalistic way. Conversely, gamers are able to intuit how games work, and are highly competent with games consoles. Second, it is not possible for the gamer to play the game while simultaneously eliciting his/her thinking. The game becomes an environment that absorbs the learning; making it difficult to engage with the complexities of the game while talking about strategies, actions, and justifications at the same time.

For the remainder of the paper we have adopted the protocol of referring to the person who provided the rich description of the game as the ‘gamer’ and the person who would play the game as the ‘player’. For the purposes of this paper, we engaged a serious gamer to work through two games (one of which is the basis of this paper) and to provide a running commentary on how to work through the game. This included how to play the game, what to expect, where to cheat, moves to make, and so forth, so that the research team could gain an understanding of the game, its challenges, and how the game is played. In seeking a person external to the mathematics education community to provide the description of the game, we were cognisant of the need to not look for the mathematics in the game. This has been a common approach in non-school settings where mathematics teachers/researchers have worked in such sites to try to uncover the hidden mathematics. This is a strong criticism of the ethnomathematics tradition. We sought to not fall into this trap since our objective was to identify the principles for learning alongside any forms of mathematics (new or old) that may be learned through participating in the games environment. By using an external to the field, this bias was less likely to occur.

The gamer used a Nintendo DS to play the game *The Legend of Zelda: Phantom Hourglass* (Nintendo, 2008). This is a game suitable for general audiences and hence suitable for primary school children. In another part of this project where we have sought to identify the types of games played by primary-aged students in terms of most popular games and the time spent playing games, we found that this game was one of the most popular among this age group. Below is an example of the text provided by the gamer.

> When you play for the first time, tap on the *NEW GAME* file to create your own save game. You will need to keep saving your game as you progress as *The Legend of Zelda* is a rather large adventure game.
>
> You will then need to *ENTER A NAME* for your character. Once you have done this, hit the OK icon on the bottom right. It will also ask you if you are left or right handed so choose the appropriate one. (You can always come back to your Save game to continue your quest after turning the console off. Just select the save game you created when loading the game back up.)

The instructions are very clear in terms of the moves and what the player needs to do to navigate through the game. The gamer also explained the various moves that were possible and how these can be used for different purposes in the game. For example:

> *Swinging your sword:* Early in the game you will find a sword to use against monsters to help you progress through the levels. When you see a monster just simply *tap on it* and your character will attack it and deal damage to it. You can also slash the long grass that you see in the environment by *sliding your stylus in a downward direction* or in a *left to right direction* to stab things. There is also a “spin” attack that is useful if you have multiple enemies surrounding you. That will deal damage to all of them: just simply *draw a large circle* around your character to do this.

Collectively, his descriptions provided a clear description for novice players (and researchers) on how the game was organised and the skills and tools that would be needed to progress through the game.

He also offered a rich description of how the game screen could be used to play the game. Much like Pokemon, the games screen on *The Legend of Zelda: Phantom Hourglass* provided partial representations of the worlds through which the game would be played. Also, this game had a large screen display which was the playing area as well as a smaller, full scale map so that the gamer could create a sense of where s/he was in the overall landscape.

> There are two screens at your disposal in this game. The *top screen* will mainly display your map with your character icon to tell you where you are on the map and other information like huts and caves you can venture into, while the *bottom screen* (touch screen) is your main *movement and interaction* tool. [Also] The bottom screen will show you how much health you have. There are the 3 Heart icons on the top left hand corner of the bottom screen. These will deplete if you take damage from monsters during the game.♥♥♥
>
> There is also a green Rupee icon underneath the hearts which tells you basically how much money you have. Rupees are the currency in the game to let you buy useful items from merchants that you will come across. ♦
>
> You can drag your MAP SCREEN (top screen) down to the bottom touch screen by pressing the **B BUTTON** or the **DOWN DIRECTION** on the control pad at any time to jot down some notes on your map so you can remember where important landmarks are or if you need to write puzzle solutions down.

Collectively these descriptions provided insights into the multiple sources of data that will be processed by the gamer as s/he moves through the game levels. Many variables must be considered simultaneously. The gamer provided 23 pages of instructions and explanations to explain to the research team how the game was played. The background information finished at page 6 and herein the game commenced.

Gee's learning principles

It is not our intention to analyse the game in terms of Gee's learning principles. However, we do want to acknowledge their presence in the game. As Lowrie's (2005) work illustrated, the game environment offers a rich site for developing spatial skills. Similarly, in *The Legend of Zelda: Phantom Hourglass* the player must navigate through a range of landscapes, creating a mental map of where s/he has been, and as s/he moves through the game, create richer memories of these worlds in order to better work through them. There are not explicit instructions given to the gamer as to how to navigate through these worlds but, as he illustrates explicitly, this is common in the games environment (see bolded text below). But as the player moves back and forth through sites/locations, a strong memory of the path is being created. This process allows the player to develop a familiarity with the spatial layout of the game. In so doing, it creates a visual memory of the spatial representation of the landscape.

> You should now leave the hut and try to walk up the pathway to the left of the hut and you should see a sign that tells you that it's dangerous to walk any further (by tapping on the sign) because of the monsters ahead. When you have tried heading NORTH Ceila

tells you that it's too dangerous so you must go back to speak with Oshus/Grandpa in his hut.

Once that is done you may now leave the hut and venture into the cave to the right hand side of the hut. There will be a barrel blocking the cave so just tap on it to pick it up and tap away from your character to throw it. The path is clear now.

***NOTE: This type of information gathering is widely used throughout the game so some backtracking will be required!**

Mathematics and the games environment

Number

An example of this potential methodological flaw would be possible in the following extract where the player must know the number of trees in order to open a cave. This is a very low level of mathematics that we do not see as enriching mathematical understandings of young people. Hence, we do not see this aspect of the games environment as creating new possibilities.

When you have walked up to the closed door Ceila will say that you must write down how many palm trees there are on the beach which is SOUTH of the cave when you exit. Simply walk around the beach area and count the PALM TREES only. If counted correctly you should have counted **7** of them.

You may now head back to the cave and tap on the sign next to the door to write down the number of palm trees you counted to unlock the door. Just write the number **7** on the screen and the door should magically open! Proceed up into the middle of the room and tap on the treasure chest in the middle of the room and you will be given **OSHUS`S SWORD**. This will help you defend yourself against any enemies you come across. You may now leave the cave and proceed up NORTH.

In terms of identifying new possibilities for learning mathematics and new forms of mathematical thinking, the use of the gamer helped to bridge the chasm between school mathematics and new mathematics.

Mapping

In line with Lowrie's work, we see that in this game also, players need to develop good mental maps of the worlds through which need to move. Moving back and forth through worlds enables this sense of space to be developed. As the gamer noted in the earlier sections of the paper, this is a strategy that is commonly used. It also helps us to explain the learning principles upon which the game is based. The novelty of repetition where the player must move back and forth between sites helps to build a robust mental image. However, the repetition is quite different from the repetition found in many of the drill exercises used in mathematics teaching. In this environment, the drill is masked by a motive to learn a new skill or information that will be used for another level or situation.

Now you must exit the dungeon and make your way back to the port in town. Head towards the ship and some more story/explanation will follow. You must then solve a little puzzle when the **Sea Chart** is on the bottom screen. You will need to rub your stylus on the bottom right hand side island until you can see a picture of a symbol. Oshus will tell you that this is the *ISLE OF EMBER*. That will be your first destination when you set sail.

> To set sail somewhere you must start *drawing a line* from where the feather quill is on your map to another point on the map. Your first destination is the isle of ember so draw a line from the feather to the ANCHOR symbol on the isle of ember. **Once you do this tap on GO!**

This moving around, travelling back over previous paths is a strong feature of the game and highlights how the player comes to create mental images. In the extract below, the player has reached the end point for a level and now must return to the start point to enable him/her to move into the next level.

> Isle of Ember - Mercay Island.
> Return to Astrid's house. Linebeck will be there, and Astrid will give you a Power Gem. After that, return to the boat to leave the island. Return to Mercay Island. Once back on Mercay, make your way back to the Temple of the Ocean King.

Using previous learnings from other levels is common in games design as it is essential to the success of the game. In "The Legend of Zelda" this principle is at work. Players learn skills in a previous level that enables them to pass through a different level. In the following extract, this principle can be observed. However, what can be seen in the extract is the complex spatial knowledge that is needed to move through this one temple.

> This will—as you can guess from the last temple—extinguish the flames in the southwest corner. Get over there and run through to the northwest corner, then hang right and **step on the small floor switch** near the three-block barrier. This lowers the blue door in the corner, so go back over there and grab the Small Key. With the key, run over to the northeast corner and use it on the locked door, then go downstairs.

The directions that the gamer has provided highlight the possibilities for developing rich spatial understandings that extend beyond what is generally possible in the mathematics classrooms. Moreover, the processes through which these understandings are made possible are quite different from those used in most mathematics teaching situations.

Conclusion

What we have sought to illustrate in this paper is twofold. First, we draw on the pedagogical principles identified by Gee at the start of this paper. While we can observe that there is considerable repetition in the games environment, it is often with purpose and function. The player must be able to build skills and understandings that will enable him/her to move through the current and subsequent levels. The scaffolding provided by this repetition enables the development of new learnings that will empower the player to move forward through the game. The repetitions are neither boring nor lacking in purpose.

What is more important, however, is the acknowledgement that the games environment not only scaffolds learning, but in so doing, enables new understandings to be developed. In this game, the movement through various worlds requires the player to build complex spatial maps that go beyond what is seen. Learners must create images that extend beyond the immediate screen, and often as three-dimensional representations. This is far more complex than the maps currently used in curriculum offerings for age groups. This challenges orthodoxies that shape curriculum offerings for young learners. How these complex understandings are made possible through the games environment represents a considerable challenge to mathematics education—not only in the terms of what is learnt, but also how it is learnt.

As the gamer has illustrated in his description of the game, there is a complexity in developing the mental image of the spatial world/s represented in the games environment. As learners engage with the game, there is considerable scope for them to learn.

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