Getting Serious about Math: Serious Game Design Framework & an Example of a Math Educational Game

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Abstract. *Serious games have been increasingly interesting to educators recently, but it is difficult to find good games that truly address the needs of young learners, especially in mathematics. Some games are either too simplistic or are not actual games. In the paper, an argument is made for the benefits of game-based learning (GBL) for instruction and assessment given what we know about Millenials and how they learn. The first aim of this discussion is to suggest a framework for designing serious games based on game features in commercial games, opinions of fourth graders and their teachers, literary studies, contemporary learning theories, as well as successful and unsuccessful similar endeavours. The second part of this paper describes a concrete example of a maths game based on the proposed framework that implicitly tests math and collaboration skills. The game is made of three components: the game itself, a social network, and a teacher reporting tool. Despite a growing interest in GBL, some teachers are reluctant to use serious games in school. To increase usage of serious games as resource, it is important to equip teachers with information and address their concerns. The paper concludes with the idea that serious games need to be designed well in order to provide the immersion and collaborative active learning that most learning theories recommend. Further, that they should be games and not just drill and practice. In that way, they can be even more beneficial than books as part of the teacher's repertoire in school. Future research avenues are also discussed.*

1. Background

Educational paradigms are constantly evolving. Sir Ken Robinson, a renowned educator, likens the current educational system to a production line that produces children in batches. They are separated according to age, and pass through distinct processes (academic subjects), and even have a bell to indicate the end of a session. However, some children who are younger are more able in certain subjects than older students and vice versa. Robinson (2010) suggests that a better way to organise and effectively teach is to group students by their stage in the learning process, as opposed to age. He points out that students who are bright are not made to feel it because of the rigidity of some tests and teaching methods in the current paradigm (Robinson, 2010). He is referring to the detrimental effect of standardisation on creativity and feelings of self worth. Instead of reaching all children and engaging them in learning, such measures deem some as not good enough because they failed to give one correct final answer within the allotted time. What this does is drain out divergent thinking, a thought process that generates creativity. It seems counterintuitive to drill such a precious skill out, when the real world demands it. Especially in math, by the time those children reach high school, they are very disinterested, frustrated, and feel unable (Klass 9A). That is not to say all traditional methods are problematic or have no merit. Their format and purpose must be revised. What if we could bridge between fun and education and cater to the individual needs of each learner at their particular level and pace? This may be facilitated by using technology in the classrooms.

The world is changing and part of that is that technology is so infused with our lives, that it has become an extension of our cognition (Clark, 2001). The assumption that today's youth have different learning styles and preferences are not simply conjectures, but are supported by numerous studies. Millenials, or those born since 1982, seem to have a unique style of learning (Mason & Rennie, 2008). That means we need to ensure that technology is well constructed to support cognition and learning. Even ICT (Information and communication technologies) has made its way as a school subject to meet the growing demands of technical skills. Using technology in schools is not only useful for practical skills, but also facilitates teaching and learning (Brom et al., 2010).

At the moment, there seems to be a rift between what children do for fun and what they are required to do at school. Shute et al (2009) observe that the same children who are struggling to work on school assignments are eager to play their videogames and what they consider to be fun when finally freed from school. It is known that student engagement is strongly associated with academic achievement (Shute et al., 2009), which means that making learning fun is a worthwhile endeavour. This is especially true for mathematics. According to Forman (1989), students' opinions on math is that it is a dry subject with not much connection to the real world, except that it is essential for university. That is a very distant goal when a child is only nine years old struggling to see the point. Further, it should not be the only reason to learn math.

There are many ways of teaching a subject so that it is engaging by involving what children gravitate towards, such as video games. According to a national survey conducted by the National Institute on Media and the Family (NIMF), 92% of children and adolescents ages 2-17 play video games (Kaiser Family Foundation [KFF]). Further, KFF's report states that kids and teens between the ages of eight and eighteen, spend nearly four hours a day in front of a TV screen and almost two additional hours on the computer (outside of schoolwork) and playing video games. Although some parents struggle to pull their children out from behind the computer screen, Gee, Barab

and many other researchers have shown how effective games can be in educational settings. Not only are they intrinsically motivating, but are also based on deep learning principles. Bente & Breuer (2009) suggest that several forms of learning occur with entertainment games, which are not always desirable (acquisition of deviant attitudes, or maladaptive social behaviour), but they can also be positive and implicit (relevant content, training perceptual and motor skills, and development of general problem-solving capabilities and cognitive meta-skills). More about this will be discussed in Section 5. Some teachers have even started to use commercial games in schools, but have difficulty in finding those that are congruent with their instructional goals.

But a game is not always the answer by virtue of being a game. Gee, Barab, Squire and Shute stress the importance of a good design for serious games, or those aimed at educating. This will be expanded on later in the discussion. As Carbonaro et al. (2010) keenly observe, the main problems with current educational games are that they are dull and repetitive, but also low in production quality. Brom et al. (2010) say that most of the material, such as games, aimed at supporting learning are ineffective because they conserve the 'drill and practice' method. Moreover, the entertainment, rich graphics, storyline, and diversity of gameplay that commercial games offer is in stark contrast to the glorified drill and practice exercises in educational 'games'. Part of this can be blamed on meagre funding for such projects, and part on a lack of multidisciplinary collaboration. Not only is it difficult to math commercial games with subject-specific content, but video games are notorious for having questionable themes, such as excessive violence and inappropriate language. There is a need for games that cater to elementary school children between ages 9-12 because most of the existing educational games are either too simplistic or complex for that age group. This has not gone unnoticed. The GBL has emerged from a niche market to about a $30–75 million market (Squire, 2008). To ensure that the game is appealing for children, they must be part of the development process. Too often do we see examples of games produced by people in one particular field without even consulting the main end-user, seemingly missing the point.

1.1 Sorting through terms

Before continuing the discussion about serious games as educational tools, it is important to sort through some of the terms that are thrown around by researchers and papers. This field is growing quickly and the research is very current, making it difficult to keep up with advances and terms. Different fields word concepts slightly differently. Some of the most common terms are *educational technology, e-learning, learning environment,* and *LMS (learning management system)*. *Educational technology* is a very general term, which refers to a variety of tools that support the development of a student as they learn. In this discussion, I use it interchangeably with *learning tool*. *E-learning* is any knowledge transfer that occurs using computers or a network. To understand *learning environment*, sometimes known as *LMS*, we look to Rieber (2008) who offers a definition. It is a space where "the resources, time, and reasons are available to a group of people to nurture, support, and value their learning of a limited set of information and ideas" (Rieber, 2008, p3). He adds that they are also social places regardless of the number of participants.

Since the focus here is educational game design, it is important to differentiate between two terms that are sometimes used synonymously, but are actually not (Charsky, 2010). *Serious games (SG)* are, in a very general sense, "any form of interactive computer-based game software for one or multiple players to be used on any platform and that has been developed with the intention to be more than entertainment' (Ritterfeld et al., 2009a, p6). Shute et al (2009) add that two key features of serious games are that they are educational and immersive. The difference is that *edutainment* is notorious for being drill and practice without an entertaining game play component (also agreed upon by the Entertainment Software Rating Board [ESRB]'s classifications). Charsky (2010) even refers to Papert who thinks edutainment and instructional computer games are Shavian reversals, taking the worst traits from their parents and shedding the good ones. The difference between the two terms is also historical because when the idea of using games in education first came about, edutainment was used, but as teaching approaches developed and the activities went beyond drill and practice, there was a shift towards SG. To be fair, edutainment does have some positive traits, although they are not exploited. "They do offer a good foundation for why and how games enable learning, which can inform the design of SG" (Charsky, 2010, p3). SG's should build on the foundation that provides learners with authentic opportunities and seamlessly integrate the entertaining aspect (Gee, 2008b). Many frameworks promise this, but do not deliver, as will be shown in Section 8. SG's have also been referred to as *disruptive technology,* a fitting term because it signifies a change, or disruption of old methods. In this paper, *educational game* is used as a general term that includes SG's, edutainment and other such digitally-based educational games. Now, game-based learning (GBL), also known as digital game-based learning (DGBL), is a field of its own with a wealth of research and work being done at present.

Commercial off-the-shelf games (COTS) are frequently referred to in this paper to mean video games, such as *The Sims*. To outline the framework of game design, I use *game mechanics,* otherwise known as *game features,* borrowed from COTS design and gamification experts (gamification.org). Gamification is a movement that applies gaming principles to businesses and other fields. On their website, they extract the essence of gaming from a collective of gamers and experts. COTS can be different types, such as Massively Multiple Player Role Playing Games (MMPORG), action/adventure, strategy, and so on. They can be played on game consoles, online, or by installing a program.

2. Introduction

The aim of this paper is twofold: First, to provide a framework for the design of a good SG. The second is to provide a concrete example of a game based on that framework. The framework is meant to address the problems with most

educational games discussed in the background and is targeted at fourth graders learning maths, but can easily be used for other age groups and subjects. It is based on COTS game mechanics, a literary study of other proposed frameworks, learning principles, a survey of 60 fourth graders and their teachers, and by reviewing some successful games as well as less successful ones. Although many attempts have been made at outlining a framework for SG design that combines pedagogy and game design, few, if any, have given anything concrete, nor have they looked to COTS for inspiration, or purposefully included learning theories or consulted the target group. Moreover, "a consensus has not yet emerged on the necessary, sufficient, and primary features of games, but there is reasonable agreement on the basic categories of games" (Graesser et al., 2009, p84). This proposed framework further tries to add a different perspective to the prevailing literature that portrays the design of educational games as an 'education vs fun' continuum. While there are some elements of truth to that, it is important to remember that learning itself can be fun. To ensure that the SG is actually a game, I propose implicitly framing mathematical problems so as not to interrupt the game flow, while practicing targeted educational content. Since the SG can be used in instruction, I further propose that it can be used in assessment, as a replacement for some of the rigid testing currently in place.

Another point raised by Graesser et al. (2009) and Davidson (2008) is that one of the biggest challenges is designing a serious game that facilitates deep learning rather than shallow learning. By deeper learning, they refer to "an analysis of causal mechanisms, logical explanations, creation and defence of arguments, management of limited resources, tradeoffs of processes in a complex system and a way to resolve conflicts." (Graesser et al., 2009, p84). More shallow levels include "perceptual learning, motor skills, definitions of words, properties of objects, and memorization of facts" (Graesser et al., 2009, p84). Therefore, this framework further attempts to encourage deeper learning by advancing to Davidson's (2008) 'slate 3 and 4' of the teaching process. He describes slate 3 as engaged in realtime, where there is no longer one way of solving something, or just one answer. In this slate, there are also opportunities for students to reflect on their experiences and discuss strategies. Slate 3 functions best when students work in groups. Slate 4 is the final unchaperoned phase where students get to practice skills and advance to higher levels. According to Davidson (2008), most educational games are limited to the second slate. He describes 'slate 2', as highly annotated, which makes it easy to see why things work and why others don't, but results in more superficial learning.

The second aim of the paper is to give a concrete example of how such a framework can be implemented. Most papers are vague about features that should be included and what is considered fun *and* educational. The aim of the game is to not only improve academic skills related to math, but also positively impact attitudes towards math, allow them to connect math to the real world, and promote collaboration. It is not the intention to use the game instead of a teacher, but to supplement their teaching using the benefits of technology, such as personalising the learning experience. This is simply a conceptual plan, so the game would need to be tested with children for its fun-factor and educational impact. Ideally, the game would be developed iteratively involving the target group and their teachers. In order to create a game that is truly geared towards the target group, it is important to understand more about them, how they learn in general, how they learn math specifically. Then, factor in how serious games can address those needs, and how to make the game a fun way to learn. That entails taking a deeper look at what 'fun' actually means.

This paper is structured as the following: Section 3 is about reaching Millenials – outlining the learning objectives, their learning preferences, as well as their views on math. Section 4 discusses how Millenials learn, in general, and math, specifically, by reviewing some contemporary theories of learning based on developments in cognitive science and pedagogy. Section 4 also includes concepts closely linked to learning, such as motivation and feedback. Sections 3 and 4 provide a foundation to show how SG's are effective educational resources that address the needs of our young learners, in Section 5. Since SG's can be used in instruction, I suggest that they can also be used as assessment tools. Using SG in education is not the magic answer, however. It must be well-designed to incorporate deep learning principles and pedagogical goals. Section 6 is the proposed framework that crosses over between education and fun, including the hypothesis that educational content should be implicitly framed within a game. Section 7 takes a closer look at what 'fun' entails in order to maximise the user experience. Although there are games that have targeted children in schools, they are not all successful. Section 8 explores the SG's and COTS that worked as well as the ones that did not to further inform the design. Section 9 describes the concrete example of a serious game based on the framework from section 6. Although some games have the potential to complement school instruction, there is still reluctance to use it. Section 10 reviews those concerns and how to address them. The paper ends with concluding remarks and questions to further explore in Section 11.

3. Reaching and Teaching Youth

In order for the game to reach and teach our youth, it is important to specify the learning goals and to understand how to appeal to their learning style. In this context, it is equally important to understand their attitude towards math.

3.1 What to teach

The basis of any lesson plan and game is to identify the learning objectives. James (2011) lists the competencies that fourth graders should learn in math, that are common to all the different curricula. She divides the competencies into four broad categories: operations and computation; number sense and patterns; geometry and measurement; and data analysis and probability. By the end of fourth grade, students must solve simple math sentences that contain a variable, and begin developing mental math ability and estimation skills among many others (for more details, please consult Appendix A). That means that activities must be centred around these goals

and provide many opportunities for students to develop these skills. To keep the material relevant, the students' prior knowledge must be determined to know what is left to be trained. In class, there is not enough time or resources to allocate to adequately address the needs of each learner, but that is where technology can help. Apart from math specific skills, it can be a good opportunity to teach students related skills, such as leveraging resources for problem solving, applying concepts to other areas, and working in groups.

3.2 Who we are teaching

Sasha Barab, a researcher in the field of educational technology, says that we must challenge the view of children as 'ignorant vessels who we are feeding with information' (Barab, 2009). Rather, we should provide them with opportunities to try on different roles. Doing so will give students consequentiality as opposed to passively tending to concepts. When students are placed in the situation, solving an equation is a tool towards a specific goal, which is more meaningful than simply fulfilling an academic requirement. Role playing and experimenting with rules, according to Barab (2009), is truly motivating and propels children to be involved. He believes that even failure, in some cases, is motivating because they can learn from their mistakes and see the effect of their actions. Barab (2009) points out that nowadays, information is available at our finger tips, as opposed to being contained in the teacher's head, or in text books. It is less about accessing information, and more about what you do with that information towards your goals, or information literacy.

Mason & Rennie (2008) also shed some light on Millenials' learning styles by summarising the results of several studies. Not surprisingly, young students show a desire for entertainment and excitement. The studies revealed that young students have a preference to learn from pictures, sounds, and video as opposed to text. They also favour interactive, networked activities rather than independent, individualistic study. They are biased towards experiential activities and learn in a non-linear way. On the other hand, these students have shorter attention spans and lack reflection skills. The studies further show that young people lack key skills in evaluating online content, and few have been taught how to judge the reliability of online information. This entails that alongside developing subject-specific skills, teaching critical evaluation of information found on the internet is necessary.

Some learners tend to feel less able when they are confused and thus give up, while others find this challenge motivating and find ways to overcome it (Graesser et al., 2009). Ensuring that the material matches the student's is not a trivial task. It means you must determine the current level of the student and make sure they are within their zone of proximal development (ZPD). Otherwise, capable students may not realise their potential and give up. It is up to the teacher find a way to bring them along and pump them with confidence and self-efficacy. Gee (2009b, 2004) shows that games are a way to involve all levels, and hopes to eliminate words like "remedial".

3.3 Different Learning Styles

One of the main advantages of using technology in education is to personalise the learning experience. It can be used to gauge the level of the player and cater to their learning style, when in classrooms such accommodation is limited due to lack of time and resources. In order to provide such a catered experience, it is important to recognise that there are different learning styles in every group. There have been numerous studies outlining all the styles, but Chen & Macredie (2004) describe learning styles in web learning. They compare and contrast field dependent learners (FD) with field independent learners (FI). While FD typically approach a task more holistically, FI tend to be more serialistic. Along with this is the tendency for FD to "pay more selective attention to social cues; they favor situations that bring them into contact with others and have the ability to get along with others" (Chen & Macredie, 2004, p378). In contrast, FI tend to be more autonomous and self-reliant. What these differences imply are that FI benefit from self-directed structures while field dependent learners need a more explicit structure and for the learning environment to be more supportive. Chen & Macredie (2004) also found that FI benefited more from doing practical tasks than did FD. While some prefer independence, others prefer support from either actual or virtual people. Inherent in a game is multimodal information dissemination, which caters to the other styles of learning, such as visual learners, those who need audio support, or those who need to go at a slower pace. In terms of game design, what their study implies is that a teaching tool must be versatile enough to cater to the different cognitive styles and provide a way for the user to control their settings.

3.4 Opinions on math

Self-efficacy can greatly impact how students perceive and enjoy math. Stodolosky et al. (1991) surveyed 60 students to find that the main negative feeling associated with math is the fear of failure because it was difficult, leading to frustration and anxiety. The most frequently asked questions were "Is this easy or hard?" "Will I succeed?" or "Can I do this?" (Stodolsky et al., 1991, p105). Only a minority thought math was boring in terms of content or activity. Similarly, the main reasons why children enjoyed math were because it was fun and easy and because they were successful at it.

In terms of how they define math as a subject, the majority thought it was arithmetic computation and doing problems. Math was also seen as a fixed and unchangeable subject both by students and teachers with neither group seeing any other way that math could be learned. The predominance of drill and practice in math communicates the idea that this subject is best learned from experts (Foreman, 1989; Stodolsky et al., 1991). "Application, experimentation, discovery, or inquiry-mathematical activities that do not necessarily involve following a prescribed procedure or obtaining one right answer-rarely prevail in elementary math classrooms" (Stodolsky et al., 1991, p113). Forman's (1989) study found that another common objection about mathematical instruction is that it "is not taught the way it is practiced" (Forman, 1989, p55). As opposed to discovering math or applying it to the real

world, students are expected to "absorb a static, fragmented body of mathematical knowledge that is disconnected from other academic disciplines" and from daily use (Forman, 1989, p55).

An early loss of self-confidence and internalised feelings of stupidity or inability in math create a vicious cycle (Peters, 2008). Students do not make an attempt at advancing because they do not see the point, and so cannot advance and the gap between them and able students only widens. Peters (2008) suggests that "the key to success in teaching is in being able to connect abstract thought with concrete experience...Informal learning can help bridge that divide that most schools don't acknowledge, or even ignore" (Peters, 2008, p116). Breaking this cycle and showing young learners that they are indeed capable, that they can work in groups, and to make the connection to the real world can greatly influence their attitude and consequently, their success.

4. Contemporary Learning Theories and Related Concepts

Since our understanding of the human mind and the learning process has improved over the years, it is worth revisiting some of the contemporary general learning theories and related concepts, such as motivation, feedback and how children learn math, specifically.

4.1 Learning Theories

One factor that may contribute to the distinct learning style of Millenials is that they are surrounded by technology, which Clark (2001) contends has become an extension of our cognition. With advances in cognitive science, psychology and education, there was a need to build on and revise some of the original learning theories that can be augmented by technology. Illeris (2009), a renowned researcher in learning theories, collected these developments in his book *Contemporary Theories of Learning*. This section gives a brief overview of some of these theories and describes their commonalities. The theories that are especially facilitated by serious games are *situated learning, constructivist learning, problem-based learning (PBL), task-based learning (TBL),* and *distributed intelligence*. The role of emotions on learning, or *affective learning* is discussed under a separate heading since it is a component of learning. What all of the theories have in common is that one learns by doing and should have an active role and hands-on experience to truly grasp a concept. These theories also promote collaborating and sharing ideas with others, whether they are peers or instructors. In all of these approaches, it is important to dynamically assess students' skill level for the material to be relevant and challenging enough.

Situated Learning, or learning when present in a situation, favors giving the child an opportunity to experience different perspectives, as in simulations, over simply hearing about them (Barab, 2009; Gee, 2009a, 2006). Simulations, often used as the basis for serious games, provide a world in which the player can make decisions and see or even virtually experience the consequences (Lieberman, 2009). By placing the player in the world, they are forced to develop system empathy, or understanding how the constraints and laws of the virtual world work to their advantage as they manoeuvre around it (Gee 2006, 2009b). Gee (2008a) adds that "humans don't usually think through general definitions and logical principles. Rather, they think through experiences they have had and imaginative reconstructions of experience" (Gee, 2008a, p48). With books, if you don't have any previous exposure to the concept, it is difficult to truly grip it. 'It's like giving someone a manual to the game, without the actual game' (Gee, 2009b). On the other hand, if you read the manual after you've played, you can completely relate to the words and the meaning. Connecting these words to real images, action and experience is *situated meaning and understanding*.

Similarly, *Constructivist learning* situates learning in an experiential and applied environment, where 'the learners take an active role and personally construct their own knowledge in authentic situations that allow them to build on what they already know' (Lieberman, 2009, p120). This means that learning is more relevant when it is built on prior knowledge, and when students are given choice and autonomy. *PBL*, too encourages active learning with the supervising adults as resources that help them achieve their goals (Tai & Yuen, 2007). *TBL* works in the same way and further stipulates that activities must have a clear relationship with real-world activities (Bellotti et al., 2009). A game based on these theories encourages fact finding, problem solving, and system empathy towards goals and gives the learner a sense of control over the process (Lieberman, 2009; Gee, 2009a, 2009b; Barab, 2009).

It is well documented that working in groups is highly beneficial (Wenger, 2009; Gärdenfors, 2010, Gardner, 2009; Klimmt, 2009; Tai & Yuen, 2007). This is because intelligence is distributed amongst peers and technology. Hutchins (1995) described that knowledge in a system is not all contained in one element of it. For instance, in the cockpit of an airplane, the pilot, controllers, and other tools in the cockpit, together, have and process the information needed to operate the plane. Similarly, Clark (2001) suggests that cognition and intelligence are distributed among people and tools. This implies that groups and the involvement of technology have the potential to be more empowering than individualistic learning. Mason, Rennie and Barab agree that course design is not just about transmission and consumption, but about interacting, collaborating, sharing and co-constructing, as the constructivist approach suggests. Scarlatos (2009) describes how "group work increases the learning potential of an activity by allowing children to scaffold off each others` prior knowledge" as long as they all have equal access to information (Scarlatos, 2009, p4). Peer learning and scaffolding benefits are exemplified in an article in The New York Times about Twitter increasing student engagement and grades. "Twitter was used for discussions, questioning professors in and out of class, receiving feedback and reminders, and reviewing course concepts reduced to terse fundamentals, all via laptop or cellphone" (Ruiz, 2011). Traditionally, scaffolding described how an adult, such as a teacher, would impart knowledge and support the learner. Puntambekar & Hubscher (2009)'s reviewed definition includes peers as a source of information. They further point out that digital forms of scaffolding thus far,

have been passive and do not involve an ongoing diagnosis of the learners' level and needs. But this is not impossible to do with technology if artificial intelligence (AI) is used to determine the level of the child and calibrate the support.

4.2 The Role of Emotions

An important condition for learning is the affective state of the learner. There are many who appreciate the role of emotional attachment to learning and memory (Rosenfield, 1988; Caine & Caine, 1991). Gee (2009), borrowing from Damasio, shows that there is deeper learning when there is an emotional attachment to their learning and problem solving, and when something is at stake for the learner personally (Gee, 2009a; 2009b). This is illustrated in Gee's (2003; 2009b) example of World of Warcraft. Group damage and performance statistics inform the team which members are truly working and which members are not pulling their weight, which encourages players to do their job and do it well. Apart from feelings of responsibility is the emotional state of the learner. Emotions are regulated by the amygdala, which is an area of the brain associated with deeper learning (Gee, 2009b). Caine & Caine (1991) go so far as to say "our emotions are integral to learning. When we ignore the emotional components of any subject we teach, we actually deprive students of meaningfulness" (Caine & Caine, 1991, p58). Self-efficacy and self-esteem are also emotionally charged, which affect achievement levels and motivation in school. When students are empowered to believe they are capable, they can be encouraged to develop further. Whereas feelings of inadequacy can lead to a vicious cycle, which does not compel students to try.

4.3 Motivation

Motivation can lead students to make greater effort, seek greater challenges, and attain higher achievement (Schunk et al., 2007). There are different ways of inducing motivation and different types of motivation, such as intrinsic and extrinsic. In this discussion, I focus on intrinsic motivation (as opposed to extrinsic) because it has shown to be important for creativity, while extrinsic motivation is detrimental to it, unless the initial levels of intrinsic motivation are high (Hennessey, 2000). It is important to mention that the two types of motivation are by no means exclusive. The two are so intertwined that it is difficult to isolate them. For the sake of this discussion, a simplified definition will be used.

One way to increase motivation comes from having goals. There are two types of goals: mastery goals and performance goals, described by Baron & Harackiewicz (2000). Students pursuing mastery goals "used deeper, more elaborate study strategies, selected more challenging tasks, persisted in the face of difficulty, and held more positive attitudes toward learning" (Baron & Harackiewicz, 2000, p232). Those pursuing performance goals, however, "engaged in more superficial or strategic learning strategies, chose easier tasks, and withdrew effort when difficulty was encountered" (Baron & Harackiewicz, 2000, p232). Ames (1992) showed how mastery goal orientation positively impacts motivation and optimally engages the learner. Therefore, teachers are urged to promote the pursuit of mastery goals as opposed to performance ones. Robertson & Miller (2009) extend this to what good digital games should encourage. That is not to say that performance goals are only negative (Baron & Harackiewicz, 2000). Both goals have some merit depending on the situation and context. For instance, those low in achievement motivation "(LAMs) showed higher levels of intrinsic motivation when assigned mastery goals, whereas individuals high in achievement motivation (HAMs) became more interested when assigned performance goals" (Baron & Harackiewicz, 2000, p236).

Another way to induce motivation comes from rewards and feedback. When a student is made to feel able and can sense their progress in a task, they can value doing well in it (*competence valuation*). That, in addition to *task involvement*, or becoming absorbed in the activity while engaged in it contribute to an increase in intrinsic motivation (Baron & Harackiewicz, 2000; Shute, 2008). It is not necessarily the expectation of a reward that contributes to intrinsic motivation, but the individual's interpretation of the reward and their role in the process (Hennessey, 2000). If not done well, it can even undermine motivation. In their study, Corpus et al. (2006) found that praise can have both beneficial and detrimental effects on fourth and fifth graders' intrinsic motivation depending on the type of praise, the context in which it is delivered, and the gender of the recipient. They compared the effects of social comparison versus mastery praise on intrinsic motivation. By mastery praise, they mean personal improvement, or development of expertise, special talents, etc.. Social comparison is measured by their relative performance in the class, a message they believe to be harmful: that success depends on how others did in comparison. Corpus et al. (2006) found that "mastery praise benefits intrinsic motivation and social comparison praise curtails it when uncertainty about children's subsequent achievements is introduced and, for girls, even in situations of continued success" (Corpus et al,, 2006, p10). They conclude that social comparison praise should be replaced by praise that focuses on skill development of the individual. More about feedback in section 4.4.

A third way that many educators promote motivation is through competition, however Lavoie (2007) warns us to be careful. He believes that competition is poorly understood in education. Many educators he has come across think that competition between students in the classroom prepares them for the real world. In his opinion, this is not only false, but that the only person who benefits from such a situation is the one who thinks they have a chance at winning. Lavoie (2007) points out that competition in the real world is never forced upon you, but is a matter of choice. It is up to the individual to partake in a tennis match if it is a skill that they are familiar with. Further, the individual will most likely choose a partner of equal ability and not Venus Williams. The real world is not about winners and losers, but recognising challenges and being prepared to find solutions to them. The best way to motivate someone is to get them to compete against themselves because that is when they do their best work. Instead of competing head to head, we must celebrate personal best, as opposed to *the* best. That is not to say that there should be no competition, but that it should not be enforced. Children should be able to

choose to participate in sports or run for school president. Lavoie (2007) also challenges the myth that teachers have no option to change the class paradigm because they are 'competitive in nature'. One should not celebrate the fall of the other, which is what is inadvertently communicated when there is only room for one person at the very top. He adds that 'no child's self concept or self esteem is based on one glorious success or one disastrous failure. It is the small things that matter and on a daily basis' (Lavoie, 2007). That is what motivates and makes children reach their potential. In cooperative learning, success or failure depends on the whole group, which encourages collaboration.

4.4 Feedback

Providing students with accurate, intelligent, and motivating feedback is a vital component to the learning process to promote desired behaviour and increase motivation. There are several components of feedback that may influence the learning process, including timing, content, control, and delivery-method (McNamara et al., 2009). Feedback helps guide the learner along the path of understanding by verifying what was understood and what needs revision and how, as well as opportunities to self-reflect. Done well, it leads to student ownership in learning more than any other practice (Brookhart et al., 2009). Improper feedback can lead to confusion and frustration with the learning process (Sondergaard & Thomas, 2004). It can also affect the students' self efficacy and self confidence. Lack of feedback leaves the student feeling uncertain about their knowledge and ability. Uncertainly negatively impacts the affective state of the learner, which leads to poorer task performance (Shute, 2008).

There are several types of assessment that provide feedback in the classroom, such as formative and summative. Garrison & Ehringhaus (2007) refer to summative assessment (such as end of unit tests, or standardized tests) as those given periodically to assess the knowledge of students at given time points. Formative assessment is ongoing and part of the instruction process and helps adjust the learning and teaching as it happens. In the latter, there is less of a focus on grades and more information on modifying thinking and behaviour to improve learning (Shute, 2008). Shute (2008) recommends formative feedback to be supportive, timely, specific and not graded.

4.5 Learning Math

Several studies describe what the optimal conditions are to learn math. Roschelle et al. (2000) in addition to many others (Scarlatos, 2009; Donovan & Bransford, 2005; Steffe & Weigel, 1994), say that cognitive research has shown that learning math is most effective when four fundamental characteristics are present: 1. Active engagement, 2. Participation in groups, 3. Frequent interaction and feedback, and 4. Connections to real world contexts. That means in addition to actively constructing knowledge from experience, interpretation and structured interactions with peers and teachers, there must be meaningful math problem solving connected to real world contexts. Donovan & Bransford (2005) add that engaging prior understanding, and self-monitoring opportunities, in addition to factual and conceptual information are also important components of learning math.

Games are a good opportunity for this because self-monitoring can arise from discussing strategies undertaken with others and reading about the experience of others. Gee (2003) further adds that videogames are partly based on the Probing Principle, which states that: "Learning is a cycle of probing the world (doing something); reflecting in and on this action and, on the basis, forming a hypothesis; reprobing the world to test this hypothesis; and then accepting or rethinking the hypothesis." Roschelle et al. (2000) showed that computer-based applications that encouraged students to reason deeply about mathematics increased learning, whereas applications that attempted to make repetitive skill practice more entertaining for students actually seemed to decrease performance. It is also important to have possibilities for creative expressions of mathematical concepts and operations in the pursuit of goals (Steffe & Wiegel, 1994). There rarely is only one way of solving a problem, so equipping students with a 'bag of tricks' can help them choose the resources best fitted to each situation. But for the technology to be effective, teachers need to incorporate it and be well trained to use it.

5. Why Serious Games are effective teaching tools

Keeping in mind the learning styles of Millenials as well as how they learn, what better vehicle to cater to their needs than serious games? An extensive body of research demonstrates the positive effects of digital games on child and adolescent players' learning (Blumberg & Ismailer, 2009). This was even empirically supported by Robertson & Miller (2009) and Owston et al. (2009), especially for less able children. In a game, all players, including those shy in class, actively participate as opposed to only those daring enough to contribute in class. The nature of games promotes several vital skills for deep learning, such as metacognition, selective attention, problem solving, perspective taking, a chance to practice, thinking of alternative solutions, multiple modularities, multiprocessing, information literacy and are motivating (Blumberg & Ismailer, 2009; Charsky, 2010; Mason & Rennie, 2008; Davidson, 2008). James Paul Gee (2003), too, finds serious games to be an effective teaching tool that involve 36 learning principles, but not just by virtue of being a game. SG's have to be infused with enough educational principles and carefully planned to guide the learner through the material. They should allow students to discover, form concepts, and encourage cooperative learning, among other forms of interactive learning. Serious games, done well, incorporate challenge, fantasy, curiosity, and control, which Malone & Lepper (1987) believe are common to all intrinsically motivating environments. Together, these characteristics induce `flow`, where the player is so engrossed in the activity that there is no sense of time or any distractions, only focus on the task at hand (Shute et al., 2009).

"Since video games are "action-and-goal-directed preparations for, and simulations of, embodied experience"

they situate the target content" (Gee, 2008b, p18). Gee (2008b) adds that players are exercising their learning muscles, though often without knowing it and without having to pay overt attention to the matter. Charsky (2010) notes that while edutainment teaches lower order thinking skills, facts, concepts, and procedures, serious games facilitate higher order thinking skills, such as how to apply their knowledge, analyze their understanding, and evaluate their learning. Annetta (2010) describes how video games exploit both verbal and visual information, each processed by different cognitive subregions. "Words are processed only in the verbal region, whereas images are processed in both regions.., the other region is the visual region allowing for greater depth of processing and increased availability of multiple retrieval cues" (Annetta, 2010, p111).

Interaction is one of the main benefits of learning with digital games over traditional methods. Blumberg & Ismailer (2009) refer to DiPietro et al and Prensky's work that show how 'interactivity allows players the flexibility to control and customise the pace, interface, complexity of the game experience, and to receive immediate feedback' (Blumberg & Ismailer, 2009, p135). These features not only command the player's attention, enjoyment, and immersion, but also provide a connection to the real (virtual) world, and promote active learning. Players need to develop system empathy: learn all the techniques, rules and related knowledge, for survival in the virtual world (Chen et al., 2009; Gee, 2008c). Ritterfeld et al. (2009b) empirically support the fact that multimodality and interactivity contribute to educational outcomes individually. Players also interact with peers and 'experts' on forums or chats, as well as collaborate with others during the game.

Apart from interactivity, serious games offer a state of alternative reality (Wang et al., 2009). Since the gaming world is not real, players are more daring to try new roles, step outside of their comfort zone, and tinker in a 'sandbox' (Barab, 2009; Gee, 2003). Gee (2004) says that good games offer supervised (guided) fish tank tutorials and sandbox tutorials – simplified versions of the system and safe versions of the system, respectively. Such games further engage learners and facilitate the development of system empathy. Moreover, they give information 'just in time' and 'on demand', which allows learners to establish rules at their own pace and in the order they decide, while connecting with others, and verifying theories.

Learning a skill in a simulated environment, such as driving a car, can increase self efficacy in the real world (Backlund et al., 2008). In order to maximise on this, Backlund et al. (2008) recommend adapting the challenge, or difficulty levels and providing appropriate semantic feedback, comprising of both instructional and performance feedback screens. Together, these features also promote scaffolding. Feedback in educational games can be provided for the learner as well as their teachers to further guide the learner.

5.1 Serious Games as Assessment Tools

Robinson (2010), among others, have pointed out that the rigidness of the assessment mechanisms in place not only discourage divergent thinking, but also can make able students feel as though they failed. Further, they do not necessarily reflect students' knowledge of a subject (Robinson, 2010; Ramani & Sirigiri, 2008; Annetta, 2010). In such tests, there is no room to give credit to students on how they arrived at the answer, but to give one answer within the allotted time. Annetta (2010) adds that "regurgitating facts on bubble sheets has proven to be an unsuccessful endeavor in ascertaining student knowledge based on norm-referenced testing results" (Annetta, 2010, p110). Moreover, presenting only one answer using one method is not reflective of reality. That is not to say that standardized testing should be abolished. It can provide some valuable information on how schools fare in comparison to each other across countries or even internationally. What should be reviewed, is using such tests as a benchmark for a student's grasp of a subject. There are better ways of exploring the level of our learners that are less daunting and more flexible.

As discussed in the section about feedback, there are several types of assessment distinguished by their focus and frequency throughout the academic year. Whether they are summative or formative, the assessment should strive towards being authentic. Authentic assessment is a form of assessment in which "students are asked to perform real-world tasks that demonstrate meaningful application of essential knowledge and skills" (Mueller, 2011). In comparison to traditional methods that require only one correct response in a contrived manner, authentic assessment asks students to perform a task that mimics reality and promotes construction and application of knowledge (Mueller, 2011). Authentic assessment is generally categorised into Performance Assessment, Portfolio Assessment and Reflection and Self-Assessment (Tai & Yuen, 2007). *Performance Assessments* test students' ability to apply acquired knowledge and skills in a variety of authentic contexts and work collaboratively to solve complex problems. *Portfolio Aseessment* is a collection of projects submitted throughout the year that best reflect the student's skills. *Self reflection* and *peer evaluation* are useful for having students analyse their own work and come to their own conclusions. Chang & Chiu (2005) empirically support authentic assessments as a better measure of student performance than standardised tests for science-related activities, especially for low-achieving students.

Games are an ideal way to test understanding because the player is continuously being assessed, and can only advance if they master the system (provided the game is well-designed). Moreover, testing is part of the gameplay as opposed to a separate activity that students fear. Players can be rewarded for creativity and group work, as well as content-specific knowledge. There have been several studies that propose using SG's as assessment tools (Shute et al., 2009; Ramani & Sirigiri, 2008; Annetta, 2010). *Stealth Assessment*, or embedding assessment into game play (Shute et al., 2009), is important to maintain flow because players are tested for educational content without even realising it. For instance, participation in chat and forum discussions about strategies and gaming techniques indirectly provides self-reflection and peer evaluation opportunities. Taking part in such commentary can even be a requirement of the game. Performance assessment is intertwined with game play. Especially at the end of a level, the player can have a chance to solve problems that encompass

concepts learned up to that point before advancing to higher levels. Level assessment can also be determined by the system's artificial intelligence to follow the player's learning curve and provide assistance when needed. All of that data can be collected and analysed and sent to the teacher as well as the player to inform them what they know best and what they need to work on. Otherwise, there can be a divide on how material was presented and how students must show understanding. Gulz et al. (2011) showed that students can best express their knowledge in the same learning conditions as they received their instruction, in a study about using Teachable Agents to learn math.

To use SG as assessment tools, they must properly reflect the target concept. Moreover, it is important for feedback and level adjustment to be clearly tied to concrete criteria. Just as in class tests, it is important to be aware what is being assessed intentionally and unintentionally. Bente & Breuer (2009) found that serious games mainly use three principles of assessment: 1. Completion assessment (finish a lesson or pass a test), 2. In process assessment (evaluates how, when and why players made their choices), 3. Teacher assessment (observations and judgements made by the teacher). A teacher reporting tool can assist the teachers in their evaluations as well. Moreover, the knowledge needed to meet the challenges of the game, and player's choices and methodology should also be measured. If desired, non-subject specific skills, such as creativity, team work, contribution to the knowledge base and other important skills can also be tracked.

6. What Good Games are Made of

In order to maximise the potential that serious games offer education, a solid design is fundamental. The old adage: 'if you want to make a game boring, bring an educator into it', may unfortunately be partially true. Although, with the right educator who truly understands how children learn and how to make them motivated enough to want to learn for themselves, the game can be both fun *and* educational. Even Gee (2008b) says that under the right conditions, learning is biologically motivating and pleasurable.

Game mechanics are a list of features to consider when designing a video game to ensure that it is enjoyable. Different games use different mechanics depending on their goal and genre. The gamification experts (www.gamification.org) compiled a full list of game features that are considered in commercial video games. Those most relevant for educational games are included here. In addition to COTS features, 60 fourth graders in Swedish schools were surveyed along with their teachers for their preferences in games. (Please consult Appendix B for more information on the surveys). The mechanics listed are also linked to research in game-based learning to show their relevance in education. The idea is to create educational games that are games first that are built on sound learning principles and have relevant content for the target group. Most of the studies portray a delicate balance between education and fun, but this approach uses both without sacrificing one for the other. In the end, the choice of features will depend on the learning goals for the target group.

In this section, the game mechanics are divided into three categories: entertaining and pedagogical, group work, and virtual world. The first category encompasses features that are basic to all commercial games that can be leveraged for educational purposes. The second category refers to game features that involve group work or collaboration, a pillar of contemporary learning theories. The third describes the features that help create a virtual world to immerse the player, and describes how each feature contributes to that.

6.1 Entertaining and Pedagogical

The following game mechanics are in tandem with active learning, interactive learning, learner control, feedback and other learning principles discussed in section 4.

Goals

Having clear goals is not only important in lesson planning, but also in game play. As gamification experts (gamification.org) put it, goals provide the reason to play. They also serve as a mark of accomplishments and progression towards something. In both game design and lesson construction, the goal and purpose of the game must be well understood by the players. The gamification team and others even suggest that allowing the players to set their own goals can be motivating, such as in the game *The Sims*. Setting clear goals can be used to promote collaboration, or as a source of healthy competition. When a player enjoys the game and connects well to the character, they almost embody the character's identity, mission and values. Gee (2008b) believes that the "marriage of personal goals and "in game" goals is a highly motivating state" (Gee, 2008b, p20).

Multimodality and Interactivity

Two of the main advantages of serious games are its multimodality and interactivity. Multimodality in a game increases likelihood of knowledge acquisition, knowledge application, and enhances understanding of complex and abstract phenomena (Klimmt, 2009). Interactivity has a similar effect since it caters to the individual learner's speed and capacity (Klimmt, 2009). Meegen & Limpens (2010) believe that interactivity is especially crucial in online education. They quote Dewald et al who say that "'interactivity in online education makes the difference between an information source and a learning experience" (Meegen & Limpens, 2010, p 273). Without interactivity, the students are learning suboptimally because they are not invited to think about the content they are reading or listening to. In order for interactivity to be fully realised, the affordances must be made clear to the player. There are many aspects of the virtual world that the player can interact with, such as the narrative, other characters and objects. A well-designed game fosters the learning process by providing a safe environment where new skills can be tried out and practiced and where the virtual world's parameters can be tinkered with, as in Gee's 'sandbox' (Gee 2003; Lieberman, 2009). Not being able to perform certain actions in the game

was among the frustrations expressed by the fourth graders who were surveyed about games.

User Control & 'Modding'

Another recommendation by the gamification team related to interactivity is giving the user control because it makes them 'feel important, safe and most importantly free' (gamification.org). The designer should consider what the player can affect, and how it can be rewarded. Giving the player choices when playing is one way to do that. There are three types of choices that a player has in a game, outlined by Charsky (2010): expressive, strategic, and tactical. Expressive choices are those that increase motivation, but are not related to learning, such as personalising their avatar. Strategic choices are the gamer's ability to change the game that affect the level of difficulty, allotted time given, and the number of players. Tactical choices refer to decisions about how to play the game in various situations along with tools and assistance along the way. Gee (2009b) takes user control one step further by showing that 'modding', or the ability to modify parts of a game, is a very attractive feature in a game. Players not only play, but make the game as they go along, adding options they cherish.

Many, such as Lieberman, Wang et al., Barab, and Gee advocate that giving users control is central to learning and giving the learner consequentiality. It is also intrinsically motivating as it leads to better performance and greater persistence (McNamara et al., 2009; Cordova & Lepper, 1996). "Both choice manipulation and personalization manipulation may be viewed as manipulations tending to increase the self-relevance of the activity." (Cordova & Lepper, 1996, p720). Gee`s (2003) 'Insider Principle' is further testament to making learners 'insiders', 'teachers', and 'producers' as opposed to simply consumers.

Challenge

Providing challenge in a game is another feature coveted by gamers that is also important in learning. Fourth graders agree and found a game that was too easy one of the main dislikes about a game, while having a fun challenge was one of the main likes about games. "Moderate levels of complexity create intermediate levels of cortical arousal, which is both optimally pleasing to most interpreters and maximally efficient for learning in most instances" (Bryant & Fondren, 2009, p109). Keeping the pedagogical goals in mind, the designer must consider if the game is challenging enough to engage the player/learner. The gamification team suggests this can be achieved by having the game require both skill and a little bit of luck. They also suggest having a variety in the challenges in terms of content and type of game play. Keeping the learner adequately challenged by staying within the proximal zone of development (ZPD) is essential for learning, according to the Vygotsky approach. Making a lesson too difficult frustrates learners, but making it too easy bores them. The ideal balance is when students are given a task at one level above their ability. Finding the right level is difficult in pre-scripted games, which are most common. Ideally, the program would model the user's level and adapt the game scenario and narrative, using artificial intelligence.

Level and content calibration using Artificial Intelligence (AI): user behaviour models

Unfortunately, many of the educational games on the market do not offer personalised learning opportunities using AI. Each player has the same experience regardless of their learning curve. 'The biggest issue limiting SEGs is the lack of good artificial intelligence to generate good and believable conversations and interactions' (Annetta, 2010, p105). That is unfortunate given that we should not simply transition from textbooks to digital media, but capitalise on the capabilities that technology can offer education. Incorporating adaptive narrative and level adjustment is not only pedagogically beneficial (Lieberman, 2009; Wang et al., 2010), but also contributes to flow and intrinsic motivation (Pierce et al., 2008). Adaptive instruction keeps the material challenging, but not too difficult (Lieberman, 2009). It seems that AI is mostly used with intelligent tutors as opposed to games (Squire, 2008). They incorporate models of users' behaviours, or why they behave the way they do, to allow their tutoring system to 'respond with customized content fitting learners' (Squire, 2008, p25). These models are based on extensive research and on prior knowledge of learners to create levels. According to Squire (2008), there are no educational games that use realtime data, or that provide such adaptive content. That is not to say it has never been done. A few commercial entertainment games have used realtime data to adjust levels, but it is more challenging in a learning environment. Dinerstein et al. (2004) present a way for the virtual character in their educational game to learn an unknown behavioural model on its own through reinforcement learning. They achieve this through two techniques: machine learning and offline character learning. Machine learning approximates cognitive models, while offline character learning uses a fitness function to allow the character to automatically learn new behaviour on its own, without the need for an explicit model. Pierce et al. (2008) describe a way of non-invasively adapting a game using the ALIGN (Adaptive Learning in Games through Noninvasion) system. Part of the challenge of adapting game play is to find indicators in player behaviour that determine the level of the player and problem areas that need more practice.

Rewards and Feedback

Feedback is essential in SG, especially because the role of the learner and player are fused (Bente & Breuer, 2009). Just like the learner, the player needs information about what she has achieved in order to plan future actions and to determine how close they are to the goal. Gamers covet statistics and analytics of their progress towards goals, according to gamification experts. When the system responds to the player's actions and input, the player will better understand how the system works and feel consequential in the virtual world. Backlund et al. (2008) noted that in their virtual driving game, feeling 'less in

control' of the car led to a decrease in self-efficacy. Therefore, the design of an appropriate feedback system is vital for learning and having players continue playing. Statistics can also inform the designer how to further development the game by tracking where the gamers start to lose interest, or which segments are too difficult. One of the key advantages of using computers is that they can keep track of students activities and provide immediate feedback about their progress, their understanding of the rules and for encouragement (Scarlatos, 2009).

Just as in classrooms, in SG, feedback can immediately follow actions or be delayed (Bente & Breuer, 2009). Each has their advantages. For instance, immediate feedback can encourage the player to continue, and reduce the risk of building on wrong information (Aleven et al, 2010). Delayed feedback can be more detailed and formative to remind the player how the session went and how to improve. Ideally, the game would provide both immediate and delayed feedback. Depending on the educational goals, the designer must think about what kind of information to display and when, as well as what behaviour to reward. For instance, the complete statistics can be made available in the user's profile, but the necessary information for game play can be made available always, such as the score and energy level.

Not just the timing influences learning, but so too does the type of feedback given and the modality. Information, such as the player's knowledge and accumulation of skills, desirable behaviour outside of academics, and what the system allows for actions, is valuable to both learners and players. Feedback on knowledge can be provided in the form of statistics, scores, progress reports, status of progress towards goals of the game, character strength development, as well as AI calibration of level and assistance. These can be presented in different modalities, such as visual, auditory, text, graphics, and so on. Desirable behaviour can be rewarded with Kudos points for team work, participating in forums, creative solutions, and other goals the instructor may have (Charles & Charles, 2009). Feedback from the system about the affordances of the system is extremely important for learning. No matter what the form, it should be dynamic and adapted to the needs of the learner, and be provided in a language that is meaningful to the player.

Keeping Score

In order to sustain motivation, feedback needs to be aligned with reward mechanisms in games. Rewards are fundamental to game design as well (gamification.org). Moreover, 'having the right reward is key to making sure players feel there is value to their actions' (gamification.org).There are different ways of rewarding players, such as increasing a score, collecting tokens in exchange for things, or changes in the avatar or virtual world in response to actions. When asked, the surveyed fourth graders were about evenly divided between getting a score and collecting tokens to use for their avatar. Some even suggested having both: after a certain score, the player receives privileges or tokens. Either way, gamification experts suggest that in order for the player to seek these rewards, they have to care about them. With some children, having a good score to share with friends is sacred. Therefore, having a 'sandbox' , or a test-run stage where the player can safely experiment without affecting the score is important (Wang et al., 2010). Rewards do not have to be limited to subject-specific content, but also desired behaviour, such as good team spirit and initiative. In their study, Charles & Charles (2009) found that Kudos points for good technique led to tremendous increase in motivation and understanding in core concepts.

Bonus Material

In order to maintain the motivation to collect points or tokens, they can be associated with bonus material. For instance, the player can have access to tools that assist them in their goals, collector items for their avatar, ability to unlock games, or upgrades to the graphics. No matter the choice, the progress towards the bonus material must be clear to the player. There are many ways to implement this. The best way to decide is to conduct some field studies with the end users. Fourth graders opted for collecting items to personalise their character. To accommodate the various preferences of players, there should be enough variety of things to collect.

Not playing too much

Apart from the score, the system should indicate if the player has played too long and encourage them to take a break for their own well being, or 'altruism' as gamification experts put it. One way to do this is for the character to have an energy meter. Once the meter reaches a certain point, the player must end the session and continue later on. Another way is to time the playing sessions to be sure they fit into classroom slots. If breaks are included, then Thomas & Young (2010) insist that there be "check-pointing and saving", where the player can begin a future session where they last left off.

Teacher Reporting Feature

The teachers can also get some feedback on the progress of their students. Once data is collected as part of the game statistics, it is easy to make reports of them for the teacher to outline the strengths and weaknesses of each student and the class as a whole. That way, the teacher can focus on relevant content and better understand the needs of their students.

Too much of a good thing

As important and helpful as feedback can be, we should be careful not to overwhelm the user with information, as it can be annoying and condescending, especially for advanced learners (Andre et al., 2009; Scarlatos, 2005). Magnus Haake remarked that when testing their game with children, they would sometimes get annoyed if there were too many comments made by the game that interrupted the game flow.

6.2 Group Work/Collaboration

Not only is interacting with the content and world within the game valuable, but so is interacting with others through a social network. By connecting with others, learners can discuss ideas, collaborate on games, or even compete. Mason & Rennie (2008) found that online cooperative learning leads to

better performance results than individual learning. This is especially true in math learning (Lindström et al., 2011). Almost all the fourth graders stated that they preferred to play games along with their friends. What's more, fourth graders surveyed showed a clear preference for a chat feature in games and was often seen as a major reason why a game would be liked. Gamers do not only limit themselves to friends, but can also connect with other gamers, creating 'affinity groups' that are bound by shared endeavours and goals (Gee, 2004). Players can communicate through a social network, a multiple player option, or getting assistance.

Social network

Communicating while playing can be achieved through a variety of mediums, such as chats, blogs, forums, etc. It is not enough to add a social networking feature to a game, though. It should be one that is congruent with the learning goals and the context. For instance, with forums information can be kept permanently and disseminated to all participants simultaneously, they also require more proactive students and do not offer an immediate response, if ever. Chats, on the other hand are instantaneous, easy to use and support multiple conversations. Unlike forums, chats do not keep information as accessible. Moreover, they can interrupt workflow, and are generally seen as time wasters by teachers (Mason & Rennie, 2008). Regardless of the medium, it is important to have a sense of community where all are encouraged to contribute. The fourth graders suggested a Skype-like form of communication during gameplay, as well as a control of inappropriate language in the chat rooms.

Not only is it beneficial to have on-task discussions, but also social spaces. Gulz et al. (2011) found that a social teachable agent in an educational math game led students to have a more positive experience of the game and even learn more than their counterparts that did not have a social teachable agent.

Multiple Player Mode

As we have seen, group work can greatly impact learning, specifically in math. It can also positively impact the opinions young learners have on math, challenging the view that math is individualistic. Klimmt (2009) finds that multiuser games support comprehension and motivation. Collaboration can occur within multiple player modes in games, where players can work together or compete against each other. In cooperative segments, Gee (2008b) calls such groups 'Cross-Functional Affiliation', where each team member specialises in a skill and learns to integrate the skills with the rest of the team towards a shared goal. This is the gaming world's equivalent of distributed intelligence.

While the surveyed students and gamers are enthusiastic about comparing their scores to their friends and competing, from a pedagogical perspective, the designer must be cautious. According to Bryant & Fondren (2009), competition was the number one rated factor why players said they chose and liked particular games. Gamification experts add that 'competition is the basis for most of humanity's progress and evolution' (gamification.org). Still, they too point out that it must be dealt with carefully. As Lavoie (2007) explained, educators should not pit students against the other because only the strongest will benefit. The 'competition' can be against the personal score of the player or in tandem with classmates against another school – so that they can be cooperative and competitive simultaneously. There should be options for players to compete if they choose to, but also many opportunities for cooperation.

Introducing this feature in a game means there needs to be a reliable way of assessing performance of the group, as well as each individual contribution. This can be facilitated by technology. Individuals can be rewarded with extra points for participation and contribution to team work. Gee (2003) points out that in World of Warcraft, showing what each player contributes to the game is a source of motivation to be more engaged and for the players to perform their 'duties'. To truly promote collaboration, the game can even *require* team work to advance through certain sequences of the game, where each player has pieces of the information needed.

Assistance

In both instruction and gaming, it is important for the player/learner to have access to assistance if they are stuck (Wang et al., 2010; Charsky, 2010). Assistance can come from peers, instructors, virtual characters, AI calibration of difficulty level, hints from the system and many other sources. It is very common for gamers to begin playing without ever reverting to the instruction manual. Through trial-and-error, and consulting others on gaming forums and YouTube, they are able to get the help they need to proceed (Meegen & Limpens, 2010). Gamers often only seek assistance when they need it. One way for the system to help the learner is that for players that need more time to carry out a task, they could be allowed to stay at a certain level until they are prepared to advance. Instruction should be dispersed throughout the game and come 'on demand' and 'just in time' (Gee, 2003; 2004), or what gamification calls 'cascading information theory'. The instructions in many games are often cleverly disguised as part of the game, so as not to bore players with a tutorial (Thomas & Young, 2010).

6.3 Virtual World

One way to promote immersion and lasting appeal is to create a virtual world where the player can connect with friends, do their homework, extracurricular activities, and more. That way everything is in one place, and they can even import other games and activities. It is also a safe environment where all accounts are associated with a school. One of the teachers surveyed was concerned that her students tend to be distracted by have access to the internet, thus having a contained world to go to helps maintain their focus. One example of such a program comes from Kafai & Giang (2008). Their game, Whyville, is a virtual land with its own newspaper, survival tips in the world, status in the world and salary. There is an active community that socialises and even elects their mayor. Members of Whyville organise events for their community and

petition for change in their virtual land. If the game is focused on one subject, though, it may not fit the purpose to create a student's world, but a virtual world with a rich narrative. A world that has elements of fantasy is very motivating and exciting and compels players to explore (Barab, 2009; Charsky, 2010; Lepper & Malone, 1987, gamification.org). Discovery in the game can also be tied to bonus points or hidden games. Creating an immersive virtual world can also result from sophisticated graphics, creating virtual characters, a good narrative, and seamless integration of educational content in the game.

Graphics

Good graphics can greatly impact the immersive experience of the player. Especially in educational contexts, if the goal of the game is to learn how to control a device, drive a car, or other specific skill sets, it is important for the graphics to be exact replicas or high fidelity (Charsky, 2010). Otherwise, it contributes more to user experience than education. On the other hand, making a scene too realistic can also overwhelm the learner with information and distract from the purpose of the game (Davidson, 2008). In some situations, such as in science, simplifying a system makes it easier to grasp. In such cases, graphics should be realistic enough not to interfere with the story. When surveyed, one the biggest factors that fourth graders liked about a game is if it had 'cool graphics', especially for boys. What's more, having bad graphics were a reason why they did not like a game. Ideally, the sophistication of the graphics would match those of COTS in order to capture the attention of young learners, or artistic, timeless renderings.

Virtual Characters

Interacting with virtual characters and non-playing characters (NPC) in educational environments have shown to induce the 'personae effect', or a strong positive effect on the perception of students' learning experience, which increases motivation and student engagement (Reategui et al., 2006). Moreover, it promotes deep learning because it provides external scaffolding (Graesser et al., 2009). Adding intelligent and realistic behaviour, as well as having relatable characters improve students' perception and experience. A relatable character increases the likelihood for the player to embody the character and share goals, strifes and successes (Gee, 2008c). In an educational context, Chase et al. (2009) notice that controlling and teaching a virtual character has shown to produce a protégé effect, where the child is more willing to make the effort to learn on behalf of the virtual character than for themselves.

At the moment, there seems to be a big divide between the virtual character's motions and believability and the virtual world in terms of graphics, which can be remedied by making sure the characters use gestures and nonverbal communication (Becheiraz and Thelman, 1996). Reategui et al. (2006), referring to Elliot et al. and De Angeli et al., found that agents that detect and react to affective states of students greatly improve human-computer interaction. Others, such as Picard highlight the importance of the characters' adaptive roles and behaviours based on user inputs. For instance, Reategui et al. (2006) describe their virtual character that could make content recommendations to students using their program based on students' profiles and behavioural patterns, improving students' perception of progress. Another point to consider with virtual characters is to allow the character to develop over time in both skills and maturity. The fourth graders surveyed showed a clear interest in the development of their character over time. It is also a way to increase immersion, and provide feedback as players progress to higher levels and capabilities. There are many ways to engage players using virtual characters, such as episodic memory modeling, personality and emotions simulation, among others (Magnenat-Thalmann & Kasap, 2009).

Based on the survey results, boys favored mature looking characters with a fantasy element, while girls preferred cute, goofy characters as well as teenaged humanistic characters (Fig. 1).

Narrative

Balance is always important when designing anything. With a storyline, if the tasks within the game are complex, it is best to balance it with a simple story line (Kenny & Gunter, 2010; Wang et al., 2010, Zea et al., 2009). Kenny & Gunter (2010) warn that too many arousing elements can distract from the lesson. The impact of the narrative on learning is discussed by Graesser et al. (2009): 'entertainment features such as drama, conflict, story-telling and empathy is essential to understand and utilize in information system development and message design for potential of IT to be realised' (Graesser et al., 2009, p109). Shute et al. (2009) add that "learning takes place naturally within the storyline of a well-designed game. The key is to seamlessly align the story and lesson, a nontrivial endeavour" (Shute et al., 2009, p317). Fantasy has shown to be very closely linked to intrinsic motivation and learning. The more fantasy is integrated, the more memorable the content will be, and thus more deeply processed (Kenny & Gunter, 2010). Humor is an important element to include and can greatly impact the affective state of the learner as well as the user experience. It was also the main reason why fourth graders liked a game. Story-telling is not only conducive to learning outcomes, but also enhances the user experience (Sharda, 2009).

Figure 1: Favorite characters. The top row were the top two favourites chosen by girls, while boys opted for the bottom row (character from World of Warcraft & Assassins Creed).
Sources of top row http://1malaysia-innovation.com/illustrator/vector-monster-from-a-pencil-sketch/;

Most of the COTS that boys chose as their favorites in the survey had violent themes and were action packed. The top three games were *Call of Duty, Counter Strike Source*, and *World of Warcraft*. All of these games have been rated by ESRB as Mature, meaning they are not appropriate for young players, because of violence, blood and gore, suggestive themes and foul language. The girls preferred *Movie Star Planet*, *Frizzle Fraz* and *Go Supermodel*. When asked for the story-lines that they would like to see, boys sought after fighting games, strategic games, fantasy themes, sports and car racing. Girls' wish list, on the other hand, included having a mirror of real life where you can personalise the character, their home and take care of virtual pets. In other words, 'playing dolls' in a virtual world. Girls focused more on relationships and connecting with friends.

Not only is the story-line important, but so is the creation of the quest. There should be a variety of quests available to choose from with varying levels of difficulty and time constraints. The completion of a mission should be clearly rewarded and the affordances, or the character's options, should be made clear. Pedagogically, and to motivate players, it is useful to show players how far along the quest they are and how well they are advancing towards to goal. This can be linked to the development of their character as well as the plot. As the player advances, the character can become bolder and more capable and the challenges more difficult – also referred to as adaptive narrative. Bellotti et al. (2009) give an example where the player builds his own narrative experience by 'interacting with contextualised situations and mini adventures during a geographic exploration of a wide environment." (Bellotti et al., 2009, p278) This is no trivial task (Pierce et al., 2008), but can be facilitated by AI and can provide the immersive experience that educators think is important.

Implicit vs Explicit Instruction

Explicit instruction is the classic model of instruction that is teacher-centered and demands the attention of the students. This style of instruction exposes rules before illustrating with examples (Brown, 2000). By contrast, *implicit instruction* is student-centered where rules are inferred from examples. Each type is useful depending on the learning goals. In order to use them effectively, it is important to understand which contexts they are useful for. Saetrevik et al. (2006) tested the impact of implicit learning on education by teaching atomic bonding rules to 11-12 year old school children. They observed an implicit learning effect, but that learning was much more effective when more explicit ways of teaching were used. In other words, mere exposure to material is not sufficient to learn rules. Kohl et al. (2007) found implicitly framed questions where the problem solving was modelled for users and where they had a choice of the approach they were most comfortable with, did better than explicitly framed questions, albeit marginal. Still, explicit instruction led to more correct free-body diagrams on the hardest problem. In other words, both approaches have merit depending on the learning goals. Further, the teachers surveyed all suggested that it is best to have a combination of the two in instruction. There is a need for studies to show the educational impact of using implicitly framed questions to be sure they direct students to the intended outcome, as well as a longitudinal study.

In a game context, however, integrating concepts to practice into the narrative of the game is a maintain the flow of game play. Gee (2008b) believes that implicitly framed questions are the advantage of using SG in education. In most math games, the questions and problems are explicitly framed with formulas to solve and numbers to plug in. I suggest that not only does this interrupt the flow, but it also does not represent reality. In the real-world, one is not faced with clear equations to solve, but with challenges that require appropriate resources to resolve. It is still possible to have the player work on target skills but just ensure that they are integrated in the game in realistic contexts. To be clear, in this discussion, by *implicit* I do not simply mean exposure to math without further instruction. Instead, the game would be used to supplement regular class instruction, and allow players to apply their knowledge without explicitly stating questions or methods of resolving them. There is a danger that if the problems are too implicit, then students will miss the point and not adequately learn the intended concept, whereas being too explicit can turn some children off of playing the game. Any teacher struggles to get their young students to play a game if they know it is educational. The teacher, then, can decide to make the link between class instruction and the game clearer. One way to decide to what extent the concepts will be disguised is to think of the pedagogical goal of the game, the intended outcomes and how it is implemented in instruction.

7. User experience

To ensure a serious game is appealing to the target group, the game developers must aim for creating a positive user experience. But simply calling a game 'fun' is too vague because it encompasses many factors. The more is understood about the components of games that are considered fun, the better they can be incorporated in the design. As discussed earlier, a positive affective state is crucial for learning.

Wang et al. (2009) found that 'enjoyment' has several dimensions: physiological, affective and cognitive. Their study further revealed that there are five dimensions of a game that are important to gamers: technological capacity, game design, aesthetic presentation, entertainment and narrativity. That is not to say that all five dimensions need to be fully developed in order for the gamer to have a positive experience. There seems to be a certain threshold that a game has to pass in order to be playable or entertaining, and even more criteria for a game to be 'superfun'. In order for a game to be playable, it must have the technological capacity and basic game elements (usability, control, challenge and decent visual presentation). To be considered enjoyable, there should be a focus on aesthetic presentation and game design. A superfun game is one that offers complexity, diversity, novelty, mechanics, and highly sophisticated aesthetic presentation, narratives, and social interaction (Wang et al., 2009). It is important to include gamers in the design process because the designers' ideas are not always appreciated by gamers, as Rosedale discovered with

A Second Life. To accommodate the individual differences, there should be options for players to personalise the game.

'Flow' is a central theme in describing the user experience with playing games (Csikszentmihalyi, 1975), highly related to learning in the Zone of Proximal Development, it is a prerequisite for success (DeGrove et al., 2010). Even 'flow' is too general of a term, so De Grove et al. (2010) summarised the study of Hoffman et al., who identified 12 concepts related to flow (based on a literary review of 16 studies): *arousal, challenge, control, exploratory behavior, focused attention, interactivity, optimum stimulation level, playfulness, positive affect, skill, telepresence and time distortion*. They further borrow from Sweetser & Wyeth who add *having clear goals, feedback and social interaction* to that list. All of these concepts are suggested in the framework presented in the previous section.

Diah et al. (2010) define desirable features from a usability point of view. They find that the program should have learnability (learning the system), efficiency (once learned, how quickly can they perform tasks), memorability (even after a break), error control (should be easy to recover from, and not severe), and satisfaction with product. These are vital components to consider when designing a game. If the player is frustrated, it interferes with learning outcomes.

8. Similar Endeavors

To reiterate, simply having some of these features does not ensure success. Looking at examples of both educational games and COTS that have been successful and those that have not can help further understand how to implement SG's well. There are many examples to choose from since about 63% of serious games are those that have a primarily academic educational content (Ratan & Ritterfeld, 2009 , p14). 16% of those games are targeted at middle and high school players, while 39% are aimed at elementary school and 39% for preschool. While for commercial games, the average age of gamer is 33 (Ratan & Ritterfeld, 2009, p17). Although it is common to assume that boys comprise the majority of players, Kafai & Giang (2008) observed that in Whyville, 68% of the visitors are girls and are, on average, 12.3 years old.

Within academic educational games, there are countless examples dedicated to math or science. A simple search on the internet will produce many results. The majority of the 'games', however, seem to be directed at younger children, even if they claim to be for elementary school, and have few game features. There are a handful of exceptions, however, such as Barab's game, *Quest Atlantis*, and Meegen & Limpens' *Saving Asia*, where the players are actively engaged throughout and are immersed in a rich virtual world. In *Saving Asia*, the player takes on the role of a candidate for the position of Junior Advisor, in an Asian country that has been devastated by tsunami. The story-line and mission is a relevant real world context, with many learning opportunities, making students invested in it.

While COTS have been proven to be based on sound learning principles, Meegen & Limpens (2010) assert that the impact on curriculum content is only accidental. Furthermore, the skills learned from COTS are 'often quite primitive; how to fire weapons, hunt, find shelter, avoid danger, etc' (Meegen & Limpens, 2010, p270). Still, COTS can teach important complex concepts that lead to deep learning (Gee, 2003). Some games, such as *The Sims* or *Fable* have been used in school to supplement the curriculum. Conceptually, many of these games seem to be the answer to every teacher's need. In reality, however, not all the games developed are actually effective.

8.1 A few less successful attempts

Unfortunately, the majority of educational games do not build on Lepper & Malone's (1987) principles of fantasy, control, challenge, curiosity and competition (Brom et al., 2010). Nor do they compare to commercial games that provide a rich and complex environment that increasingly challenge the player as he/she explores the world. Some endeavours attempted to provide some of the attractive features discussed in Section 6, but missed key features, such as interactivity and user control. *Maths Garden,* a game to help train elementary school computation skills, attempted to have a theme of maintaining a garden with decent graphics. While it was a noble goal, it is not much more than drill and practice. Players simply solve addition and subtraction equations repeatedly without affecting the garden's success. Apart from the lack of integration of skills, academic content does not correspond to what a fourth grader should know and practice. What's more, level four does not differ from level one.

Another example of a worthwhile attempt is by *Amanita Design*. They are incredibly talented and creative artists that build imaginative virtual worlds filled with humor. The only game they created aimed at being educational was made for the BBC. It has an interesting storyline of the main protagonist trying to retrieve his friend's lost hat in his hot air balloon. To continue to travel upwards and find the hat, he must answer multiple choice questions with different themes and collect air bubbles. The actual game play, however, can be frustrating because there is no instruction available. The themes do not appear in any particular order and are not related. One round may question knowledge about science and the next English literature, without any transition. Furthermore, there is no indication of how much farther the player is from retrieving the hat. It does have beautiful animation, bizarre characters and plenty of humor to keep the player hooked, though.

On a serious games enjoyability assessment asked of players with ten years of experience playing digital games in all genres and relevant content areas, Shen et al. (2009) found that *Electrocardiogram* scored only 40/100. Electrocardiogram teaches players 16 years and older the basic elements and operations of ECGs, where they assume the role of a doctor who uses ECGs with various patients. The main complaint was that it lacked complexity. Some of the players felt it was more of a lecture than a game, which made it less enjoyable. Further, the graphics and sound were not compelling, but were acceptable. Similarly, *Londoner* scored only 35/100. Londoner supplements an undergraduate level history class on 17th century England. The player is a young Londoner who must make decisions about money, raising a family and increasing social status. Although the concept was intriguing, the game

play was limited in terms of controlling the character. One player said 'It quickly became obvious that the financial choices I made had little bearing on the game'. (Shen et al., 2009, p55). Because of the disconnect between the player's actions and the outcomes, the game did not engage the players, or provide a sense of challenge or reward. It also impacted the player's learning of the intended content. Moreover, the graphics were still images with no sound, which did not immerse the player in the game. *Darfur is Dying*, a game about the plight of Sudanese citizens during the war, was similarly received. The motions of the characters were repetitive and clumsy, according to one of the players. He said "the collecting of water was superfluous and awkward and I lost attention quite quickly. After collecting the water a few times, I let the character be hit by a militia truck just to go on to the village" (Shen et al., 2009, p56). Further, the player found little connection between the tasks and the intended outcomes, which interfered with the purpose of the game. Brom et al. (2010) talk about the importance of making affordances visible to users, as does Norman, otherwise it interrupts the flow and causes frustration.

These examples show that even though many factors are in place, a multidisciplinary team is needed to make the game educational, fun, and well-designed with a rich narrative and a clear goal. The lesson to learn is that interactivity and clear learning goals and affordances, as well as good graphics are needed for the learner to be engaged.

8.2 Better examples of games

Not all educational games fail to measure up. There are some good examples, such as Learnalot's game *Settlers.* Players are given a mission to get to Mars and must have enough supplies to get there, find the best route there, and establish a colony there. It is still being developed, so there is much more that can be done, but it is immersive and the player can affect the success of the mission. The game can become repetitive, because it asks the player to calculate the needed amounts of supplies for the mission repeatedly. The different tasks can also seem disconnected due to lack of transitions between the collecting of supplies for the trip. Transitions, such as displaying what the character has collected thus far is one way to inform the player what remains to be collected and how close they are to taking off to Mars.

Barab's *Quest Atlantis* is yet another good example because it encourages exploration, has relatively impressive graphics, and is highly interactive. The character's motions can become awkward, but there is a lot to explore. One point of criticism is that there is no guidance on where the player visits in the virtual world. When the player first begins, a tower is visible in the distance. Upon entering, however, there is not much to see or do. If every location in the virtual world had content for the player to learn from, it would be an excellent resource. A third good example is *Lost Mind of Dr. Brain*. The goal of the player is to retrieve the brain and intellect of the mad scientist by solving puzzles and conundrums. The questions are explicitly stated, but it works within the context. The story-line and graphics are well done and the content is relevant for the target age group. *Genomics Digital Lab*, is a game where players have to save a dying plant by combining the right amount of light, soil and other factors. As the player varies these factors, they can see the effects it has on the plant. There are many other activities that encourage discovery and tinkering. The player can use a notebook in the game to log discoveries and thoughts about the content, that can be shared with the teacher.

Other good examples come from COTS. Especially the two most popular COTS: *The Sims* and *World of Warcraft* (WoW). Several forums about these games suggest that the main attraction to these games are that they offer an alternate reality where the player can take on roles that they could never do in reality. In The Sims, the player can be an architect, a fashion designer, or anything they wish they could have been beyond the constraints of real life. In WoW, the player can develop their fictitious character's strength and skills. Both games offer a social world where they can connect with friends, whether or not they have met them in real life. The feeling of control and the experience of 'playing God' is something most people do not have the opportunity to do in real life. Moreover, in both games, there is always a fresh gaming experience that is completely responsive to the player's input. Several players say that collecting tokens based on good team work and good performance, then exchanging them for their character was a big source of motivation in WoW. One complaint about WoW from an experienced player was that there are many long unnecessary sequences that do nothing but waste time. For instance, traveling to another area is a drawn out process and happens each time. It is beautiful the first time, but then can become tedious.

There is a need to have good choices to practice math for children between 9-12 that is not only appropriate for school, but is also fun to play. The next section gives an example of such a game. *Please refer to Appendix D for a review of several games and how they fare in comparison to each other.*

9. A serious math game: Messenger Quest

Given what is now known about Millenials, how they learn, and what it takes to make a good serious game, it is time to illustrate with a concrete example. The example given here is by no means the only way to implement it, but is meant to be a starting point for further discussion and suggestions from end users. In this discussion, I use 'program' and 'game' to mean the same thing. Also, 'station' refers to an individual game within the quest, or location on the map.

This program has three main goals of equal importance. The first is to improve students' high-level skills: to increase their ability to discuss, negotiate, work in teams, and make group decisions. The second goal is that students learn facts about math (based on the competencies) and mathematical thinking as they navigate through the world and interact with it. The third goal is that students can get a good idea of how math is used in the real world and general mechanisms of how it works as opposed to simply solving equations on a page without any context. Hopefully, playing this game would influence the idea that math is fun.

The program is comprised of three components: the game, the social network and the teacher console. The game is a quest

Figure 2: Choosing the character. The player can choose from an array of characters that they can control. The characters shown here were chosen according to the survey results regarding preferences and are based on existing characters. For a close-up of this image and others in this section, please refer to Appendix C. Original pictures were found on the web. The fourth character is from the videogame Assassins Creed.

where the challenges require math skills to overcome without explicitly stating math, but seamlessly integrated in the game, which is why the title and the plot do not allude to math, but sound like a videogame.

9.1 The game

9.1.1 Plot

A friend entrusts the player with a letter to be delivered to the queen that is of vital importance. He warns that many are trying to destroy it or steal it, so it is a dangerous mission. He is known to too many predators, which is why he can't deliver it himself. Once the friend leaves, a hidden figure emerges from the shadows, points a laser gun at the letter and rips it to shreds. A gust of wind blows the pieces all over the town. It is the player's job to find all the pieces as he/she travel around the town. There is a map to guide them in their quest. Each station in this fantasy world is bizarre and filled with humour and strange characters that can either help the player or harm them. At each place, the player collects one piece of the letter at a time and can get bonus material if they perform well or show good team spirit. At the end of each level, the player can weld the pieces collected together. The player must avert danger as it arises around them and deliver the letter to the queen to prevent war. Some missions are only possible to complete with the help of friends.

9.1.2 Game Play

Getting Started

When the player first starts the game, they must choose their character from an array of animated, female and male protagonists (Fig. 2. N.B.: *For a close-up of the figures, please refer to Appendix C*). For the players to embody the characters, they must be relatable, so there should be enough variety in characters to choose from. When selected, each character shows a list of skills and capabilities to add dimensions to their personality and further connect to the player. Throughout the game, the player will have full control of the character's actions to lead to the 'marriage of goals' that Gee (2008b) believes is highly motivating. This way, the educational benefits from both avatars and characters are at play. Each

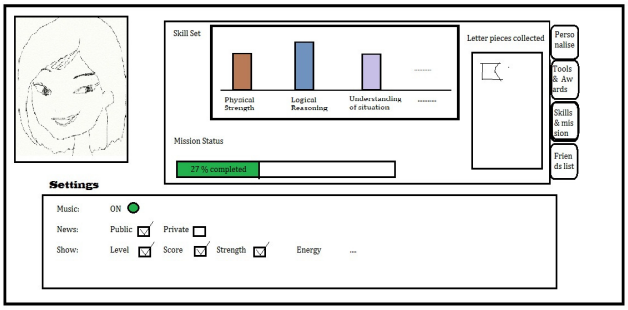

Figure 5: User Profile. Here, the Skills and Mission tab is clicked, revealing information about the character's skill level, letter pieces collected and remaining work to completion of the mission. The player can also personalise their settings, personalise their avatar, manage their friends list and view their tools and awards.

character can be further personalised by going to the profile and viewing the collected bonus material that had been 'bought' by tokens (Fig 5).

After choosing their character, the player sees the friend approach him from the shadows and explain why he cannot deliver the letter himself. Once he hands over the letter (Fig 3), he disappears from view. Then the letter is shredded and spread over town. An introduction to the quest appears revealing part of the plot (cascading information theory), so only necessary information is given.

After the introduction, the player will see a map of the town (Fig. 4). The player is now ready to select one of the stations on the map and begin playing. The order of the stations visited is up to the player as is the length of time spent on each. At each station, the player collects pieces of the letter, awards for good behaviour, as well as tokens to exchange for items or bonus play. Before beginning the mission, the player gets some cryptic information about what to expect and the estimated time it should take (to provide a clear goal). The number of attempts for each game and the time it took to complete it are all recorded for the report displayed to the user and the teacher (Fig 5 & 9). Although the player obtains a piece of the letter at each completed station, if the teacher would prefer them to practice more, they will need to revisit the same spot and get several flags in order to keep the piece of the letter.

Figure 3: Letter Exchange. The friend who entrusts the player with the letter to be delivered to the queen. This character was reconstructed based on a character from the videogame Trine.

Figure 4: The town. The quest map of the town that the player has the explore to collect pieces of the letter. Source: http://www.gameinformer.com/blogs/members/b/warbuff_blog/archive/2010/12/21/vacationing-in-video-game-land.aspx

Ongoing gameplay

In subsequent sessions, the player will continue to play using the character initially chosen. The virtual world is highly interactive to allow players to understand how the system works. This makes it important for the graphics to be sophisticated. In case of errors, the player will see the effect on the narrative. For instance, in one of the stations, the player must mix a potion to make the plant grow enough to climb to the top and retrieve the letter. If the potion is not done well, the plant will not grow adequately and the player will need to continue to try. Not only does this allow the player to see the effect of their actions, but it also contributes to the notion of fresh game play – that each time the game is played, it can lead to a different experience. Moreover, two players will not experience exactly the same scene unless the play together.

The system will use AI to calibrate the level of the player and accordingly adjust the complexity of the problems faced and provide support from non-playing characters (NPC) offering words of wisdom. NPC's can further give clues about where to find hidden tokens. Assistance will also come from peers in their social network, and the instructor, aided by the report results. As the game progresses, more of the story is revealed as well as instructions on how to proceed. The NPC's that try to sabotage the mission are 'evil', but funny. There is no violence in the game, but the evil NPC might mock the player or be a nuisance by clumsily and accidentally cause problems. This maintains a challenge without inappropriate themes.

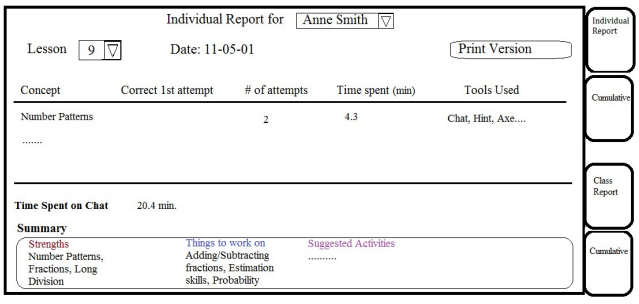

Figure 9: Teacher Reporting Tool. From here, the teacher can view reports on students performance for each session and cumulatively. It is also possible to view a report for the entire class per session and cumulatively.

In Messenger Quest, players will be given modding ability to allow them to add features of the game that they would like to see. It is not necessary for continued play, but is an option for interested players. Philip Rosdale, producer of the popular game *A Second Life*, described how some of the features he thought would be well-received were eventually scrapped, while others were sought after and created by players.

Development in the game

In the lower levels, each station practices a discrete skill based on the competencies (Appendix A). As the player's level increases, there is more integration of concepts to match what is taught in class. For each game, there is the option to switch from single player to multiple player mode (Fig 6 & 7). Some missions will even require it in order to advance. In the multi-player mode, there will be a chat box to discuss strategy and other thoughts. If the player chooses a competitive mode, the system will mention if the players are at a matched level, so the players can decide whether or not to proceed.

At the end of a level, the concepts practised throughout are all combined in one bigger challenge (corresponds to an end of unit test). If they succeed, they can weld part of the letter together. More of the story line is revealed telling them what is left for them to do and a NPC wishing them luck and congratulating them if they have received awards for good behaviour. At this point, they can also exchange tokens for tools for future challenges or things to personalise their character with. The tools may not make sense at first, adding to the humor, but will be used later in other challenges (such as a squeaky hammer or water gun). It also promotes planning and strategic thinking. Once the player begins the new level, new stations are opened in addition to the ones from the previous level. The older stations in the higher level will practice the same concept but be more difficult to solve.

Rewards & Feedback

Rewards are given for good performance (completing the activity) with a score. Creativity of solutions, good team work, participation in forums and chats, initiation of group work, sharing tools with others, and commenting on friends' victories (explained below) will receive tokens. Tokens can be exchanged for tools for future missions, items to personalise

Figure 6: Single Player Mode. In this game, the player must build a bridge to cross the river and retrieve the letter. The player can switch between the game, chat and friends list. Source: http://www.123rf.com/photo_202610_a-river-flowing-in-the-forest-surrounded-by-trees-and-bushes.html

Figure 7: Multiple Player Mode. Here, two players can chat while playing the game to discuss strategy. They are looking for the safe that contains the letter. Source: http://www.downextra.com/n/Natalie+Brooks+-+Secrets+of+Treasure+House.html

Figure 8: Butterfly Room. Hungry creatures rising and threatening the ecosystem. The player must keep the butterflies alive. Source: http://www.brothersoft.com/flowers-and-butterflies-277733.html

the character, and extra mini games. Along the way, they will receive immediate feedback to encourage them and show if they are along the right track from NPC's. As the energy meter dwindles, it tells the player to take a break from playing. There will also be information on how much longer they have to complete the mission. Whenever a player beats their own personal score, their page will be updated and can have their friends congratulate them (explained in the social network section).

As time goes on, the characters develop in strength and maturity. This can be seen by how healthy the character looks, their ability to easily perform certain actions and the complexity of the problems they face. Such changes will also be marked in the user's profile.

Profile and personalising

Each player can personalise the game and their profile (Fig 5). There will be information about their current level and progress report, time spent on each game, tokens they have collected, strength level and a chart of progress, tools they have collected and can share with others, the pieces of the letter, friends on their network, and game settings (sound, music, private vs public display of information) to accommodate different styles and needs. The player can also decide which information will always be displayed on the game screen, such as the score, energy meter, etc.

9.1.3 Examples of stations

One example of a station is in the forest by the river. The player must build a bridge using the available tools to get to the other side of the river and pick up the piece of the letter. This game practices measuring using tools, arithmetic, and estimation skills. In higher levels, there will be NPC that add to the challenge, such as the overzealous goofy creature that follows you around and can accidentally push you in the river (Fig. 6).

Another station is in the mansion of the richest family in the town. The player must circumvent all the strange creatures in the mansion and make their way to the mansion's study room. (Fig. 7). In the study, they player must find the safe where a piece of the letter is stored. The safe is locked with a combination lock. The player must figure out the code on the lock before the alarm sounds. This game practices recognising and completing number patterns. After three unsuccessful attempts, the player must restart at the front door of the mansion and make their way back to the safe. As the levels increase, the number patterns become more and more complex.

A third station is in a townsman's backyard. The player enters the scene only to realise they have crashed a children's birthday party. The mother assumes they are the waiter(ess) and hands them a tray with 30 pieces of cake. The player has to hand out the cakes before the children cry, keeping in mind the tray must be balanced at all times. This game practices weight distribution, fractions, and estimation skills.

A fourth station would take place in the Butterfly Room of the local zoo. The player must keep the temperature constant to make sure the butterflies flourish. If the room is too warm, some hungry bugs appear on the scene (Fig. 8) and begin eating the flowers that keep the butterflies alive. The player must restore the room back to order to make them disappear and grab the piece of letter. The skills required are reading a thermometer, equations with changing conditions while maintaining a constant (temperature).

9.2 Social network

The social network will be a collection of resources, such as chat during and between game play, a social networking page, similar to Facebook where they will have a sortable friends list. Updates from the game, such as score records and awards for creativity will be linked to their page. Their friends can congratulate them to give an opportunity for all players to shine, not only the best players. It could even lead to a discussion of strategy and skill for others to get the same. There will also be a knowledge base/forum where players can post questions and discussions to all the members of the network (not just their direct friends). Any updates to their comments will also be sent to their page.

During game play, multiple players can chat while playing (Fig 7). Otherwise, the player can click on the tabs on the side to switch to full chat mode or to view their page. From their settings, players can decide what information becomes public, and to personalise their page and friends list (Fig 5).

9.3 Teacher console

The teacher will also be able to view and print reports about the progress of their students (Fig. 9). The report will be available for individuals per session or cumulative. The tasks within the game will be coded according to the skill set they require. That way, statistics can pinpoint which areas the student is strong in and which areas need more support. The teacher can also see the number of attempts made at the game, the AI calibration of the student's level and the student's use of tools and assistance. These statistics will also be available for the class, as a whole, per gaming session and as a cumulative over a time period. This helps the teacher tailor the class with relevant content. The reporting tool will even suggest types of exercises the teacher can use. There will be a plethora of worksheets and teacher resources to choose from in the teacher console. The teacher will have the ability and is encouraged to comment in the forum and guide the students, as well as chat with the students.

The teacher will also have access to technical support and modification ability to set the parameters for what the students will learn. They will also have information on how to use the game in the class, or for homework to supplement class work.

10. Challenges for serious games adoption in schools

Despite the compelling evidence for the effectiveness of serious games as teaching resources, not all educators are on board. The majority of the studies about teachers' attitudes regarding serious games as educational tools find that teachers are sceptical. Brom et al. (2010) observe that many teachers perceive games as leisure time activities with no educational value, except for IT skills. That is how the teacher reporting tool can help. Once teachers see that the game follows the school curriculum and helps them in their instruction, they may be more inclined to use it. Luckily, recent surveys show that this attitude is slowly changing. Another reason Brom et al. (2010) believe mitigates the use of serious games in education is a transfer problem. While the game requires the development of skills, they are doubtful that these skills are used in the real world. By using the teacher reporting tool and suggested related activities, teachers can find out if the concepts learned while playing have transferred into other areas and modes. Further, the teacher can help link the mathematical thinking and concepts from the game to class assignments and instruction. A third problem they found was that teachers lack experience with computers and technology and feel uncomfortable using them. To support those teachers, the game should be user-friendly and technical support should be provided. The same teachers also fear that they would be replaced by technology. However, just as we cannot expect a child to independently learn from a book, we cannot simply give them games and hope for results. Granted, games offer advantages over books, such as interactivity and personalised learning opportunities, but they still require a teacher to integrate the game in the curriculum.

Not just teachers, but also parents are concerned with the negative effects of watching television and playing videogames on children, especially when it comes to violence. Given that some children spend as much time playing games than having a full time job (Owston, 2009), parents are worried that it will affect their development. KFF suggests that for younger players, long hours in front of electronic media can interfere with having a balanced life of playing outdoors, interacting with others and exploring the world. Unfortunately, increasing numbers of health groups report problems for teens and pre-teens who battle with video game addiction. "Studies estimate that 10 percent to 15 percent of gamers exhibit signs that meet the World Health Organization's criteria for addiction" (video-game-addiction.org). But it is important to distinguish between some COTS and educational games. While many commercial games stand to benefit from enthusiastic gamers, the goal of educational games is not the same. There should be a way to maintain the player's interest as long as needed to train the concepts from school adequately, but not that they cannot do anything else. For that reason, a time limit can be imposed, where the player needs recuperation time in order to continue.

11. Conclusion

The emerging theme from research is that group work and completely immersing the child in the content and allowing them to take charge of their learning, instead of passively listening to the teacher is ideal for learning. Further, studies on Millenials show that they prefer different modalities when learning, such as pictures, sound and video, as opposed to text (Mason & Rennie, 2008). They also value interactivity and working with others. Serious games seem to offer exactly what is needed and preferred by Millenials. However, due to a lack of consensus on what a good serious game means, it is difficult to find good examples. In most of the literature about educational games, the challenge of designing a game seems to be a tug of war between education and fun, but it doesn't have to be. If they are to be considered games, they must first be games that are based on sound learning principles. As discussed throughout the paper, built in to most video games are deep learning principles even though the content is not best suited for elementary school. It seems intuitive to design a serious game that functions like a video game, but with more appropriate content. Yet, this has rarely, if ever, been done.

The first part of this paper proposed a framework for the design of serious games based on COTS' game mechanics, learning theories, and by surveying fourth graders. The framework incorporates gaming features from commercial games to make sure they are fun, that are linked to contemporary learning principles to make the game suitable for school. It also looks to existing commercial games and serious games that have been successful and those that have not, to further learn what it takes to make a good serious game. The second part of the paper showed an example of a math game based on that framework called Messenger Quest (MQ). Although the game is targeted at fourth graders learning maths, it can easily be applied to other age groups and subjects. MQ aims at facilitating deep learning since studies have shown that most serious games only lead to shallow learning. The goal is

to not only improve academic skills related to math, but also positively impact attitudes towards math, allow them to connect math to the real world, and promote collaboration.

There are many benefits of using technology in teaching, especially because it helps personalise the learning experience for each student by catering to their level, target content and learning style. Games show a promising future of being used in schools, but must first be well-designed. That means building on the essence of COTS, which are already attractive to children, modifying the content to fit the learning goals, purposefully creating deep learning opportunities, and catering to the user experience. In order to succeed, the game must be developed by a multidisciplinary team that iteratively develops the game with the intended learners. In the future, serious games can be used as resources alongside books in classrooms, except that they offer much more active and personalised learning opportunities than books. There is no such thing as a perfect resource, but it is important to highlight the strength as well as the weaknesses with each one to be able to maximise its potential for education before discarding it. Further, games, such as MQ can be used to replace tests as a non-threatening way for students to showcase their knowledge.

Once a good game is implemented, it should be tested for its educational impact and user experience. There are so many questions left unanswered. To name a few: If we do implement a game based on this framework, how does it fare in reality? How effective are the learning outcomes? How engaging is the game? What is the user experience? To what extent can the educational content be implicit before it no longer is pedagogically relevant for the learner? To what extent can it be explicit before turning off students from playing it? Can games truly replace tests? What does a game need to have in order to do that? Will these games lead to learning transfer?

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Appendix A. Fourth Grade Mathematics Competencies

Education.com provides information on what fourth graders learning math should know at the start of the year and what they should learn by the end of it. On their page, written by Amy James, they write:

Curriculum varies from state-to-state, but there are some constants. Students working at the standard level at the beginning of fourth grade:

- Comfortably add and subtract large numbers
- Know the basic multiplication and division facts
- Understand how place value works in our number system
- Can round numbers in order to make a reasonable estimate
- Use tools, such as rulers and thermometers, to measure
- Can differentiate solids from shapes
- Can find fractions of a whole and fractions of a set
- Understand basic probability and statistics
- Understand how bar graphs, line graphs, and tables communicate information

By the end of fourth grade, students working at the standard level:

- Discover, describe, and extend geometric and number patterns
- Solve simple math sentences that contain a variable
- Read, write and rename whole numbers through the millions
- Read, write and rename decimals to the hundreds
- Compare and order whole numbers and decimals
- Explore equivalent and nonequivalent fractions and begin to compare, add, and subtract them
- Multiply larger numbers
- Are comfortable with long division
- Begin developing mental math ability and estimation skills
- Know the basic characteristics of lines and angles
- Have established measurement benchmarks
- Can collect, record, and analyze data to investigate probability

Source: http://www.education.com/magazine/article/fourth_grade_math/

Appendix B. Surveys Asked of Fourth Graders and their Teachers

I. Student Survey. 60 fourth graders were given this survey to fill out to find out about video game preferences. 50 of the participants were boys, leaving only 10 girls who responded. *N.B. The survey has been formatted to fit this paper. In the original survey, students have a lot of space to give their answers.*

Your Initials: Girl/Boy

1. Name your three favourite games (preferably video games) and what you love about it

    1. Name of game:

        Why you love it (circle answers):
        Hard but fun cool graphics chat funny educational break from studies
        Other:_____

        Why you don't (circle answers):
        Too easy bad graphics no chat not funny educational too slow
        Other:_____

    2. Name of game:

        Why you love it (circle answers):
        Hard but fun cool graphics chat funny educational break from studies
        Other:_____

        Why you don't (circle answers):
        Too easy bad graphics no chat not funny educational too slow
        Other:_____

    3. Name of game:

        Why you love it (circle answers):
        Hard but fun cool graphics chat funny educational break from studies
        Other:_____

        Why you don't (circle answers):
        Too easy bad graphics no chat not funny educational too slow
        Other:_____

    2. If you could design your own game, would you use fantasy characters, or real ones that look like you?

        _____

3. Which of these characters do you like? Order them from 1-14 (1 = favourite, 14 = least favourite).











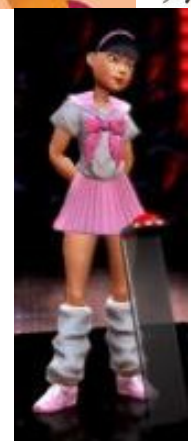

4. Do you think it would be cool if your character grows older with time? What if they just become stronger?

5. In your dream game, would you have a score? Or would you rather have tokens that you can exchange for stuff, like things for your avatar, or more games?

6. Would you want to see how you did in comparison to your friends? Or would that discourage you?

7. Do you like playing with your friends (cooperation)? Do you like competing with them? Or do you prefer playing on your own?

8. Would you like to have a chat feature? What would you like to see there?

9. Now it's time to hear some of your ideas… in your dream game, what would the story be?

Anything else you would like to add?

THANK YOU FOR YOUR ANSWERS!

II. Teacher Survey. 3 math teachers were interviewed about what factors they look for in educational games and what they find missing in existing educational games. . *N.B. The survey has been formatted to fit this paper. In the original survey, teachers have a lot of space to give their answers.*

1. If you were to choose an educational game to use with your students, what features do you think are important? Please circle as many answers as you wish, and add any comments you may think of:

   Explicit teaching Implicit teaching Discovery Challenging Rewarding correct answers

   Rewarding good behaviour (not related to academic skills) Allowing mistakes

   Humor Good graphics Chat ability Teacher console Teacher reports

   Recommended activities related to game Healthy competition/collaboration opportunities

   Individual gameplay (not multiplayer) Obvious educational content Hidden educational content

   Other:

   What about features you think should not be included?

2. Would you rather see games for each subject, or for integration of subjects?

3. Do you think implicit teaching is more interesting than explicit? Which of the two do you think is more affective? What about for math?

4. For the teacher reporting features, what information would you like to see that will help you help your students? (Ex: in comparison to others in the class, which games/skills they did best or worst in, how much time it took them to complete it, which tools they used, how many attempts they made, etc….)

5. What kind of feedback do you think will most benefit your students?

6. Would you use this game in your class or would you recommend it as an extracurricular activity? Would you like to use games in your classroom? Why or why not?

7. With the available games and technology, what gaps do you see that you think should be addressed? Does that prevent you from using them more often?

Any additional comments are very welcome:

Thank you very much for taking the time to respond to the survey!

Appendix C. Messenger Quest Close-ups

Note that the illustrations here are sketches to support the text descriptions. Due to the author's artistic limitations, the pictures are simplistic or have been borrowed. Moreover, the missing details are accounted for in the figure descriptions. The final product should have sophisticated graphics in par with the most recent COTS.

Figure 2: Choosing a character. The player can choose from an array of characters or click on the arrow for more options. The characters are animated and each have their own strengths.

Figure 3: Letter exchange at the start

Figure 4: Map of the town. This map was taken from: http://www.gameinformer.com/blogs/members/b/warbuff_blog/archive/2010/12/21/vacationing-in-video-game-land.aspx

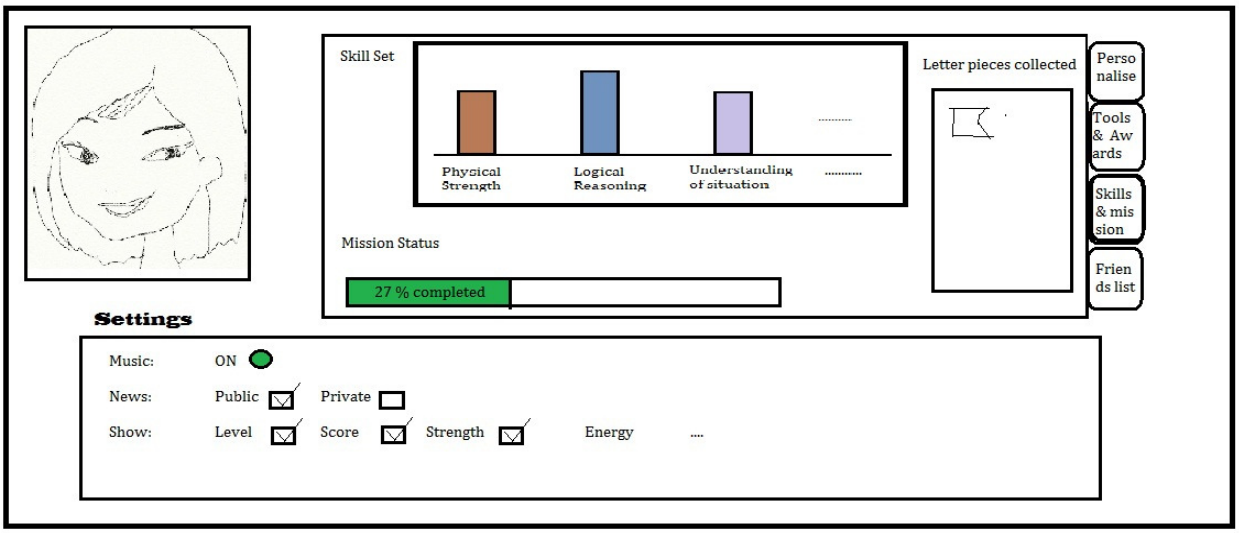

Figure 5: User Profile. The user can tab between personalising their character, viewing items they have collected, viewing a summary of their skills and mission progress, as well as personalising their friends list. They can also adjust the settings of their account.

Figure 6: Single player mode. Players can tab between the game, chat and friends list. Depending on the player's preferences, the score and energy meter would also be displayed, as well as the available tools to build the bridge. In higher levels, critters would be wandering around making it more challenging to complete the task. Scene taken from: http://www.123rf.com/photo_202610_a-river-flowing-in-the-forest-surrounded-by-trees-and-bushes.html

Figure 7: Multiple player mode. Players can see who is currently playing and chat while playing. Here, too, the score and energy meter of the player will be displayed only to the relevant person. This scene was taken from: http://www.downextra.com/n/Natalie+Brooks+-+Secrets+of+Treasure+House.html

Figure 8: Butterfly Room game. As the temperature drops, hungry creatures emerge, threatening the ecosystem and the livelihood of the butterflies. The player should also see the thermometer and ways to control the temperature, as well as the score and energy meter of the player. Scene taken from: http://www.brothersoft.com/flowers-and-butterflies-277733.html

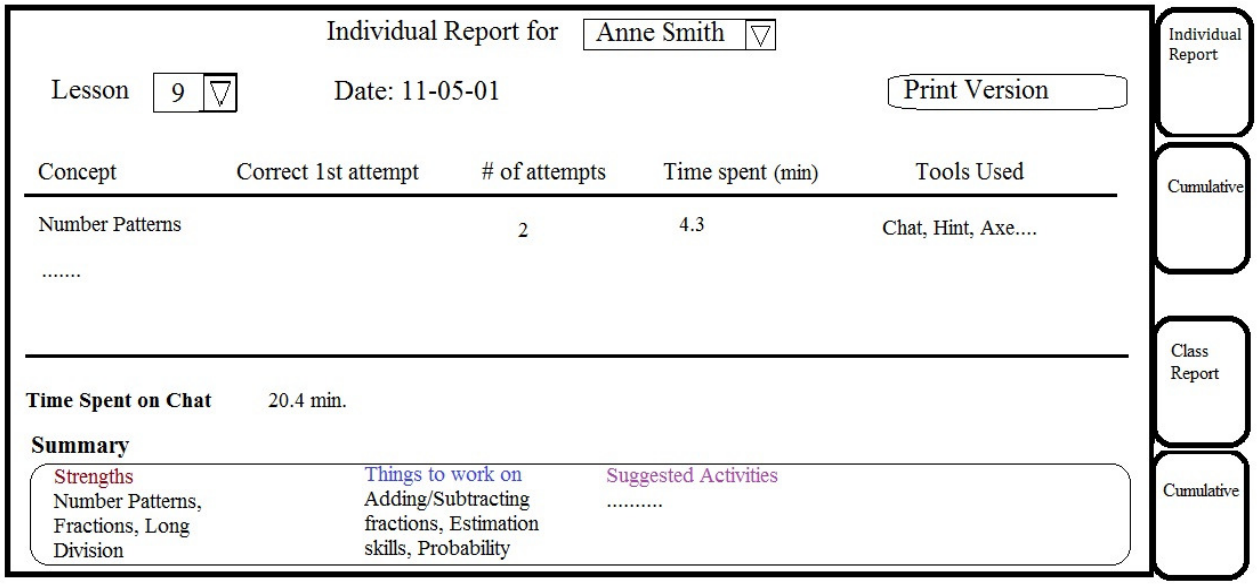

Figure 9: Teacher Reporting Tool. This figure is showing individual student's assessment of lesson 9, but can choose another lesson from a drop down menu. The teacher can also choose to see another student's report by looking through the drop down menu of all the available students in the class. Statistics about performance and a summary of strengths and weaknesses is also shown. The teacher can tab between other views, such as a cumulative view for an individual student, or the entire class report.

Appendix D. Game Comparison Chart

The following chart shows how various games (both COTS and SG) meet the ideal features that an SG should have based on the framework (section VI) and lessons learned from other games (section VIII). 'X' indicates strong agreement, '\' marks that it is somewhat true, while no marking suggests no agreement.

Ideal features	World of War Craft	The Sims	Quest Atlantis	Lost Mind of Dr. Brain	Maths Garden	Darfur is Dying	Amanita Design	Messenger Quest
Multimodality & interactivity	X	X	X	X	X	X	X	X
User control	X	X	X	X	\	\	\	X
Modding		X						X
Challenge	X	X	X	X	\	\	X	X
Clear goal	X		\	X	X	\	X	X
AI to tailor content and level								X
Rewards & feedback	X	X	X	X	\	\	\	X
Social network	X	X						X
Multiplayer mode	X	X						X
Assistance	X	X	X	X				X
Good graphics	X	X	X	X	X	X	X	X
Good narrative	X			X		\	\	X
Rich virtual world	X	X	X	X		\	X	X
Fresh gaming experience	X	X	X				\	X
Discovery based, active learning	X	X	X	\				X
Implicit teaching	X	X	\	X		\		X
Appropriate for school		X	X	X	\	X	\	X

While World of Warcraft (WoW) and The Sims showed great potential, the content of WoW is not appropriate for school or the target age group. The Sims has been used in education, but is not the best tool to practice math skills. The better examples of serious games, such as Quest Atlantis and Lost Mind of Dr. Brain are impressive, but have room for improvement. Maths Garden, Darfur is Dying and Amanita Design, while have a lot of merit have only a few gaming elements, rendering them less appealing and beneficial. Messenger Quest is an example of how the ideal features of an SG can come together in a game that is not only fun for fourth graders, but for a wide age range.