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A Gaming Perspective on Mathematics Education

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ABSTRACT

This article explores how motivation in computer games could be integrated into mathematics education. The scope of the study was confined to four motivation dimensions, namely challenge, control, complexity and collaboration. A phenomenology study was conducted with the purpose to obtain a common understanding of nine teachers and 11 students about mathematics education, particularly focusing on teaching practices and learning difficulties in mathematical problem-solving. Qualitative interviews have revealed that the existing mathematics education is built on drill-and-practice approach with Polya's problem-solving technique, i.e. exam-oriented, rote memorization and the use of predefined strategies. This approach to learning has failed to motivate students to learn (affective) and failed to develop an understanding and creativity (cognitive/metacognitive). Looking from a gaming perspective, mathematics problems should be challenging and complex, and students should be given control to carry out a plan. And finally, collaboration should be encouraged to enable reflective learning.

KEYWORDS

Challenge, Collaboration, Complexity, Computer Games, Control, Mathematics, Motivation, Problem-Solving

INTRODUCTION

In Asian countries, mathematics has been taught using a didactic method. It is primarily in the form of drill-and-practice and repetition of instructions (Li, 2006). Mathematics is exciting and challenging. Yet, many children find it dull and boring. Children tend to be negative, less motivated towards mathematics and not confident in solving complex and challenging mathematical problems (Awanta, 2009; Kislenko, 2006). Despite this, children are drawn to and able to solve sophisticated problems in computer games (Papert, 1998; Prensky, 2001). It is really impressive to see children as young as seven to play complicated games, e.g. Yu-Gi-Oh that involves complex language, vocabulary, and thinking skills (Gee, 2008). Computer games could motivate children to learn and go through consecutively more challenging tasks in the games, voluntarily and successfully. It would be interesting to look at how these games engage children in addressing various problems, and how these motivations could be incorporated into mathematics education.

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The research question addressed in this study was: how mathematics education could be improved by understanding the motivation of gaming? Three operational research questions were derived to govern the research process:

1. What were teachers' perceptions and teaching practices in mathematics education?
2. What were students' perceptions and learning difficulties in mathematics education?
3. How mathematical problem-solving was related to the motivation in computer games?

In this study, data about gaming was drawn from the literature so no experiment was conducted in this area. Firstly, a review of the literature was conducted to understand mathematical problem-solving and motivation in computer games. Then, qualitative interviews were conducted to understand the existing mathematics education in schools. Finally, the author tried to compare and integrate the game motivation into every stage of mathematical problem-solving.

LITERATURE REVIEW

Mathematical Problem-solving

Problem-solving is one of the fundamental human cognitive processes that plays a significant role in mathematics education. Mathematical problem-solving approach is fundamentally built on the Polya's (1945) four-stage model:

1. **Understand the Problem:** Problem-solving should be driven by a deep interest in understanding what is required by the problem (Polya, 1945). The approach to problem-solving depends on how people understand the problem (Sternberg, Sternberg, & Mio, 2012);
2. **Devising a Plan:** A problem solver has to plan at least in outline, which calculations or constructions to be performed in order to obtain the unknowns (Polya, 1945). A plan is how various items are connected and how the unknowns are linked to the data to obtain the idea towards a solution;
3. **Carrying out the Plan:** A problem solver should control and self-regulate to keep track and carry out the plan;
4. **Looking Back:** A problem solver has to reexamine the complete solution to consolidate his/her knowledge (Polya, 1945). Mistakes are inevitable so metacognitive skills such as reflection and evaluation are required for effective learning (Yimer & Ellerton, 2006).

The use of Polya's (1945) four-stage model alone could not automatically lead to a solution of a mathematics problem (Orton, 2004). There is a debate of whether mathematics should be taught using drill-and-practice or with an understanding or creativity (Davis, 1990). The drill-and-practice approach is a deeply rooted traditional way of teaching mathematics. Students are told what to do and how to do, and then followed by substantial amount of drill-and-practice (Davis, 1990). This approach is grounded on the assumption that people can become experts through imitation and practice repeatedly (Li, 2006). The primary focus of drill-and-practice is to memorize a routine algorithm (Davis, 1990). In this case, students do learn mathematics, but they learn to memorize a collection of procedures that are useful for certain purposes (Romberg & Kaput, 1999). It is similar to learning to match the right collection of procedures to a specific problem without looking at the reasoning behind the procedures. Routine practice involves the deployment of a set of routine that does not require creativity, guesswork or discovery (Romberg & Kaput, 1999). It is an effective way to foster retention in the memory (Orton, 2004). Here, mathematics is perceived as a fixed and static body of knowledge because it involves only the mechanistic manipulation of numbers, algebraic symbols and proving of geometric deductions (Romberg & Kaput, 1999). This approach might be useful to solve routine problems, but not non-routine problems. The drill-and-practice approach to mathematics learning is a controversial issue.

Mathematics is not simply a body of knowledge, it is also a creative activity that involves both process and product (Orton, 2004). A creative approach is necessary because mathematics is too complex to be learned merely through rote or routine procedures that are dull, demotivating and not helping students to develop their analytical thinking skills (Davis, 1990). Problem-solving is not a routine process because each problem should have a certain level of novelty that requires learners to be creative (Orton, 2004). If learners can easily solve a mathematics question using rote, then the problem does not exist or the problem is routine. Polya's (1945) four-stage model provides a general guideline on how to proceed in problem-solving, but if students do not understand a particular lesson, they will learn the routine problem-solving as an isolation skill that cannot be applied or extended to new and unfamiliar problems (Polya, 1945). Thus, one of the major difficulties faced by the students is to transfer knowledge learned to solve a new problem. Knowledge transfer is hard when students could not relate what they have learned to a bigger picture.

Motivation in Gaming

In computer games, players can transfer the prior knowledge to mix with an innovation to enable problem-solving of new challenges (Hamari et al., 2016; Hou & Li, 2014). They are mastery-achievement oriented in which they are interested in learning for its sake and understanding. Intrinsic motivation is built on inner psychological needs that can prolong the passion for learning effectively. The three innate psychological needs for competence, relatedness, and autonomy are used to understand what and why someone pursues a goal (Deci & Ryan, 2000). Good computer games are built on the psychology needs: (1) competence - give power to players to test and experience; (2) autonomy - provide alternatives that allow creativity, audacity and exploration; (3) relatedness - foster socialization and communication (Denis & Jouvelot, 2005). To satisfy players' innate psychology needs, intrinsic motivations can be fostered through challenge (Hou & Li, 2014; Liu, Cheng, & Huang, 2011), complexity (Akcaoglu & Koehler, 2014; Yang & Chang, 2013), control (Hou & Li, 2014; Qian & Clark, 2016; Yang & Chang, 2013) and collaboration (Girvan & Savage, 2010; Hamalainen, 2008; Sung & Hwang, 2013; Vos, van der Meijden, & Denessen, 2011). The four motivation dimensions are game design elements (Qian & Clark, 2016).

Challenge

Challenge is defined as "the degree to which individuals finds it difficult to cope with specific tasks involved" (Shin, 2006, p. 3). The challenge of effective games should match with players' growing abilities to facilitate continued learning in game-based learning environments (Hamari et al., 2016; Hou & Li, 2014). If the challenge is easily achievable, players may get bored; if the challenge is too tough and unachievable, players may give up and worry (Hou & Li, 2014). The challenge in computer games works on the principle of hard fun, in which fun and life-enhancing because it is hard and challenging (Gee, 2007; Papert, 1998). Computer games are fun because they are challenging.

Complexity

High quality games possess complex problems. Cognitively complex problems are used to engage players more deeply, and hopefully to facilitate the learning of complex strategies and significant problem-solving skills (Hamari et al., 2016). Popular games such as *FIFA, The Sims* and *Candy Crush* require not only complex problem-solving skills but also concentration, logical thinking and multitasking skills. The complexity of games generates perceptual curiosity and motivates players to explore the games (Hamari et al., 2016). Past studies have shown that engaging students in games-design facilitates complex knowledge construction (Akcaoglu & Koehler, 2014; Yang & Chang, 2013).

Control

According to De Charms (as cited in Wishart, 1990, p. 141), "man is motivated primarily by a desire to produce changes in his environment, that is to say to control it." Control is a factor of flow experience in game-based learning, i.e. when players enjoy playing games, they can control the quality of their experience (Hou & Li, 2014). People will feel motivated and empowered if they feel that they are in control because it satisfies the innate psychological need for autonomy. In gaming, players are motivated to play because they have control over the game characters and decision making. Players who experienced a greater sense of control would perceive higher levels of the ease of use (Hou & Li, 2014). Engaging students in games-design promotes self-control of learning and thinking (Yang & Chang, 2013). The motivation in games comes from being able to learn effectively and exert some control over the games' outcome.

Collaboration

Collaboration satisfies the innate psychological need for relatedness. Relatedness can be fostered in collaborative groups and teamwork (Hamalainen, 2008; Sung & Hwang, 2013; Yang & Chang, 2013). Games built on situated learning place a strong emphasis on the social context, and knowledge is constructed through participation in the learning communities (Girvan & Savage, 2010; Hamalainen, 2008; Sung & Hwang, 2013). For instance, in role-playing games, a player can feel the sense of belonging in virtual world communities and relatedness to other players. The player may also feel deeply connected to the game characters for adoring and respecting their powers and capabilities.

METHOD AND DATA COLLECTION

This is a phenomenology study of a sample of 20 participants from five secondary schools in Malaysia. The sample was recruited through purposive and snowball sampling. The author specified the characteristics of the population of interest and locates key informants she felt will yield the best understanding of what she was studying, i.e. senior mathematics teachers and male/female students. Though the decision could be wrong, almost all qualitative researchers use purposive sampling because random sampling normally is not feasible (Fraenkel & Wallen, 2006). After that, the key informants (i.e. the senior mathematics teachers and students) recommended and led the author to other teachers and students based on their knowledge of who would be the best to help in the research area. Nine mathematics teachers and 11 students were recruited. The recommended sample size for phenomenology studies is approximately six participants (Mertens, 2010), which is smaller than other qualitative research methods. In qualitative research, there is no exact sample size that is considered as appropriate, but it depends on the purpose of a study (Cohen, Manion, & Morrison, 2007; Patton, 1987). This study aimed to explore the perspectives of a few individuals in greater depth to obtain rich information about their worldviews in mathematics education. The author did not attempt to generalize the results beyond the population pool. According to Creswell and Plano Clark (2011), the use of a small sample size in qualitative research is not a problem because the intention of collecting the data is to seek an in-depth understanding of a few people. Teachers' and students' perceptions were explored through standardized open-ended interviews structured around three major themes - demographic information, teaching methods, and students' performance and attitudes in learning mathematics. The interviews were useful to understand what the participants were thinking and why they thought what they did.

RESULT AND DISCUSSION

The findings of this study are discussed in two major sections (1) the existing mathematics education, and (2) the comparison of problem-solving methods in mathematics and computer games.

Mathematics Education

To teach problem-solving skills, most of the mathematics teachers present some kind of strategy, modeled after Polya's (1945) four-step process. The impact of Polya's works in mathematics education is remarkable. Three teachers said:

Understand the problem, do proper sketching; we need to draw a simple diagram to understand yes, they do. Then write down your equation and then solve it and check your answer.

We ask them to read question at least more than 3 times. And then try to identify what are the information given. Then try to plan out the strategy. What formula to be used. What have to find. Step-by-step.

They have to understand the question, and then they have to identify what is required by the question. I will ask them to underline the important points. Identify the formula and solve it. Finally, check using a calculator.

In the first phase of understanding the problem, students are advised to read the question for at least three times. In this stage, students need to understand what is required by the question based on the information given and highlight the important points. During the second phase of devising a plan, students should plan their strategy (e.g. do proper sketching or diagram) and identify the formula to be used. The third phase is to implement the plan. Finally, the fourth stage is looking back, and students are advised to check their answers, e.g. using a calculator. The four processes are linked to Bloom's Taxonomy (Krathwohl, 2002) – remembering (recall a formula), understanding (comprehend the question), applying (solve the problem), analyzing (draw a diagram), evaluating (check the validity of the answer) and creating (construct a strategy). Despite this, students' interviews have revealed some challenges and difficulties in learning mathematical problem-solving (see Table 1).

The findings in Table 1 have shown that teaching Polya's problem-solving technique alone is inadequate to develop interest (affective), and understanding and creativity (cognitive/metacognitive)

Table 1. Theme – students' learning difficulties

Code	Students' Participants
Cognitive/ Metacognitive	● When it comes to all those higher order thinking kinds of questions… So it takes me quite some times to understand. So, it's a struggle. ● Yes struggle quite a lot… one thing I notice about Maths… All are patterns… As long as I understand the pattern, I can catch up. ● I am not very good with diagrams (visual-spatial). ● Drawing graph… I am not good at finding how to do draw it (visual-spatial). ● Confusing because it involves many unknowns so my head is very confuse seeing the question (analysis). ● I find it hard… carelessness…That can lead to answer wrong (evaluation). ● Expose us to the questions that students commonly cannot answer or the mistakes that students usually do (evaluation).
Affective	● Maths is interesting and fun and challenging… Is just that, it is not shown to me in a fun way. Mostly is too bored. ● Boring… when I cannot understand the method. But I find it interesting when I understand fully the whole method. ● When it comes to exercises, it has to be a challenging. ● I prefer Add Maths to Modern Maths because Add Maths is more challenging and requires more thinking. Thinking a lot. ● When I don't find something fun, I lose focus. Then I won't be able to understand it that easy.

in mathematics. Many mathematics non-routine problems do not automatically lead to a solution by applying the technique. To solve non-routine problems, metacognitive skills and higher order thinking skills (HOTS) are important to develop mathematical thinking skills (Mayer, 1998). HOTS and metacognitive skills could help students to apply what they have learned to a new unfamiliar problem.

The Comparison of Problem-Solving Methods in Mathematics and Computer Games

In this section, the author has attempted to connect the Polya's four stage plan for problem-solving with computer games. In some cases, the problem-solving approach that is offered by gaming is different from the Polya's four stage plan. The discussion compares the learning context in a regular mathematics classroom and gaming environment, and draws out the similarities and differences. This will allow the identification of good practices in gaming that could be used in the mathematics classroom for improvement (see Figure 1).

Understand the Problem

Before solving a problem, students need to have a genuine interest (affective) in them, and the capability to understand (metacognitive) the context of the problem. Teachers' interviews have revealed that students lack of interest in learning mathematics and are weak in certain mathematical skills.

Table 2 has shown that teachers' major concerns are circled around learning interest and assessment. The teachers have asserted that students are trained to be exam-oriented, and they could perform well through drill-and-practice. The teachers have characterised their students as field dependent or performance achievement oriented learners because they do what is asked and only learn what is needed to achieve the performance. The finding has implied that the existing formal education in schools has failed to support transfer of knowledge and learning of HOTS. Mathematics requires understanding and application of mathematical processes to enable transfer of knowledge.

Gaming Perspective

In computer games however, learning is transferable. Games usually provide proper guidance and practice to ensure that the knowledge learned is transferable. In a single game, players are required to use the skills and strategies gained from the previous level, and the knowledge is often applicable to

Figure 1. Integration of motivation in computer games and mathematical problem-solving steps

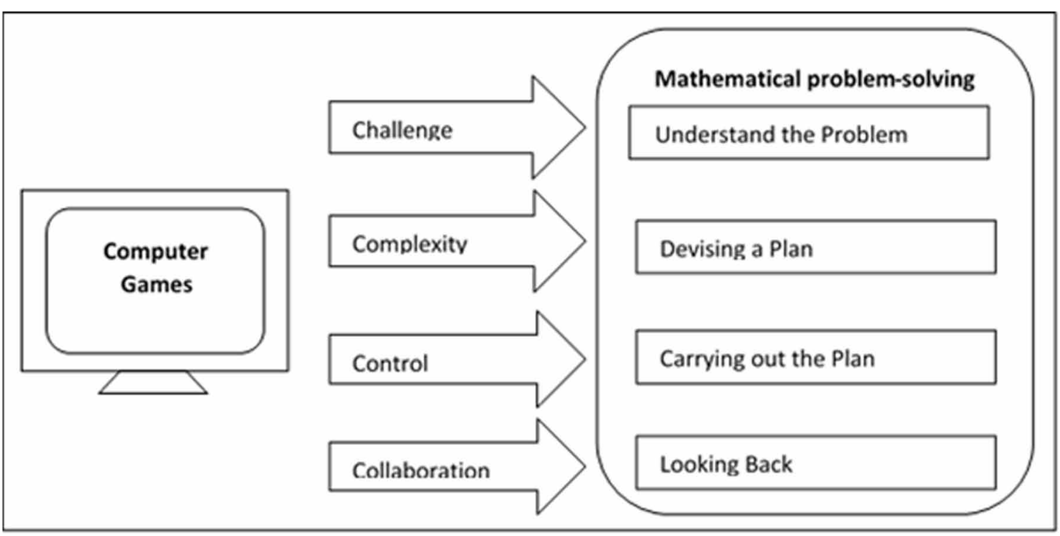

Table 2. Theme – affective and metacognitive

Code	Teachers' Participants
Affective (Interest)	• They do not like mathematics because they do not like numbers. • Some can say a little phobia about numbers. • They see a long story, the problem-solving question… they will just give up. • Some of them are not really interested in maths. • Most of them have no interest. • They easily give up, no patience in solving. • For those who are not interested, they only do what is required.
Affective (Exam-oriented)	• I think most of them study for the sake of exam. • They are exam-oriented. • We need to train the students, prepare students for the exam. • One (exam) paper…they don't emphasise the working, they emphasise the answer. • We need to drill the students to do pass year questions. • They study for the sake of achieving a good result.
Metacognitive (Application/Transfer of knowledge)	• Students are lack of exposure in problem-solving or application questions. • They know what it means, but application wise they have a little bit trouble. • Transfer the information - that is what they can't. • Our syllabus more of just maths only… Very few topics got application daily life.
Metacognitive (HOTS)	• We have not really train the students… Before that we are not talking about higher order thinking skill. • They won't be able to think in deep. • Very few HOTS… certain topics none of the HOTS question, just using formula. • I think only 20% of them use their brain to do analytical thinking… They do not have analytical and logic thinking. • They are using calculator…indirectly their logical thinking will be very very low.

other games or the entire genre. The challenges in games are new and unpredictable (i.e. non-routine), yet the players see the underlying similarities and differences between previous gaming experience and the current problems in the games. HOTS are required to play computer games, e.g. strategy and simulation games (Hung & Van Eck, 2010). In computer games, players are learning HOTS naturally without external force. Moreover, computer games are motivating and enjoyable. Computer games usually draw players' interest and curiosity by giving novel surprises. The uncertainties in games stimulate players to play and discover more (mastery achievement oriented learners). Curiosity and playfulness are human nature because people love to know the answer to everything (Stafford, 2012). The curiosity will drive the desire to play and this will create a fun and interesting experience (Denis & Jouvelot, 2005). When the players' curiosity has been satisfied by overcoming challenges in the games, it creates a positive and pleasant experience.

Devising a Plan

During planning, a problem solver has to strategize which computations to be performed in order to obtain a solution. Teachers' interviews have revealed that predefined strategies are taught by giving step-by-step examples.

Table 3 has shown that direct instruction of predefined strategies is a deeply rooted traditional way of teaching mathematics. Teachers will explain a concept by giving a few step-by-step examples, and students are expected to practice the predefined procedures until they have mastered the concept. Mathematics in this sense is portrayed as tedious, monotonous route to follow and a lot of problems to clear (Romberg & Kaput, 1999). In particularly, a teacher will begin a lesson by giving some examples and then followed by more exercises. Students are expected to follow a step-by-step predefined strategy laid down by the teachers.

Table 3. Theme – predefined strategies

Code	Teachers' Participants
Example	• I still prefer showing more examples on the board. • Our syllabus is more rigid. Students learn whatever taught by the teachers. • They won't use their own strategy… wait for teacher's answer. • Give the basic first then example…Then drill them through exercise. • After I teach, I give a few examples. I let my students to do exercise.
Step-by-step/ straightforward	• I am more straightforward… Explain the step by step. • I will encourage them to do it step by step. • Our questions are more straightforward to the point… when they are asked, they can answer. • When you are talking about something different situation (not straightforward)…definitely they cannot. • Students are quite straight. They don't see can modify the question to get the final answer. • Some students are overcomplicating. For simple (straightforward) questions, they are thinking too much.

Gaming Perspective

In computer games however, there are no predefined step-by-step strategies to win the games. Players are free to adopt any strategies that they think will work through trial-and-error. The players can learn and progress by testing a hypothesis, taking a risk and reflecting on the mistakes (Gee, 2007). Each player has a unique strategy, and they are learning by making mistakes. Game strategies are complex, informal, natural and flexible. According to Martinovic et al. (2014), there are 23 cognitive elements found in computer games, e.g. mental mathematics, problem-solving, planning and selective attention. Challenging and interesting games do not repeat the same pattern of problem again and again (as in route learning).

Carrying Out the Plan

During implementation, a problem solver has to control and self-regulate to keep track of the plan. Teachers' interviews have reviewed that routine practice is the main approach used.

Referring to Table 4, teachers strongly believe that routine practice is the best way to learn mathematics because they believe in practice makes perfect. Here, the practice is a form of behaviorist learning theory. Given a particular type of mathematics question (stimuli), one then uses the predefined method or formula that matches the question (response). The students only have to memorise the appropriate response to the observed stimuli. Routine practice does not support understanding and

Table 4. Theme – routine practice

Code	Teachers' Participants
Practice	• They are drilled repeatedly… they have to keep on practising with many exercises. • Definitely mathematics there is a lot drill for that. • More practice and more actual practice. So they do more questions per day. • You have to do a lot of exercises. • First they need more practice and second, understand the concept. • Very simple…They just have to do exercise that's all. • Succeed in math mean they just have to learn how to solve problem and do more practice. • They supposed to be exposed with more real life problem-solving exercises.
Memorization	• So many things to remember, so many concepts to apply, so they cannot cope. • If students want to excel in exams, they just have to memorize. • Now, the Form 1 students can't even memorize the multiplication table. • So they memorize even number, odd number, even number, like that.

creative thinking. Even so, the teachers have to spend most of the time re-teaching and providing routine practice because the school is exam-oriented.

Gaming Perspective

In computer games however, the nature of practice is different. Practice in games is a form of experiential learning. Knowledge is constructed from user-centered practice and reflection of concrete experience (Fenwick, 2001). In games, knowledge is usually not conveyed explicitly. For instance, in shooting games, there is no manual given on how to be a good shooter. The player has to learn by exploring the games. If a player can figure out the opponent's pattern of movement, the player can anticipate where he (opponent) will go so that the player has a better shot at him (opponent). The player has to discover the knowledge through practice and control of the game characters. In games, knowledge and understanding are internalized through continuous practices. The learning is a cyclic process in which cognitive structures are constructed through practice in the game world (Kiili, 2005). Players are in control of the game characters, and have full grasp of the strategies contained in the games.

Looking Back

In the final stage, a problem solver has to re-examine the complete solutions. Teachers' interviews have revealed that students are facing difficulties in checking their own works.

Referring to Table 5, teachers have mentioned that students could not reflect on what they have calculated or learnt. It is interesting to see the difference in perspectives between educators and learners. The teachers expect students to do self-reflection while the students expect teachers to provide them with individual feedbacks and guidance (see Table 1). For the teachers, they may not have sufficient time to pay attention to individual student due to time constraint to complete the syllabus and heavy workload in schools. It is difficult to achieve such a personalized attention in a conventional classroom teaching that normally has a large number of students in one class.

Gaming Perspective

Computer games however are responsive to players' needs. The responsiveness in games enables players to learn from feedbacks. The players subconsciously reflect on what they have done and observe the feedback about the success or failure of the action (Gee, 2007). The players are taking an active role to reflect on lives experiences constructed through activity in the game world or virtual social interaction. Consequently, the gaming experiences rely on players' interactions with the gaming environment and the responses of other players (Feinstein, Mann, & Corsun, 2002). Other players could help them to reflect on what they have done, and even offer them with helps. For instance, in massively multiplayer online role-playing games (MMORPG), social interaction is important because

Table 5. Theme – reflection

Code	Teachers' Participants
Reflection	• Check your answer. I do emphasize that. Some will follow, some will not follow. Depending whether they are lazy or not. • They have no common sense… X is length. They calculate, calculate, calculate. They got -8 so that is the answer. Is it logical (negative length)? They cannot reflect whether the answer is logical or not. • That's it is very hard for us to make them to do our exercise, they end up copying. They don't know what they copy also (no reflection). • For easy question, they feel it is too easy. So, they are not certain whether it is right or wrong (poor reflection).

the players are helping each other to succeed by offering and receiving assistance. Computer games support relatedness through cooperation, friendship and social reinforcement. Players are connected and related to other players who share the same interest and this forms a sense of belonging.

CONCLUSION

Looking from a gaming perspective, drill-and-practice approach to learning is analogous to edutainment. Edutainment is built on behaviorist learning theory and the game encourages learners to drill-and-practice more to response correctly to a sequence of stimuli (Egenfeldt-Nielsen, 2007). In the carrot and stick approach, learning is achieved through training and rote memorization (Charsky, 2010; Egenfeldt-Nielsen, 2007). Edutainment usually starts with the delivery of content knowledge and follows by some exercises to reinforce the knowledge learned. The game forces learners to go through a linear progression (Denis & Jouvelot, 2005). Edutainment is claimed to be the worst type of education (Charsky, 2010; Van Eck, 2006) because it drills-and-kills learning (Van Eck, 2006). Education is seen as a suffering that is compensated for with sugar-coated entertainment (Resnick, 2004). Obviously, edutainment that is built on external motivation is neither educating nor entertaining. In contrast to edutainment, understanding or creative approach to learning is analogous to commercial off-the-shelf (COTS) games. To play the games, one needs to have complex language, vocabulary, and mental abilities, e.g. cognitive and metacognitive skills. "Modern video games have evolved into sophisticated experiences that instantiate many principles known by psychologists, neuroscientists, and educators to be fundamental to altering behavior, producing learning, and promoting brain plasticity" (Green & Seitz, 2015). Children nowadays are very keen and excited to solve these sophisticated problems in COTS games (Papert, 1998; Prensky, 2001). COTS games that are characterized as challenging, complex, controllable and collaborative to foster problem-solving skills and develop both an understanding and creativity.

Learning from COTS games, mathematics should be taught with an understanding or creativity. Firstly, to motivate students to understand the problem, it is crucial to engage students' interest rather than using extrinsic motivation, e.g. exams. Like COTS games, the problems should be challenging and non-routine. The difficulty of the problems should be within the students' regime of competence, whereby they feel the challenge but achievable within their mental capabilities; or else the students would be frustrated and give up because the challenges are beyond their grasp. Likewise if students solve only routine problems, they would fail to develop creativity and new cognitive or metacognitive skills. Secondly, to motivate students to devise a plan, it is crucial to stimulate students' curiosity. Like COTS games, the problems should be complex, i.e. not simply require step-by-step and predefined strategies, but complex and creative strategies. The complexity of the problems stimulates curiosity in students and this motivation can be relieved by specific exploration of the stimulus. To support students' cognitive processes, the complexity of the problem should be increased gradually and this requires progressive construction of complex strategies. To draw students' curiosity, novelty and innovation should be included in the problem. Thirdly, to motivate students to carry out the plan, it is crucial to give autonomy to the students. Like COTS game, control should be given to enable self-regulation in keeping track and carrying out the plan, i.e. not follow strictly and memorize the appropriate responses for a given stimuli through routine practice. The students having the need to feel in control of the strategies that could lead to a solution. The capacity of the problem should be appropriate to support optimal cognitive processes so that the students are able to monitor the feasibility and accuracy of the solution. And finally, to motivate students to look back, it is crucial to provide feedbacks to the students. Like COTS game, collaboration should be encouraged in learning. For instance, peers interaction could help students to reflect on what they have done, and observe the feedback about the success or failure of the plan (action-and-reflection). Students should take an active role to discover and reflect on their problem-solving experiences, then interpret and generalize these experiences to form mental structures. In this study, the author has tried to draw a new teaching strategy out of COTS games instead of edutainments. Even though edutainments fit well into the teachers' current teaching practices, the games merely replicating the existing drill-and-practice in schools. In contrast to edutainments, COTS games provide a new perspective to look at mathematics education. This study has laid down a general principle on how to teach mathematical problem-solving skills effectively. The principle however should be further tested in the actual classroom settings.

REFERENCES

Akcaoglu, M., & Koehler, M. J. (2014). Cognitive outcomes from the Game-Design and Learning (GDL) after-school program. *Computers & Education*, *75*, 72–81. doi:10.1016/j.compedu.2014.02.003

Awanta, E. K. (2009). Students' Views of Mathematics: A Survey of Junior and Senior High Schools in the Ashanti and Brong Ahafo Regions. *Ghana Policy Journal*, *3*, 90–109.

Charsky, D. (2010). From Edutainment to Serious Games: A Change in the Use of Game Characteristics. *Games and Culture*, *5*(2), 177–198. doi:10.1177/1555412009354727

Cohen, L., Manion, L., & Morrison, K. (2007). *Research Methods in Education* (6th ed.). New York: Routledge.

Creswell, J. W., & Plano Clark, V. L. (2011). Designing and conducting mixed methods research. Applied Linguistics (2nd ed., Vol. 2). USA: Sage Publications, Inc.

Davis, R. B. (1990). *Learning mathematics: The cognitive science approach to mathematics education*. New Jersey: Ablex Publishing Corporation.

Deci, E. L., & Ryan, R. M. (2000). The "What" and "Why" of Goal Pursuits: Human Needs and the Self-Determination of Behavior. *Psychological Inquiry*, *11*(4), 227–268. doi:10.1207/S15327965PLI1104_01

Denis, G., & Jouvelot, P. (2005). Motivation-driven educational game design: applying best practices to music education. In *Proceedings of the 2005 ACM SIGCHI International Conference on Advances in computer entertainment technology - ACE '05* (pp. 462–465). Valencia, Spain: ACM. doi:10.1145/1178477.1178581

Egenfeldt-Nielsen, S. (2007). Third generation educational use of computer games. *Journal of Educational Multimedia and Hypermedia*, *16*(3), 263–281.

Feinstein, A. H., Mann, S., & Corsun, D. L. (2002). Charting the experiential territory: Clarifying definitions and uses of computer simulation, games, and role play. *Journal of Management Development*, *21*(10), 732–744. doi:10.1108/02621710210448011

Fenwick, T. J. (2001). *Experiential Learning: A Theoretical Critique from Five Perspectives. Information Series No. 385. Experiential Learning: A Theoretical Critique from Five Perspectives*. Ohio: ERIC Publication. Retrieved from http://eric.ed.gov/?id=ED454418

Fraenkel, J. R., & Wallen, N. E. (2006). *How to Design and Evaluate Research in Education* (6th ed.). Boston: McGraw-Hill.

Gee, J. P. (2007). *What Video Games Have to Teach Us About Learning and Literacy*. England: Palgrave Macmillan.

Gee, J. P. (2008). Learning theory, video games, and popular culture. In K. Drotner & S. Livingston (Eds.), *The International Handbook of Children, Media, and Culture* (pp. 196–212). Los Angeles, CA: Sage. doi:10.4135/9781848608436.n13

Girvan, C., & Savage, T. (2010). Identifying an appropriate pedagogy for virtual worlds: A Communal Constructivism case study. *Computers & Education*, *55*(1), 342–349. doi:10.1016/j.compedu.2010.01.020

Green, C. S., & Seitz, A. R. (2015). The Impacts of Video Games on Cognition (and How the Government Can Guide the Industry). *Policy Insights from the Behavioral and Brain Sciences*, *2*(1), 101–110. doi:10.1177/2372732215601121

Hamalainen, R. (2008). Designing and evaluating collaboration in a virtual game environment for vocational learning. *Computers & Education*, *50*(1), 98–109. doi:10.1016/j.compedu.2006.04.001

Hamari, J., Shernoff, D. J., Rowe, E., Coller, B., Asbell-Clarke, J., & Edwards, T. (2016). Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning. *Computers in Human Behavior*, *54*, 170–179. doi:10.1016/j.chb.2015.07.045

Hou, H.-T., & Li, M.-C. (2014). Evaluating multiple aspects of a digital educational problem-solving-based adventure game. *Computers in Human Behavior*, *30*, 29–38. doi:10.1016/j.chb.2013.07.052

Hung, W., & Van Eck, R. (2010). Aligning problem solving and gameplay: A model for future research and design. In *Interdisciplinary Models and Tools for Serious Games: Emerging Concepts and Future Directions* (pp. 227–263). Hershey, PA: IGI Global. doi:10.4018/978-1-61520-719-0.ch010

Kiili, K. (2005). Digital game-based learning: Towards an experiential gaming model. *The Internet and Higher Education*, *8*(1), 13–24. doi:10.1016/j.iheduc.2004.12.001

Kislenko, K. (2006). Structuring students' beliefs in mathematics: A Norwegian case. In K. Hoskonen & M. S. Hannula (Eds.), *Current State of Research on Mathematical Beliefs XII. Proceedings of the MAVI-12 Workshop*. (pp. 45–57). Helsinki: University of Helsinki.

Krathwohl, D. R. (2002). A Revision of Bloom's Taxonomy: An Overview. *Theory into Practice*, *41*(4), 212–218. doi:10.1207/s15430421tip4104_2

Li, S. Q. (2006). Practice Makes Perfect: A Key Belief in China. *Mathematics Education in Different Cultural Traditions-A Comparative Study of East Asia and the West*, *9*, 129–138. doi:10.1007/0-387-29723-5_8

Liu, C.-C., Cheng, Y.-B., & Huang, C.-W. (2011). The effect of simulation games on the learning of computational problem solving. *Computers & Education*, *57*(3), 1907–1918. doi:10.1016/j.compedu.2011.04.002

Martinovic, D., Ezeife, C. I., Whent, R., Reed, J., Burgess, G. H., Pomerleau, C. M., & Chaturvedi, R. et al. (2014). "Critic-proofing" of the cognitive aspects of simple games. *Computers & Education*, *72*, 132–144. doi:10.1016/j.compedu.2013.10.017

Mayer, R. (1998). Cognitive, metacognitive, and motivational aspects of problem solving. *Instructional Science*, *26*(1), 49–63. doi:10.1023/A:1003088013286

Mertens, D. M. (2010). *Research and Evaluation in Education and Psychology. Research and Evaluation in Education and Psychology* (3rd ed.). United States: Sage Publications, Inc.

Orton, A. (2004). *Learning Mathematics: Issues, theory and classroom practice*. London: Bloomsbury Publishing.

Papert, S. (1998). Does easy do it? Children, games, and learning. *Game Developer*, *5*(June), 1–5.

Patton, M. Q. (1987). *How to use qualitative methods in evaluation* (Vol. 4). Newberry Park, CA: Sage Publications.

Polya, G. (1945). *How to Solve It: a new aspect of mathematical method*. Princeton, NJ: Princeton University Press.

Prensky, M. (2001). Fun, Play and Games: What Makes Games Engaging. In Digital Game-based Learning (pp. 5-1-05–31). McGraw-Hill.

Qian, M., & Clark, K. R. (2016). Game-based Learning and 21st century skills: A review of recent research. *Computers in Human Behavior*, *63*, 50–58. doi:10.1016/j.chb.2016.05.023

Resnick, M. (2004). Edutainment? No Thanks. I Prefer Playful Learning. *Associazione Civita Report on Edutainment*.

Romberg, T. A., & Kaput, J. (1999). Mathematics Worth Teaching, Mathematics Worth Understanding. In E. Fennema & T. A. Romberg (Eds.), *Mathematics Classrooms That Promote Understanding* (pp. 3–19). New Jersey: Lawrence Erlbaum Associates Publishers.

Shin, N. (2006). Online learner's "flow" experience: An empirical study. *British Journal of Educational Technology*, *37*(5), 705–720. doi:10.1111/j.1467-8535.2006.00641.x

Stafford, T. (2012, June 19). Why are we so curious? *BBC News*. Retrieved from http://www.bbc.com/future/story/20120618-why-are-we-so-curious

Sternberg, R. J., Sternberg, K., & Mio, J. (2012). *Cognitive Psychology*. Belmont: Wadsworth Cengage Learning.

Sung, H.-Y., & Hwang, G.-J. (2013). A collaborative game-based learning approach to improving students' learning performance in science courses. *Computers & Education*, *63*, 43–51. doi:10.1016/j.compedu.2012.11.019

Van Eck, R. (2006). Digital Game-Based Learning: It's Not Just the Digital Natives Who Are Restless. *EDUCAUSE Review*, *41*(2), 16–30.

Vos, N., van der Meijden, H., & Denessen, E. (2011). Effects of constructing versus playing an educational game on student motivation and deep learning strategy use. *Computers & Education*, *56*(1), 127–137. doi:10.1016/j.compedu.2010.08.013

Wishart, J. (1990). Cognitive factors related to user involvement with computers and their effects upon learning from an educational computer game. *Computers & Education*, *15*(1), 145–150. doi:10.1016/0360-1315(90)90140-3

Yang, Y. T., & Chang, C. H. (2013). Empowering students through digital game authorship: Enhancing concentration, critical thinking, and academic achievement. *Computers & Education*, *68*, 334–344. doi:10.1016/j.compedu.2013.05.023

Yimer, A., & Ellerton, N. F. (2006). Cognitive and Metacognitive Aspects of Mathematical Problem Solving: An Emerging Model. In *MERGA 2006 Conference Proceedings: Identities, cultures, and learning spaces* (pp. 575–582). Mathematics Education Research Group of Australasia Incorporated. Retrieved from https://www.merga.net.au/documents/RP672006.pdf

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