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Similarities and differences in learning of metacognitive skills: computer games versus mathematics education.

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Similarities and Differences in Learning of Metacognitive Skills:
Computer Games Versus Mathematics Education

Su Ting Yong, The University of Nottingham, Semenyih, Malaysia
Peter Gates, The University of Nottingham, Nottingham, UK
Andy Tak-Yee Chan, The University of Nottingham, Semenyih, Malaysia
https://orcid.org/0000-0003-2267-4949

ABSTRACT

This article explores the potential use metacognitive skills learned in computer games to teach mathematics. This study explored the similarities and differences in the learning of metacognitive skills between computer games and mathematics education. A mixed-methods approach was employed in which a quantitative survey (students, n=174) and a qualitative interview (six mathematics teachers, eight students) were administered to concurrently at two secondary schools in Malaysia. Data collected has shown that there is no direct and explicit connection between the two learning contexts. In computer games, pupils could learn: (a) multitasking, (b) land navigation, (c) teamwork, (d) bottom-up approach to problem solving, and (e) concentration skills. However, it is understandable that a mathematics education (a) is single-tasking, e.g. solves problems step-by-step, (b) uses graphic representation, (c) involves collaborative learning, (d) follows top-down approach to problem-solving, and (e) could use multiple sensory modalities to ameliorate learning.

KEYWORDS

Computer Games, Concentration, Land Navigation, Mathematics, Metacognitive Skills, Multitasking, Problem-Solving, Teamwork

INTRODUCTION

Modern computer games are becoming more advanced and sophisticated. The games require not only physical skills but also strong metacognitive skills, flexibility and adaptability. “Modern video games have evolved into sophisticated experiences that instantiate many principles known by psychologists, neuroscientists, and educators to be fundamental to altering behaviour, producing learning, and promoting brain plasticity” (Green & Seitz, 2015, p. 102). The evolution of computer games has changed the mental abilities needed to play the games. Apparently, gamers have sophisticated knowledge and thinking skills.

Similarly, solving mathematics problems requires sophisticated and strong mental abilities to think critically, logically, and creatively. Mathematics problem-solving is not simply the application of formula and model answer. It requires associated thinking, strategies and motivation. Problem-solving plays a significant role in mathematics education since it requires a proper understanding and manipulation of various complex thinking skills. There are a few approaches to mathematics

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problem-solving and all the approaches are fundamentally built on the four-stage model of Polya (1945). Other than the four-stage model, non-routine problem-solving requires higher-order thinking and metacognitive skills.

The purpose of this study was to explore the similarities and differences in learning of metacognitive skills between computer games and mathematics education. Firstly, the authors identified the key metacognitive skills learned in computer games. Then, the metacognitive skills were analyzed from the context of mathematics education. Finally, a mathematics pedagogy was proposed in the conclusion.

LITERATURE REVIEW

Metacognition

Metacognition is the second-level mental operation. Metacognitive is defined as "knowledge and cognition about cognitive phenomena" (Flavell, 1979, p. 906). Following the original definition given by Flavell (1979), multiple definitions are given in the literature. An overview of these definitions clearly demonstrates that metacognitive is the awareness of one's thinking, and assessment of one's own ability to think and control one's cognitive processes. Metacognition is thinking about thinking. Metacognitive skill is one of the metacognitive components. Metacognitive skill is knowing what one can do (Biryukov, 2004) or "knowledge of when to use, how to coordinate, and how to monitor various skills in problem-solving" (Mayer, 1998, p. 53). Metacognitive skill includes a control aspect of learning (Kleitman & Stankov, 2007) and regulation of cognition (Ozsoy & Ataman, 2009). The regulation of cognition involves: (1) planning and prediction: selection of appropriate strategies and allocation of cognitive resources before the task; (2) monitoring: awareness of one's understanding and performance during the task; (3) evaluating: appraising the performance and efficiency after task completion (Ozsoy & Ataman, 2009; Schraw, 1998). Metacognitive skill enables a problem solver to analyze the problem, select an appropriate strategy to address the problem from an array of possible alternatives, and monitor the problem-solving process to ensure that it is carried out correctly.

Metacognition in Mathematics Learning

Mastering each component of cognitive skill is not sufficient to promote non-routine mathematical problem-solving because the problem solver needs to know when and how to apply specific learning strategies and monitors these cognitive processes (Mayer, 1998). Efficient use of the cognitive content is possible only through metacognitive skills (Mayer, 1998; Ozsoy & Ataman, 2009; Yimer & Ellerton, 2006). Problem solvers may master the basic cognitive skills, but fail to apply what they have learned to a new situation as they may not have the ability to organize and control the basic skills in solving a higher-level task (Mayer, 1998). A learner with poor metacognitive skills is not able to provide accurate monitoring, reflection, evaluation, and adjustment of effective learning (Yimer & Ellerton, 2006). Failure in metacognitive skills may lead to failure in mathematical thinking and problem-solving. Cognitive and metacognitive strategies work well together in attaining the solution of mathematical problems.

Metacognition in Computer Games

During the early development of video games in the 1980s, the gameplay mainly focused on the speed and capability to operate the game controllers and not much in the way of mental abilities were involved. Nowadays, a children's game like *Pokemon GO* involves land navigation skill, spatial ability, vocabulary, and thinking skills. In addition, metacognitive skills can be developed or improved by playing different types of computer games. The metacognitive skill learned in a strategy genre is problem-solving (Cherenkova & Alexandrov, 2013) because strategy games involve planning, decision-making, and execution and adjustment of actions (Martinovic et al., 2014). Games within a simulation genre require specific domain knowledge about the system in the game (Martinovic et al., 2014) and the metacognitive skills that could be learned include land navigation and problem-solving skills (Cherenkova & Alexandrov, 2013). Role-play games allow players to become connected to the game characters (Martinovic et al., 2014) and the metacognitive skill learned is teamwork (Cherenkova & Alexandrov, 2013). In adventure games, a player has to overcome a series of obstacles (Martinovic et al., 2014) and the metacognitive skills learned are land navigation, visualization and problem-solving skills (Cherenkova & Alexandrov, 2013). Action games require eye-hand coordination and fast reaction time (Martinovic et al., 2014) and the metacognitive skill acquired is land navigation (Cherenkova & Alexandrov, 2013). As for driving games, players can learn problem-solving, concentration and land navigation skills (Cherenkova & Alexandrov, 2013). Puzzle games such as Tetris could help to improve spatial ability. In *Tetris*, players must imagine how a two or three-dimensional block would appear after it has been rotated with a given number of degrees. In summary, the key metacognitive skills are listed as follows:

1. **Multitasking:** Multitasking is the capability of attending to multiple tasks at the same time. Multitasking games can improve mental cognition and broaden mental functioning (Zelinski & Reyes, 2009). Memory contamination and time pressure are two of the multiple factors that can affect time estimation in multitasking situations (Moon & Anderson, 2013). In role-playing games, a player has to perform multitasking with a memory load by managing multiple characters simultaneously (Zelinski & Reyes, 2009). In real-time games, the action continues while the player is making a decision and this creates a time pressured multitasking (Zelinski & Reyes, 2009);
2. **Land navigation/spatial:** The game world is transparent, so land navigation skills are essential to identify the directions of other players, enemies, resources and goals (Beck & Wade, 2006). Land navigation requires spatial aptitude which enables players to use their imagination and creativity to deal with challenges, threats and predators (Corbeil, 1999). Males generally have better spatial ability than females (Paul, 2013);
3. **Teamwork:** Teamwork is the capability of working collaboratively with a group of people. Children like to play computer games because they can collaborate with others and in so doing go on to develop social skills (Prensky, 2001b). In a teamwork setting, all players are encouraged to think and reflect on their metacognitive knowledge (Gee, 2007);
4. **Problem-solving:** Computer games provide a meaningful problem-based learning environment that enables players to set personal goals, gather information, make decision, plan strategy, monitor and evaluate problem-solving processes (Prensky, 2001b). Problem-solving skill could help players to think differently and faster to solve complex tasks with greater accuracy;
5. **Concentration:** Playing computer games involves the integration of touch, audio-visual, animation, and text (Martinovic et al., 2014). Expert gamers are more capable of focusing their attention on relevant information and disregarding what is irrelevant. Gaming has a positive effect on attentional skill (Cherenkova & Alexandrov, 2013; Martinovic et al., 2014).

AIM AND RESEARCH QUESTIONS

This study aims to explore the potential use of metacognitive skills learned in computer games to teach mathematics. The research questions addressed in this study are stated as follows:

1. What are the similarities and differences in learning of multitasking skill between computer games and mathematics education?
2. What are the similarities and differences in learning of land navigation skill between computer games and mathematics education?

3. What are the similarities and differences in learning of problem-solving skill between computer games and mathematics education?
4. What are the similarities and differences in learning of teamwork skill between computer games and mathematics education?
5. What are the similarities and differences in learning of concentration skill between computer games and mathematics education?

METHODOLOGY

Data Collection

A mixed methods approach was employed in which a quantitative survey [Students, n=174] and a qualitative interview [six mathematics teachers, eight students] were administered concurrently at two secondary schools in Malaysia. Given the permissive access to schools, only the Form 4 students were recruited in this study. The students were 16 years old and had equivalent academic qualifications to those at the General Certificate of Education Ordinary Level (GCE O-level). Data collection was administered by the first author. The survey questionnaires were distributed through their respective school teachers. The survey took approximately 10-15 minutes to complete. Overall, 174 out of 196 of the students responded to this survey, with an average response rate of 89% (see Table 1).

For the qualitative interview, multilevel and nested samplings were employed. The student interview data was collected from a sub-sample of the same group of students participated in the quantitative survey (nested sampling). Then, the teacher interview data was gathered from the students' mathematics teachers (multilevel sampling). The respondents participated in the interviews are depicted in Table 2 and Table 3. The names of the students and teachers would be kept anonymous due to ethical consideration. Instead, pseudonyms are used to represent their names. All interviews were conducted face-to-face and each conducted interview lasted 30-45 minutes. All interviews were voice recorded.

Instruments

Survey

Section 1 (Computer Games): A questionnaire was developed based on the classifications of metacognition defined in the literature. The instrument was specifically focused on multitasking, land navigation/spatial skill, teamwork, problem-solving and concentration. Students were asked to indicate the degree of their agreement or disagreement on a five-point Likert-type scale: 1 (Strongly Disagree); 2 (Disagree); 3 (Neither Agree nor Disagree); 4 (Agree); 5 (Strongly Agree). Students were asked to rate whether computer games had helped them to develop the following knowledge/experience, e.g. multitasking skill, thinking skill, understanding of complex tasks, etc. The detailed variables are shown in the results section.

Section 2 (mathematics Education): Five questions were adopted from mathematics and Technology Attitudes Score (Pierce, Stacey, & Barkatsas, 2007) to measure students' attitudes towards mathematics. Students were asked to indicate the degree of their agreement or disagreement on two

Table 1. Students participated in the survey

Gender	School 1	School 2	Total
Male	44 (38%)	23 (40%)	67 (39%)
Female	72 (62%)	35 (60%)	107 (61%)
Total	116 (100%)	58 (100%)	174 (100%)

Table 2. Students participated in the qualitative interview

Student	Student 1	Student 2	Student 3	Student 4	Student 5	Student 6	Student 7	Student 8
Gender	Female	Female	Female	Male	Male	Male	Female	Male
Age	16	16	16	16	16	16	16	16
School	School 2	School 2	School 1	School 1	School 2	School 2	School 1	School 1
Language	English	English	English	English	English	Malay	English	English

Table 3. Teachers participated in the qualitative interview

Teachers	Teacher 1	Teacher 2	Teacher 3	Teacher 4	Techer 5	Teacher 6
Gender	Female	Male	Male	Female	Female	Female
Age	39	29	42	40	56	42
School	School 1	School 1	School 1	School 2	School 2	School 2
Language	English	English	English	English + Malay	English	English + Mandarin

five-point Likert-type scales: 1 (Strongly Disagree); 2 (Disagree); 3 (Neither Agree nor Disagree); 4 (Agree); 5 (Strongly Agree) and 1 (Hardly Ever); 2 (Occasionally); 3 (About half the time); 4 (Usually); 5 (Nearly Always). The five questions are shown in the results section.

Interview

A standardized open-ended interview was employed whereby the exact wording and sequence of questions were determined in advance. All participants were asked identical research issues in the same order. Some of the major interview questions are shown as follows:

Section 1: Computer Games (Students/ Teachers)
- (a) Have you ever played computer games?
- (b) What are your favourite computer games?
- (c) In computer game, do you think you could learn (1) multitasking skill? (2) land navigation skill? (3) teamwork skill? (4) problem-solving skill? (5) concentration skill?

Section 2: Mathematics Education (Students)
- (a) What do you think of mathematics?
- (b) What are your strengths/weaknesses in mathematics?
- (c) How does your mathematics teacher teach in the classroom?

Section 3: Mathematics Education (Teachers)
- (a) How do you describe your students' attitudes towards mathematics?
- (b) Tell me about the approaches you used to teach mathematics?
- (c) What are the strategies used by your students to solve mathematics problem?
- (d) How would you describe your students' ability in solving mathematics problems?

Data Analysis

The survey data was analysed using SPSS Statistics. Descriptive statistics was calculated in terms of percentages and the results were depicted in tabular forms. The interview data however required addressing the issues of validity and reliability of results obtained from the process of transcription and translation. During transcription, the qualitative research data (audio recordings) was transformed into typed text. There is no single and correct way to do transcriptions, but the most significant concern is how and to what extent the transcription is beneficial and useful for the researcher to achieve the research objectives (Cohen, Manion, & Morrison, 2007). After the process of transcribing, the next phase was to deal with the issue of translation. In total, there were 14 interviews conducted – 11 in English; one in Malay; one in English and Malay; one in Mandarin and English. Thus, three interviews required translation. The interview data was translated using the back-translation model.

The interviews data was analyzed using content analysis procedure to achieve qualitative data reduction. The procedure abided by the principle of fitness for a purpose and guided by Cohen et al. (2007). There were two categorical sampling units, students and teachers. Then, two types of coding systems were used to initialize the process of segmenting. Before the process of segmenting, a priori codes were established to answer the research questions, i.e. multitasking, land navigation, problem-solving, teamwork and concentration. Then, a priori codes were applied to fit the segments of data. However, if the data could not be fitted into any of the a priori codes, an inductive code would be generated. For instance, inductive codes derived were single-tasking, graphic representation, spatial skill, collaborative learning, top-down approach, bottom-up approach and multiple sensory modalities. Finally, a composite description of the essence of the experience for students and teachers was developed.

Both survey and interview data were analyzed independently and combined in the final interpretation and discussion. The survey data provided a general understanding and statistical generalization from a sample of 174 students. Then, the interview data was used to provide detailed understanding of 14 individuals (six teachers and eight students). This is a qualitative dominant mixed research design because metacognition is the study of how humans think and control their own cognitive processes. Qualitative interviews are useful to obtain detailed information about what is in the participants' mind, i.e. opinions, views, knowledge, reasoning and feelings about something (Fraenkel & Wallen, 2006). There is a lack of qualitative research in instructional games literature (Ke, 2009). Hence, the results of this study will provide new insight into the relationship between metacognition in computer games and Mathematics education.

RESULTS

Survey Data

Data collected has indicated that most of the students acknowledge the many benefits of computer games (see Table 4). More than 50% of the students have agreed that they can learn various multitasking skills in computer games such as multitasking, land navigation, teamwork, problem-solving and concentration skills. However, Table 5 has shown that students' mathematical abilities (M1, M2 and M3) are not evident, i.e. about 50% of the students are neither positive nor negative. Despite that, more than 50% of the students have claimed that they are putting efforts to learn mathematics (M4 and M5). The findings will be further discussed in the next (discussion) section.

Interview Data

For interview data, only the significant findings are reported. Verbatim or the translated verbatim quotations would be included to present the spoken words of the research participants (see Table 6). Student interview data shows that they are aware of learning various types of metacognitive skills in computer games, namely multitasking, land navigation, teamwork, problem-solving and concentration skills. Each of the metacognitive skills is compared with the mathematics learning context described by the teachers and students during the interviews. The interview data will be discussed further in the next (discussion) section.

Table 4. Gaming experience and knowledge learned in computer games (in percentage)

	Disagreement	Neutral	Agreement
Multitasking skill	3	22	75
Thinking skill	2	5	93
Understanding of complex tasks	2	16	82
Land navigation skill	3	23	74
Learning in realistic contexts	5	26	69
Observation of the phenomena	1	27	72
Teamwork	6	12	82
Social interaction and collaboration	5	32	63
Social skill	9	31	60
Problem-solving skill	1	9	90
Solve problems with authentic activities	5	34	61
Experiential learning	2	21	77
Efficient problem-solving	3	27	70
Concentration	3	6	91
Games addiction	41	26	33
Neglecting study and social activities	58	20	22

Table 5. Mathematics learning experience (in percentage)

	Disagreement	Neutral	Agreement
I know I can handle difficulties in mathematics. [M1]	13	53	34
I have a mathematical mind. [M2]	12	51	37
I am confident with mathematics. [M3]	15	42	43
	Hardly Ever/ Occasionally	**About Half the Time**	**Usually/ Nearly Always**
If I can’t do a problem, I keep trying different ideas. [M4]	11	26	63
I concentrate hard in mathematics. [M5]	12	26	62

DISCUSSION

Multitasking

Computer Games

Survey and interview data have shown that students report they like to play multitasking games. The survey data has revealed that 75% of the students are aware they can learn multitasking skill in computer games. They have claimed to understand complex tasks (82%) and improve thinking skills (93%) in gaming. The interview data has further revealed that there are two factors that influence time estimation in multitasking games. Student 2, Student 3 and Student 5 have mentioned that they can handle multiple tasks simultaneously and make a decision under time pressure, e.g. manage several requests at one time, decide on how to drift a ball while other players continue to move around, and decide on how to prioritize the cooking tasks. They seem to load their memories with multiple tasks (multitasking with a memory load) and this creates memory contamination from a shorter time interval in the task. Moreover, they have to take appropriate actions in time (time-pressured multitasking).

Mathematics Education

In schools, however, students are not encouraged to multitask. From the interview data, it seems that teachers encourage the students to follow a step-by-step problem-solving process, specifically the Polya's (1945) four-step method. Teacher 2 has mentioned that students are trying to multitask when solving mathematical problems, which unfortunately, is unsuccessful. This could be a reason why survey data has shown that only 34% of the students agree that they are confident in handling difficulties in mathematics [M1]. Students' intentions to perform multitasking have been labelled by the teachers as impatient and lazy; the students want it to be fast and easy. Students could be bored in schools because their multitasking abilities are underused. According to Prensky (2001a), the digital native students have to power down in schools. Which may result in them being unchallenged and bored.

Land Navigation

Computer Games

Survey data has indicated that 74% of the students are aware they can learn land navigation skill in computer games. They have claimed that they could learn in realistic contexts (69%) and observe a phenomenon (72%) in the game world. Follow-up interviews have revealed that the students are aware they could learn how to use map, compass and global positioning system (GPS) in computer games. For instance, Student 3, Student 5 and Student 7 have mentioned that land navigation skill could be learned in Persona 4, Grand Theft Auto, Resistance and Hakuna Matata. According to Student 3, the land navigation skill learned in games could enrich her geographical knowledge. Superficially, land navigation skill is not related to mathematical knowledge except for certain topics such as bearings, earth as a sphere, angle of elevation and angle of depression. Looking in depth, spatial knowledge is acquired through land navigation (Self & Golledge, 2000).

Mathematics Education

Spatial skills are crucial for mathematics performance. From the interview data, it is evident that Teacher 3, Teacher 5 and Teacher 6 have used different types of software to visualize abstract concepts, such as the rotation of objects in three-dimensional space and the changes of a graph in real time. This is particularly useful for students with weak spatial visualization skills. Survey data has indicated that only 37% of the students agree that they have mathematical mind [M2]. Teacher 1 and Teacher 4 have mentioned that female students tend to be weaker in spatial visualization skills. This has been admitted by both Student 2 and Student 7. Although females with poor spatial skills are well documented in the literature, they are poorly understood. In this study however, a female

Table 6. Comparison of metacognitive skills learned in computer games and mathematics education

Computer Games	Mathematics Education
Multitasking In Sims, we can play a lot of sims. Then if this Sim wants this kind of thing, then we have to do it while handling other sims. (Student 2) For example, I want to harvest everything by 5 O'clock. To initial time, two hours before need to start the pie making process. For harvesting of the milk maybe it takes 30 minutes, so I need to do it 30 minutes before 5. (Student 3) While playing football, while say I drifter around, I have to check for offside line, check for nearby players. (Student 5)	**Single-tasking (step-by-step)** Depending whether they are lazy or not, i.e. follow the step-by-step problem-solving strategies. Some are lazy. (Teacher 1) They think that they can combine everything into one. They want to be fast. And they don't want a lot of working. They want to be easy. They want to find the simplest. Actually I want them to step by step. (Teacher 2) I said read slowly, read one by one, and then transfer. They want to be fast. If it takes time to read and transfer, they are impatient. (Teacher 4, translated from Malay language)
Land Navigation (Spatial Skill) Yes in Resistance and in Hakuna Matata too… I am not really good at walking compass myself, but in the game I feel I'm expert at it. I can understand map… if they happen to ask anything about Africa, then I can answer it... Actually I play chess and strategy games also. (Student 3) In shooting games. Where you have to find the enemy base or the direction you are heading to using game compass. (Student 4) Like when driving a car in GTA, there will be a GPS to lead to the place or direction where I'm heading. (Student 5) It's called Persona 4, we need to find a way out from the place. So we just use the map to go out. (Student 7)	**Graphic Representation (Spatial Skill)** I do use games and courseware. Let say I teach the quadratic function or equation. I can show them how does the effect of A, how the graph look like. (Teacher 3) I might use PowerPoint like graph, curve, the change of the graph of sine and cosine, trigonometry graphs. How the solid is formed. Then they rotating about the axis, especially the 3D one. (Teacher 5) I just use courseware to show 3D objects. How it rotates to form a solid. It is very effective for students who could not visualize. (Teacher 6, translated from Mandarin language).
	Mathematics requires spatial skill right? Boys can get it, they can imagine. For example imagine the earth and sphere, how the earth rotates? Girls can't do it. (Teacher 4, translated from Malay language) When they come to abstract, locus, geometry construction, girls don't really like. (Teacher 1) When it comes to graph, drawing graph, I am not really good at that. Yes, I think so (weak spatial skill). (Student 7) I am not very good with diagrams (Student 2). (Strength) Easiest will be indices and also geometrical construction and graph. Yes, it's very fun (Student 3).
Teamwork For example Game Resistance, there are this chimaera, say half zombie but there are intelligent zombie right? So my brother will ambush them in two ways like, me from the front and my brother from the back door, then like shooting la… In Little Big Planet, there is a mini game where two players need to push two buttons at the same time. And the third needs to climb the stairs…Two players to push and two players to pull. (Student 3). Like playing sport game, shouldn't be a solo player. We need to make full use of all players in the field. (Student 5).	**Collaborative Learning** Mostly I used group discussion. Most of the time I will divide the questions and give them time to think. Then call them out to show their working. So, they share their answer with the others. (Teacher 1) I always use group discussion. I give the questions to whole class. Then I will seek volunteer. Who can solve it, they come and present and teach. They like actively involve them… Little project I asked them to do. Maybe like statistics. (Teacher 5) Group project. They do not want to sit in the class because they have a lot of energy. Let them go out. They learn statistics using field data. That means they go and find the data in the school. (Teacher 4, translated from Malay language)
Problem-solving (Bottom-up Approach) Most of the problem-solving in games is very exaggerated… they don't apply physics or knowledge of physics. Like the characters jump from a high building and they don't break their legs. (Student 8) Sometimes I play the CSI games, something that related to forensic and investigation. Usually we need to find the clue. Maybe we need to make a very accurate decision… We have the solution. (Student 1) For example in Little Big Planet they give us a lot of square cushion stuff, we need to reach the key at the top. We need to assemble it like maybe a stair of thing. Sometimes we don't have enough blocks, so one of us needs to help up for one of the block. (Student 3) My game is Sherlock Holmes…There will be murder cases, murder investigation. You have to find the killer before it is too late… . It will teach us to be more creative. (Student 4)	**Problem-solving (Top-down Approach)** (Predefined approach) Firstly, understand the problem. Secondly, find out what is required by the question. Then, look for an appropriate formula that can be used to solve the problem. Finally, checking the answer or looking back. (Teacher 6, translated from Mandarin language) (Predefined approach) Follow the rules of mathematics, which one should they do first, which one second and third… I will normally tell them to find the simplest way first. Break it into small parts to find the answer then follow the sequence. (Teacher 2) (Predefined approach) The students will follow whatever taught by the teacher without any question… Whatever problem-solving method I teach them, that is what they will study. They won't go beyond or explore other methodss. (Teacher 4, translated from Malay language)
Concentration I think that I should keep my eyes open especially in Resistance. The bad guys can come anywhere and I should regularly check how many bullets I still have. (Student 3) If I don't concentrate in the game, I will lose the game…It also improves my reaction. (Student 4) Yes (concentrate). Like aiming for prey and aiming for enemies… It helps me to think fast, helps my eyes coordination, such as I can learn to spot thing fast. (Student 5)	**Multiple Sensory Modalities** I can learn while listening to song. I am feeling refresh. It makes me much more focus. Maybe it can lighten up my mood. Then I am much more contented in doing it. (Student 1) When I was doing my homework, I can play my games. It can help us do the work longer. (Student 2) I'm listening to music while typing school work, so that I don't easily get bored. I don't waste time. (Student 5) Sometimes, watching TV while doing homework. Simple homework like mathematics. (Student 7)

student (Student 3) who likes to play strategy and chess games has claimed to have strong spatial skills in mathematics. The finding opens up the possibility of future research to explore female students' spatial abilities in relation to the games they played, specifically strategy and chess games.

Teamwork

Computer Games

Survey data has indicated that 82% of the students are aware they can learn teamwork in computer games. Furthermore, they have claimed that they could learn social skill (60%), and knowledge is constructed through social interaction and collaboration (63%). The young generation seems aware they work better as a team. From the student interview data, it is evident that teamwork has fostered positive learning experiences and bonding among the players. Every player can offer and receive help and support each other to succeed. For instance, Student 3 has mentioned that in Little Big Planet and Resistance, each player has a different role to play, e.g. pushes the buttons, climbs the staircases, ambushes from the front or ambushes from the back. These unique roles make them feel special and important. The young generation do like to feel important (Beck & Wade, 2006). In this case, teamwork could satisfy their inner needs for relatedness.

Mathematics Education

Teacher interview data has indicated collaborative learning (e.g. group discussion and project) has been actively adopted in the classrooms. In group discussion, every student is solving a common problem. The students have no special or unique roles to be recognized as important. Thus, students are neither motivated nor excited; none of them have mentioned any group discussion during the interview. Furthermore, teamwork in schools is different from the gaming context. Homework usually must be completed individually. Sometimes offering help or asking for help may constitute cheating. There are no group exams in schools and teamwork is not allowed during exams. They must believe in themselves because they cannot help each other to succeed. Survey data has indicated that only 43% of the students agree that they are confident in mathematics [M3]. Apparently, teachers must work to build self-confidence in their students.

Problem-Solving

Computer Games

Survey data has shown that 90% of the students are aware they can learn problem-solving skill in computer games. Furthermore, 61% of the students have reported they can solve problems with authentic activities. However, during a follow-up interview, Student 8 has mentioned that problems in games are sometimes not real. Everything in games is pseudo-reality, but there are certain gaming economics that can be learned. For instance, in World of Warcraft a player can learn the gaming economics, which is based on supply-and-demand. If fewer people are playing the game during week days, the price of things will drop. The player can buy those things on weekdays and put them for sale during the weekend to earn profit. From the survey data, students also agree that computer games have trained them to solve problems efficiently (70%) and helped them to develop experiential learning (77%). In the follow-up interviews, Student 1, Student 3 and Student 4 have revealed that they have learned how to achieve their goals (accurate decision, reach the key or solve a murder case) by considering the resources available (clues, blocks or evidences). In games, every decision made would determine the success or failure of the gameplay. However, there are no fatal consequences of failing because players can always try again in another life. Players are active problem solvers that persist in exploring, testing hypothesis, taking a risk and seeing mistakes as opportunities for reflection, learning and progress (Gee, 2007). The learning process employs a bottom-up approach. Players are free to use various strategies to explore the games, and knowledge is developed through trial and error (experiential learning).

Mathematics Education

In schools, problem-solving follows a top-down approach as the predefined strategies are taught explicitly. During the interview, Teacher 6 has shared her problem-solving strategies in four phases: (1) understand the problem, (2) devise a plan, (3) carry out the plan and (4) reflection. In Asian culture, it is a norm that students should follow the path outlined by the teachers (Hofstede, 1986). Students are not encouraged to risk their exam performances by using alternate problem-solving strategies other than the one that is taught by the teachers. Students have no opportunity to test different problem-solving strategies to enable active learning. Survey data has also indicated that only 63% of the students have claimed that they will try different ideas if they cannot solve a problem [M4]. Apparently, there is a lack of experiential learning in the schools.

Concentration

Computer Games

Survey data has shown that 91% of the students are aware they can learn concentration skill in computer games. Although they have to pay full attention during gameplay, only some students report they are addicted to games (33%) and neglecting their study and social activities (22%). The students seem to believe that the benefits of computer games outnumbered the drawbacks. During the interviews, Student 4 and Student 5 revealed that concentration skill in games has helped them to learn visuospatial attention. This finding is aligned with literature highlighting the enhancements in visuospatial attention among computer game players (BBC, 2015). In games, information is available in numerous modalities including animated two or three-dimensional graphics, texts, and various sound effects. Players must learn to focus or divert their attention to multiple stimuli within complicated visual environments. This is similar to multitasking with a memory load. Therefore, ones should not presume that children who are capable of multitasking cannot concentrate.

Mathematics Education

Survey data has shown that 62% of the students report having to concentrate hard in mathematics. Mathematics is usually learned through numbers, texts, diagrams and graphs. One may assume that having less multimedia elements (e.g. sound, animation, and video) would allow students to pay more attention in the class. However, interview data has shown that most of the students do enjoy listening to song or watching movie while doing their homework. A past study has reported that students normally use information and communications technologies (ICTs) while doing schoolwork (Junco & Cotten, 2012). This has implied that students prefer learning with multiple sensory modalities. According to Student 1, Student 2 and Student 5, multitasking could help and motivate them to concentrate in their study. Since homework is an unpleasant experience and is boring, students need an entertainment to motivate and lighten their mood so that they can continue paying attention to their study. The students have made use of the metacognitive skill concentration by keeping their general attention and arousal high while doing boring homework. Despite that, multitasking while studying will overload their ability to process information and prevent them to engage in deeper learning (Junco & Cotten, 2012). It is an interesting argument of whether multitasking can help to improve or decrease the quality of learning. While distraction is generally detrimental for learning, it can raise arousal which is positive for learning. The students might hit a spot where the positive effect on arousal outweighs the negative effect of distraction. Here, the excitation-transfer theory may apply. Excitation transfer theory posits that the residual excitation from an initial stimulus (e.g. music) will amplify the excitatory response to another stimulus (e.g. homework).

CONCLUSION

In this paper, the authors have discussed the metacognitive skills that can be learned through computer games and how these skills could be applied into mathematics learning context – yet appear to be currently absent. There is no direct and explicit connection between the two learning contexts. In computer games, pupils could learn (a) multitasking, (b) land navigation, (c) teamwork, (d) bottom-up approach to problem solving, (e) concentration skills. However, it is understandable that mathematics education (a) is single-tasking, e.g. solve problems step-by-step, (b) is using graphic representation, (c) involves collaborative learning, (d) follows top-down approach to problem-solving, (e) could use multiple sensory modalities to ameliorate learning. Although the findings are generated based on the teachers' and students' self-reported data, their views and perceptions are important as a way to address what they experience, recognize, like and what they do not like; their predilections would go on to influence their practices and engagement in teaching and learning. The nature of metacognition in both learning contexts tend to be dissimilar. Metacognitive skills in mathematics education are taught explicitly through top-down approach, but metacognitive skills in computer games are acquired through bottom-up approach. In a top-down assimilation (mathematics education), explicit metacognitive skills are taught and learned, and the processes are gradually assimilated into implicit skills (Sun & Mathews, 2003). The top-down approach is a deliberate learning because explicit metacognitive skills are learned consciously and planned. For instance, students are taught or verbally told to learn metacognitive skills. In a bottom-up direction (as in computer games), implicit metacognitive skills are learned through trial and error, and then explicit rules and strategies are acquired (Sun & Mathews, 2003). Implicit metacognition is learned without awareness so one may not know of its existence. Therefore, bottom-up approach is an implicit learning in which implicit metacognitive skills are learned unconsciously and unplanned. For instance, continuous practice situated within the gaming context is required to construct the meaning of the knowledge. Learning from the gaming context, certain teaching approaches could be considered in mathematics education. Firstly, the excitation-transfer theory could be explored further. For instance, what is the best stimulus (e.g. music) that can help students to concentrate or focus in their study, particularly mathematics. Secondly, collaborative learning could be done differently. Students could be asked to work as a team to experiment a challenging problem (bottom-up approach) and each student is given a unique or special role. Thirdly, certain topics could be taught using computer games, simulations or virtual reality to visualize abstract concepts. Overall, the resources and associated pedagogy currently adopted in mathematics classrooms could be enhanced and modernized.

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Su-Ting Yong is an Assistant Professor in the Department of Foundation in Engineering, The University of Nottingham Malaysia Campus. She joined the University in 2008, having taught in a few universities for a number of years. Dr. Yong obtained her bachelor's Degree in Science and Computer with Education (Mathematics) and master's Degree in IT Management from The University of Technology Malaysia. She completed her PhD in Engineering Education at The University of Nottingham. She is a fellow of The Higher Education Academy and has a wide variety of research interests, largely focused on technology in mathematics education, educational games, gamification and programming. Her latest project is funded by the University Teaching and Learning Fund.

Peter Gates is Associate Professor in the School of Education of Nottingham University where he works within the Centre for Research in Mathematics Education. Previously a teacher of mathematics, Peter researches around equity and social justice, visualization in the learning of mathematics.

Andy Chan is the current Dean of Engineering at the University of Nottingham Malaysia Campus (UNMC). His responsibility is to oversee all research, teaching, external and operation matters of the faculty. He is a member of the UNMC management board. Professor Chan's area of expertise is on air pollution and computational fluid dynamics, especially towards urban climates. During the 2003 severe acute respiratory syndrome (SARS) episode, he was one of the team leaders appointed by the World Health Organisation (WHO) to discover the dispersion of mechanisms of the SARS virus in the dense cityscapes of Hong Kong. He is currently the leader of the multinational 7SEASNASA project (Seven South-east Asian Studies-National Aeronautics and Space Administration), which studies the propagation of haze in Southeast Asia. He is currently also serving as the government expert consultant on the development of urban planning guidelines against air pollution and extreme weather conditions.