

Learning Mathematics via an Interactive Educational Game

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Abstract: Mathematics has always been labelled as a difficult subject by most of its learners. Yet, it is undeniable fact that it is crucial in daily lives. Therefore, people force themselves to understand the lessons and press on the process with the hope to be enlightened at a later moment of study. This study focuses on identify the current status and issues of students in learning Mathematics and developing an interactive computer environment in learning simple arithmetic calculations and provides students (aged 8-10 years old) with tutorial and games to enhance learning experience in an enjoyable way. Questionnaire and interview have been used to collect feedback in developing and testing the prototype. From the consolidated responses, most respondents are satisfied with the prototype developed and are convinced that young users would be beneficial from using this application by overcoming certain identified obstacles such as less interesting approach of delivery and not knowing the reason of learning it. Nevertheless, more researches such as the appropriate procedure of using such game-based learning are to be conducted for a more conclusive remark.

Key words: Mathematics, educational game, game-based learning, computer environment, consolidated responses

INTRODUCTION

Mathematics is undeniably a very important subject in daily lives, ranging from a simple arithmetic calculation in daily grocery payment to calculus that explains the marvellous scenarios of aerodynamics. Mathematics has been introduced to people and they have learnt all theories as early as possible and even today, they are still learning. Obviously, many students notice the importance of principles or concepts of Mathematics and yet they fail to grasp those concepts. Sometimes, even teachers, no matter how good they are still, might have difficulties in explaining those principles or concepts to their respective learners. It may simply because some of the mathematical concepts are too abstract to be imagined or explained to students. In learning Mathematics, learning sequence of the concepts is crucial as some of the preceding concepts are directly related to the latter concepts.

Many attempts or approaches have been proposed to overcome the challenges encountered in learning Mathematics such as the use of multimedia and computer games. For example, Kebritchi *et al.* (2010) argued that utilizing game for learning purpose can create an interesting and entertaining environment for the user. Moreover, participants of this study reported that the

mathematics computer game they played was able to improve their mathematics achievement and motivation.

Thus, this study focuses on developing an interactive computer environment in learning simple arithmetic calculations and provides students with tutorial and games to enhance learning experience in an engaging and enjoyable way. More specifically, this study has the following aims: to identify the current status and issues of students in learning Mathematics. To develop an interactive computer environment that provides specific yet simple teaching material about simple arithmetic calculations (addition, subtraction, multiplication, division) and to explain the calculation process to young users of aged 8-10 years old.

Literature review: Many researchers such as National Research Council (2001), Gutierrez *et al.* (2008), Lo and Lin (2012) have been discussing on the reasons that lead to a common scenario among students, mathematics is not among the subjects that are listed as their favourite subjects. Thus, several statements have been emerged from different point of view, following the different findings from different case studies.

According to National Research Council (2001), parents are more concerned about the languages than the

mathematics learning of their children at the early ages. They prioritize the languages compared to mathematics. While it is undeniable that languages are ways of communication, failing to recognize or misunderstand the importance of the Mathematics by children may discourage them from learning the subject at a later time. In short, the researchers recommended that the introduction to Mathematics for young children had to be started early while the importance of Mathematics should be kept in mind of the parents.

Besides, some researchers studied the causes from the perspective of learners. Gutierrez *et al.* (2008) argued that Mathematics could be a very problematic subject since it requires the students to identify and analyze general patterns in mathematical thinking which made Mathematics to be very complex and troublesome for students. Lo and Lin (2012) presented that advance cognitive skill is required in order to understand mathematical concepts which are generally abstract. Besides, since some of the mathematical concepts are interrelated, failing to understand a fundamental concept would impact the subsequent, usually more complicated, concepts. Not only that, Mathematics also require students to understand and memorize certain formulae which could be very difficult, without a clear visualization or imagination (Zaini and Ahmad, 2010). Haiguang *et al.* (2009) believed that if the content of subject is not specifically delivered by the teacher, it gives impact to the students as they can hardly figure out the main point that is to be delivered.

Thirdly, teachers could also become the main cause in these never-ending learning issues. Alzahrani (2013) stated that Mathematics teachers have been challenged with the Mathematics anxiety. Mathematics anxiety causes teachers to experience fear and risk, thus ruins their capacity to engage to complex thinking (Shechtman, 2010). In real situation, Mathematics anxiety may be caused by lack of preparation and understanding of the material. In addition, teachers and educators may be challenged by the learning styles of students. Different learners may have their preferred learning styles. For instance, some learners may perceive knowledge easily by reading while others may best receive information by looking at graphics or visual animation. It is not saying that each learner cannot receive the knowledge to be delivered via reading but with her preferred learning medium, the knowledge is best delivered and comprehended. These learning styles are referred as learning modalities.

According to Powell, learning modalities refer to how a person prefers to use her senses in the learning process to capture information, processing it and store it in her

memory. By using different senses, one can determine in which way she can capture, process and store the information better and understand anything caught by her senses. In a typical classroom study, students are usually being taught by using 2 modalities which are: visual (seeing) and auditory (hearing) while the other 2 modalities, kinaesthetic (moving) and tactile (touching) are seldom to be implemented. However, some students might have weaknesses in one or two modalities and they can only do better if the preferred modalities are used. That is the reason of studying the learning trends of each individual and diversifies various modalities used in knowledge delivery in order to improve the learners learning ability.

It is not a new idea to integrate the educational elements into a computer game. In fact, in the study conducted by Kebritchi *et al.* (2010) they found that users of those educational games are motivated to learn in such an interactive and interesting yet entertaining learning environment. The overall results indicated that the Mathematics games used in their study were effective teaching and learning tools to improve the Mathematics skills of the students.

Lo and Lin (2012) had developed a game that encourages its players to calculate Mathematics in a strategic way, where they have to finish the game before their opponents by moving their token faster while answering some arithmetic questions. In that game, users can determine which arithmetic operation (addition, subtraction, multiplication and division) they want to use and whether negative number is allowed in the game. In this game, players are motivated by various challenges and it is enriched with shops and events that diversify the winning strategies. Their result showed that most students understood the importance of Mathematics and eager to learn it via the game developed. In short, the researchers concluded that game-based learning is one of the solutions that should be developed further because of the enjoyable moment of playing game and they believed that the game can help those players to learn better.

In another research, Chiu *et al.* (2012) developed a mathematical scaling application integrated with a digital map that helps students in understanding the meaning of scale meter on maps. Basically, players of this application will interact with the Non-Player Characters (NPCs) and will need to solve problems that are related to scaling factor such as the distance between two buildings. From the observation studied, users realized the usefulness of mathematics in the real world situation and their eagerness of learning about the concept of scale meter had increased.

Similarly, a European Schoolbook publisher, Die Keure and Larian Studios, has been developing educational computer games. One of the commercialized computer games is Monkey Tales Games. This game was made mainly to improve children's arithmetic skills. By using the time pressure and an artificially intelligent character, it creates a competitive in-game environment. Players are motivated to participate in the exercises, by outperforming the artificially intelligent character in the game. Besides that, Castellar *et al.* (2014) had utilized this game to conduct their research on second grade students and based on the study conducted, most children responded that they prefer to play the game instead of doing paper exercise. They also added that playing the game is more fun, exciting and not boring at all.

Another group of researchers reviewed the claims on gaming in education (McClarty *et al.*, 2012). Among some of the claims on using computer games for learning are firstly, it gives an opportunity for play through simulated environments, these games can be an integral part of learning and intellectual development. It provides opportunities to its players to improve their decisions and failure. Secondly, games provide an opportunity to personalized learning for students according to their learning speed and such games strongly require the player to master a concept in order to advance. Thirdly, games provide more engagement for the learners. Such games support many of the components of flow such as clear goals, direct and immediate feedback can increase student engagement and it is strongly associated with student achievement.

From the reviewed literature, several researchers had identified some of the major factors that contribute to the learning issues in Mathematics. On the other hand, some group of researchers had utilized game element in their researches as an alternative approach to overcome some of the difficulties in learning Mathematics. They used this element to attract and engage their users in learning Mathematics. Their players might engage to the game to an extent that they did not feel the boredom as expressed by many other students in their learning of Mathematics. Besides, storyline was also implemented in the game. The real life issues/problems were delivered in the game story. Therefore, it is not hard to summarize that learning Mathematics can be challenging especially when the importance of Mathematics is misunderstood, the abstract mathematical concepts are misinterpreted or the Mathematics anxiety is not resolved properly. Regardless of these challenges, instructional games become a promising approach in creating an interesting, less stressful and fun learning environment to its users in learning Mathematics.

MATEREALS AND METHODS

In this research, an educational computer game was developed and user's feedback was essential in developing such instructional game. Besides reviewing the findings and analyses collected from other researchers, personal thoughts and opinions were also gathered by using questionnaire and interview approaches. In the first approach, questionnaire was set and was made available online via Google Drive and was announced by sending emails and posting it in social media. In the second approach, interviews were conducted either by arranging a physical face-to-face interview, teleconferencing or sending emails.

Meanwhile, the proposed educational game was developed in the form of Flash game. Thus, ActionScript 2.0 had been used to develop the prototype of this educational computer game. ActionScript is supported by Adobe Flash Software which is an easy-to-use software in creating animation and interactive application. Players of this game are able to choose an item from the main menu that is to start the journey with storyline, to test their skills with quizzes, to explore various calculation techniques or to view the achievement and reward.

In addition, since the target users are young learners, simple English, simple vocabularies with bigger font size and audio instruction to emphasize every instruction in the application have been considered. Moreover, colourful graphics have been used to attract and prolong their attention in this game-based learning.

RESULTS AND DISCUSSION

Data collection and discussion: In the process of collecting responses of respondents, two methods had been utilized, namely the questionnaire and interview. Questionnaire had been prepared and distributed online via Google Drive and in total there were 30 responses received. Meanwhile, three interviews had been conducted to gather their personal opinions about Mathematics learning, obstacles in its learning and their views about the interactive learning approach.

The analysis of the questionnaires: From the questionnaires collected, there are in total 30 respondents participated in this survey which comprises of 24 students of high schools to universities, three educators and the remaining respondents were categorized in others (unemployed, a marketer and an engineer). Feedbacks from these students are valuable in assessing the challenges and difficulties encountered during their young ages learning, particularly in the subject of

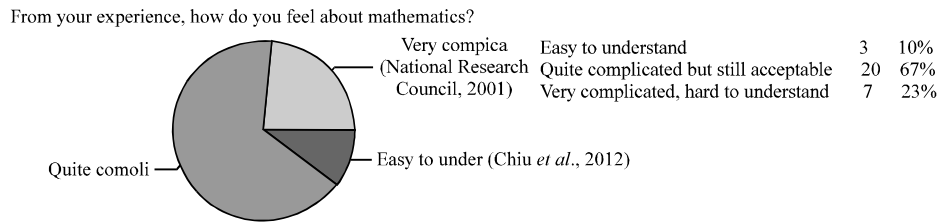


Fig. 1: Respondent's perception on Mathematics

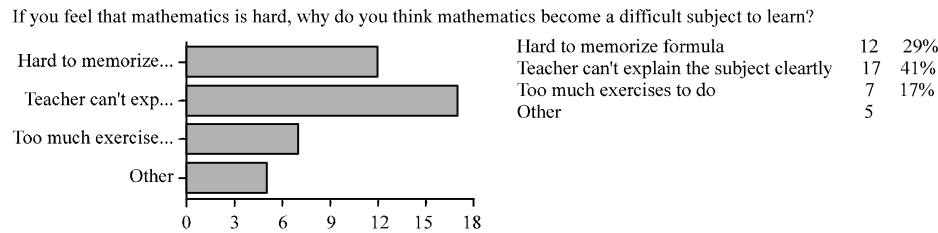


Fig. 2: Respondent's perception on obstacles in learning Mathematics

Mathematics. Meanwhile, responses from adults are expected to reflect their teaching experiences and the challenges encountered and the role of Mathematics in their daily livings or works that may be related to.

Among the data collected from conducting questionnaire, part of the analyses is presented. The 90% of respondents expressed the complication of learning Mathematics (Fig. 1). Besides, they admitted that Mathematics is a challenging subject partly because school teachers cannot explain the subject clearly in class or at least from their perspective (Fig. 2). This may explain the reason of many respondents saying Mathematics is complicated and also may prove that teacher's anxiety may be an issue that affects children's learning.

The analysis of the interviews: Interviews had been conducted to three candidates to gather their feedbacks about learning/teaching Mathematics and the interactive Mathematics learning application. They were a postgraduate student, a high school teacher and a Mathematics and Science educator cum parent. They did agree that without mathematics, people cannot think logically and cannot make decision. They further expressed their views in various factors that affect the learning process of a student, particularly in the subject of Mathematics. In summary, they agreed that Mathematics is essential and important. They acknowledged that the difficulty in learning Mathematics might be contributed by not knowing the reason of learning it, discouragement received from teachers should a different approach be utilized, the relationship between

the mathematical concepts and real life scenarios is remained unclear, incompetency of Mathematics teachers, less interesting approach of delivery and students are lack of confidence.

System design and implementation: In this interactive mathematical learning application, there are four main modes available, namely the story mode, the quiz mode, the achievement and the tips and trick (Fig. 3a). In the first mode, player follows the storyline in which the character, Bonet, is requested to perform arithmetic addition, subtraction, multiplication and division operations in four different levels (Fig. 3b). Among these four levels, real life examples have been integrated into the levels. For instance, adding up fruits, grocery purchase and food sharing among friends are commonly experienced by young learners (Fig. 3c). These levels are progressing in sequence to ensure that lessons are delivered appropriately.

In the quiz mode (Fig. 3d), it is subdivided into four various arithmetic operations, namely the addition, subtraction, multiplication and division. Score will be accumulated for every question answered correctly. Questions of each category have been preset and will be randomly chosen from the pool of preset questions to run the quiz. Meanwhile, when certain scores have been achieved, prizes will be unlocked and will be displayed in the achievement mode. All these unlocked achievements are displayed in colour while those yet to be unlocked awards are found in grey colour. When pointing to those prizes, instruction of unlocking them will be shown on screen (Fig. 3e).

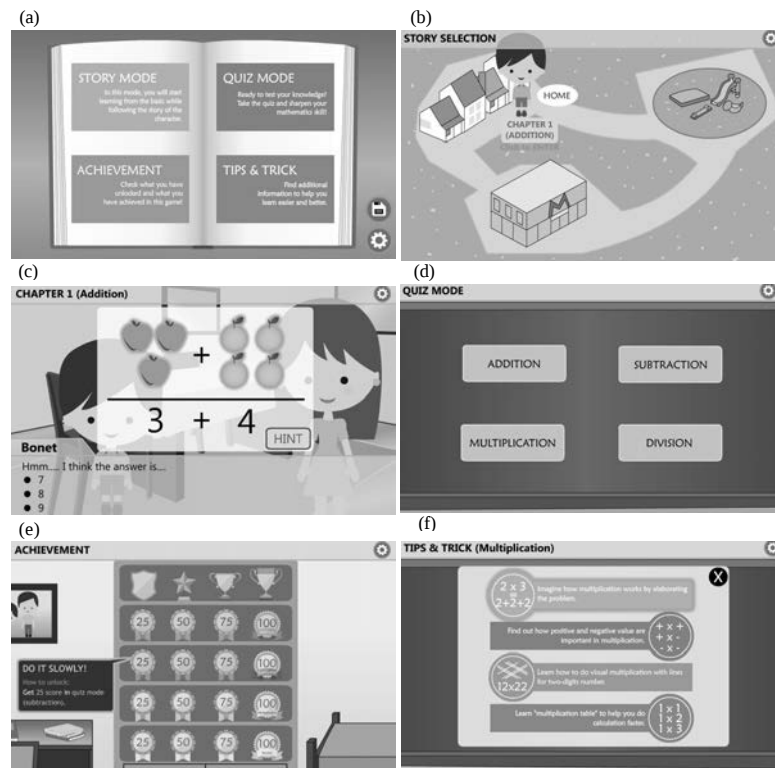


Fig. 3: Various in-game screenshots: a) main menu; b) story selection; c) example of addition operation in story mode; d) quiz mode; e) achievement and f) tips and trick

Lastly, in the tips and trick mode (Fig. 3f), player is shared with some of the creative techniques in solving the mathematical questions. This is also a place for her to quickly review her arithmetic skills without going through the story or questions.

System analysis and evaluation: One of the obstacles in learning mathematics is learners do not know the reason of learning it. To overcome this issue, real life examples have been integrated in this interactive application. Bonet encounters various real life challenges such as counting number of fruits and buying grocery with price and sharing food with friends. These examples might seem to be trivial to some readers but it brings a positive message to its young players, Mathematics is part of their lives and can be very relevant to them.

Moreover, various techniques have been implemented in this application in the Tips and Trick mode, to allow young users to realise that solving mathematical questions can be interesting by using different techniques or approaches. They may choose their preferred methods to solve the problems. By doing so, they are encouraged to overcome the encountered problems with various techniques and indirectly to build

up their confidence on their problem solving skills. Besides, it encourages them to think differently in problem solving. While other friends may use a “traditional and typical” approach, new method is introduced to achieve the same result. This may resolve one of the dilemmas summarized in the interviews that discouragement received from teachers should a different approach be utilized.

In this application, user may role-play as Bonet and starts her journey in the story mode. She is given an opportunity of learning not only through what she sees or hears, but also her imagination, putting herself in the character’s shoe which involves more senses of hers. With more senses involved, it is anticipated that the learning efficiency will be increased and she learns in an engaging approach. In addition, since this is an interactive application, users may customize their learning speed or repeat the task for skill refinement. This is a new and interesting experience to young learners especially if they used to learn their Mathematics lessons in traditional classroom teaching and learning environment.

Besides that a colourful user interface and simple English vocabulary have been utilized in the development. It would defeat the purpose if these users lose their

attention and interest on this application. At the same time, visual representation such as graphics and recorded explanation has been implemented to make the whole interactive learning more lively and attractive.

User's feedback on the application: A group of seven users, consists of teacher, student and parent have been asked to use the developed application and their comments and feedback have been collected. Based on their experience, the overall application is well-made lessons are delivered accordingly and is suitable for the target users. On the other hand, they did suggest improvement to the interface design to provide better navigating experience such as entering the story levels directly by clicking on the icon or allow the users to proceed with the conversation in the story by pressing the 'Enter' key. Extra feature or bonus such as wallpaper was suggested to be given away to the users according to their achievement. Young learners usually are attracted to such colourful rewards and are motivated with these additional features. However, they did also show their concerns about the guidance to be provided. Parents or mentors guide are still needed especially for the debriefing of the application. Therefore, human mentors are still essential in this learning process.

CONCLUSION

In conclusion, an interactive environment through game approach, focuses on arithmetic operations has been created as an alternative option to help children of aged eight to ten years old to get better understandings in Mathematics calculation. Furthermore, by providing clear visualization and animation in the calculation process and more interactions between the player and the game environment, student engagement is sustained. Next, the application has been designed with animation and audio instruction, apart from role play an in-game character which is to accommodate children with various learning styles, regardless of visual, auditory or kinaesthetic based. Lastly, daily experiences have been integrated into the storyline with the hope that the skills learnt in the game could be transferred into player's daily lives. By doing so, users will get the idea that Mathematics is not rocket science and it can be very relevant to their day by day experience.

Apart from the suggestions provided by interviewees, the relationship between games and academic performance is yet to be studied and analysed,

as suggested by some of the researchers (McClarty *et al.*, 2012). It is still too early to conclude that computer games are the new definite approach of teaching and learning process. Nonetheless, it looks promising to implement the computer game approach in such process. Therefore, it is good also to study the appropriate procedure to use such games for learning such as the settings, timings and materials for the best interest of learners and educators.

REFERENCES

- Alzahrani, F., 2013. Evaluation of videogames for mathematics education with young children. Proceedings of the International Conference on Computer Applications Technology (ICCAT), January 20-22, 2013, IEEE, Saudi Arabia, ISBN:978-1-4673-5285-7, pp: 1-4.
- Castellar, E.N., J.V. Looy, A. Szmalec and L.D. Marez, 2014. Improving arithmetic skills through gameplay: Assessment of the effectiveness of an educational game in terms of cognitive and affective learning outcomes. *Inf. Sci.*, 264: 19-31.
- Chiu, J.H., C.C. Cheng and K.H. Huang, 2012. More than learning mathematics: The impact of mathematics games on learning in geography and community education. Proceedings of the IEEE 4th International Conference on Digital Game and Intelligent Toy Enhanced Learning (DIGITEL), March 27-30, 2012, IEEE, Chiayi, Taiwan, ISBN:978-0-7695-4663-6, pp: 141-143.
- Gutierrez, S., M. Mavrikis and D. Pearce, 2008. A learning environment for promoting structured algebraic thinking in children. Proceedings of the 8th IEEE International Conference on Advanced Learning Technologies, ICALT'08, July 1-5, 2008, IEEE, London, England, UK., ISBN:978-0-7695-3167-0, pp: 74-76.
- Haiguang, F., L. Xuemei and H. Hoivik, 2009. Research on improving learning interests for elementary students based-on mental mode by using mathematics animations. Proceedings of the International Conference on Application of Information and Communication Technologies, AICT 2009, October 14-16, 2009, IEEE, New York, USA., ISBN:978-1-4244-4739-8, pp: 1-5.
- Kebritchi, M., A. Hirumi and H. Bai, 2010. The effects of modern mathematics computer games on mathematics achievement and class motivation. *Comput. Educ.*, 55: 427-443.

- Lo, J.J. and F.M. Lin, 2012. A study of 2nd grade students attitude on a mathematics game. Proceedings of the 2012 IEEE 4th International Conference on Digital Game and Intelligent Toy Enhanced Learning (DIGITEL), March 27-30, 2012, IEEE, New York, USA., ISBN:978-0-7695-4663-6, pp: 111-113.
- McClarty, K.L., A. Orr, P.M. Frey, R.P. Dolan and V. Vassileva *et al.*, 2012. A literature review of gaming in education. *Gaming Educ.*, 2012: 1-36.
- National Research Council, 2001. Adding It Up: Helping Children Learn Mathematics. National Academies Press, Washington, DC., USA.,.
- Shechtman, N., 2010. Math anxiety in middle school math teachers: Implications for teacher practice and professional development. Proceedings of the 9th International Conference on International Society of the Learning Sciences Learning Sciences, June 29-July 2, 2010, ACM, Chicago, Illinois, pp: 409-410.
- Zaini, Z.H. and W.F.W. Ahmad, 2010. A study on student's motivation in learning mathematics using multimedia courseware. Proceedings of the IEEE International Symposium on Information Technology (ITSim), June 15-17, 2010, IEEE, Perak, Malaysia, ISBN:978-1-4244-6718-1, pp: 1-3.