Math Island: Designing a Management Game of Primary Mathematics for Facilitating Student Learning

Charles Y.C. Yeh[a], Hercy N.H. Cheng [b], Zhi-Hong Chen [c] & Tak-Wai Chan [d]

[abd]*Graduate Institute of Network Learning Technology, National Central University, Jongli, Taiwan*
[c] *Information Communication, Yuan Ze University, Jongli, Taiwan*

[abd]Charles, Hercy, Chan@cl.ncu.edu.tw
[c]zhchen@saturn.yzu.edu.tw

Abstract: In Taiwan, primary mathematical education currently adopts teacher-centered learning. Teachers are the main source of course and students must to be engaged in the same activity in the same place at the same time. In this study, we designed a digital game-based learning system which called “Math Island” to help students’ mathematics learning by themselves. In the system, we produced 488 mathematics interactive materials, videos and games into a management game and combing “knowledge map” help students to understand the relationships of mathematic concepts. In the system, students can learn mathematics by their own pace by a variety kinds of learning tasks to learn different types of mathematical materials. Moreover, we also collection all user data toward the system and examine how the Math Island system influences on students learning performance and progress. The preliminary results showed that the Math Island may help students make a good progress. In the future, we will In-depth analysis in the further research and implement a diagnosed mechanism to help students learning.

Keywords: knowledge map, knowledge structure, mathematics learning

1. Introduction

In recent years, digital learning has become a more and more popular issue. Digital learning is the use of electronic media, information and communication technologies in education. In addition, it includes game-based learning, intelligent systems, virtual classrooms and digital collaboration. Digital learning will bring new revolutions and learning approaches to education (Evans, 2008; Liaw, 2008). Among all digital learning approaches, game-based learning is a famous one. This may be caused by the fact that there are many research indicating that game-based learning has some benefits to improve learner’s motivation and learning effects (Papastergiou, 2009;Huizenga, Admiraal, Akkerman, & Dam, 2009; Liu & Chu, 2010; Paraskeva, Mysirlaki, & Papagianni, 2010 ;Huizenga, 2009; Paraskeva, 2010; Liu & Chu, 2010; Prensky, 2001; Kiili & Ketamo, 2007; Van Eck, 2006;Kiili, 2005). More specifically, Traditional learning is absorbing knowledge passively. Conversely, digital games provide control and challenge that can make player feeling fun (Prensky, 2001; Crawford, 1982). Some findings are in agreement with the result of Kiili (2005) which indicating that game-based learning environments can inspire students’ learning and provide students with a great deal of learning opportunities to improve their learning. Additionally, many studies have shown that game-based learning has positive effects on student’s spatial abilities and attention (Barlett, 2009). Moreover, a digital game also has a specific goal which motivates players to complete their task (Terborg, 1976). Furthermore, some research such as situated learning, problem solving, and learning motivation are also reported in the digital game-based learning (Li & Tsai, 2013; Tüzün, Yılmaz-Soylu, Karakuş, İnal, & Kızılkaya, 2009). Due to such diversity, there is a possibility that digital game-based learning will bring new learning methods.

Digital game-based learning can occur in the classroom or out of campus because learners can use mobile devices. As a matter of fact, digital game-based learning can also be employed to support education in any environment and give an opportunity for students to choose what they want to learn, and understand how well they learn. Thus, the learning and assessment method need to be changed because the information technology introduction in education. There are many previous studies indicate that mathematics is a very useful skill in daily life and impact learning on science (Espy et al., 2004). However, students learning mathematic are passives (Downes, 2005). In Taiwan, primary mathematical education currently adopts teacher-centered learning. Teachers are the main source of information, while students are required to be engaged in the same activity in the same place at the same time (Hwang et al., 2012). However, personal differences exist in every student. It is important that let students choose what they want to learn (Barr & Tagg, 1995). Among a variety of mathematical knowledge method, knowledge map is a useful method because it can affect how students associate the relationship with their prior knowledge. There are some prior studies showed that knowledge maps can help learners to memorize knowledge and connect the relationship with concepts (Davenport, 1998). A famous learning platform which called “Khan Academy” is also used knowledge maps and portfolio to help learners learn. Knowledge maps could help students to understand the relationships of mathematic concepts between course units and chapters. For this reason, knowledge maps could improve student’s learning performance (O'Donnell, 2002).

If we imported digital learning into learning environment, it may be brings many possibilities. Students can control their own learning progress and use all kinds of tools for learning. Therefore, teachers can be converted to the role of mentor and learning materials can be shared for each teacher (Hwang et al., 2012). Moreover, in the digital environment, it can record all students learning portfolio to show students learning effects. To this end, we try to design a digital game-based learning system which allows students control their learning by their own pace and provide a complete learning content with game-based model to enhance students’ motivation for learning. Based on the above background and motivation, this research develops a digital game-based learning system which called “Math Island” to help students learning. This system provides a variety of mathematical learning materials in a game-based knowledge map that allows students to choose learning contents and adjust learning directions by themselves. In other words, students can decide what they want to learn by their own-pace and reach self-regulation in this system. In addition, students’ learning situations are all recorded in the system. The system not only provides a visual city which using visible surface features such as building, people, and money to motivate students learning, but also have a learning portfolio to show students learning effects. In this way students can guide their own learning and achieve the learner-centered design. Finally, this study wants to explore Influence of students’ mathematical learning effect and motivation in the "math island" system.

2. Literature Review

2.1 Knowledge Map

The knowledge maps include concepts and relationships between concepts indicated by a connecting line linking two concepts. It can provide guidance for students to explore concept (Davenport & Prusak, 2000). A study by Patterson et al. (1992) indicates that training benefited students'' performance with knowledge maps. Novak (1990) investigated the concept maps are graphical tools for categorizing and representing knowledge. The other study by “SDC Learning and Networking” indicating that “A knowledge map is a useful tool for presenting what knowledge resides where (e.g. people, media, organizational units or sources of knowledge) and for demonstrating the patterns of knowledge flow”. Casonato（2000）consider that that knowledge map is a guidance that shows what resources can be used to help users in the shortest time to find the necessary knowledge. The main purpose of knowledge map is to present a variety of knowledge sources and guide users to use. Holsapple (2002) indicating that using a graphical presentation of a knowledge map can help users to understand and explore knowledge. In addition, O'Donnell (2002) research on the use of knowledge maps has consistently shown benefits for students with low verbal ability or skills. The aforementioned research shows that knowledge maps could improve student’s learning performance. To this end, this study attempt to transfer the curriculum to the knowledge map and evaluating the knowledge map design for student’s mathematic learning.

2.2 Self-regulation

Self-regulation refers to individual monitoring, controlling and directing aspects of their learning for themselves. Nowadays, students catch their own learning more effective with learning technology. After digital content has been imported in learning, students have the opportunity to decide what to learn. As a result, student Self-regulation learning becomes a new learning way. Self-regulation means that students can refer their own personal learning portfolio to decide personal learning goal and plan learning plan, then do self-paced learning. After learning, they can improve and adjust their individual learning (Bandura, 1986). In general, self-regulation is widely used in the learning situations because it can explain individual learning portfolio, monitoring individual effectively, and catch corrective self-reactions during learning. On the one hand, using technology to develop self- regulation learning is helpful for students to re-organize knowledge (Winne et al., 1998). As a result, students' learning and motivation are interdependent via self-regulation (Zimmerman, 1990). Furthermore, developing students' ability and skill about improving learning performance with self-regulation in school education and family education is an important thing. Moreover, the Self-paced learning also related to the self-management learning. Self-paced means that there are no group assignments or peer review and that learners are able to move with their own speed. Accordingly, using technology to help developing self-paced learning allows students to explore new forms of self-regulation learning and helps students re-organizing knowledge (Winne and Hadwin, 1997). In addition, another important approach is that learning and motivation of students is interdependent (Zimmerman, 1990). The study by Pintrich and Schrauben (1992) examined students are active while learning rather than being passive to accept information. Indeed, it's the best learning method for students that students are active in looking for learning opportunities and after finding learning opportunities, they learn with passion. Moreover, they try to find solutions themselves like setting goals and self-reflecting to adjust their learning method. As in section 1, students were often seemed as passive role in learning process and their learning methods and learning outcomes had a parallel relationship with the teacher teaching way (Kember, 1997). In brief, teacher not only was an assistant but also the protector of class order. Thus, students should leaded their own learning and it was meaning that they has a choice in their learning.

2.3 Learning Portfolio

Traditional approaches of learning, teaching, and assessment need to change after technology imported (Birgin & Baki, 2007). In the current learning environment, learning process should be more emphasized because the traditional test assesses student learning difficulty. Portfolios can be a valuable research tool to gain understanding about personal accomplishments (Tillema, 2001) and displaying student problem solving process, learning attitude, and the growth after learning (Lin, P.J. & Tsai, W. H., 2001). Student learning portfolio is a complete record which collecting information about learner purposely and keeps all student activity processes to understand the student's efforts, growth and achievements (Arter & Spande, 2005). More specifically, learning portfolio can be a useful tool to help student reflection and display their learning outcomes. In addition, the extracted portfolio data can present students' learning performance clearly for teachers, parents, and themselves.

Digital learning has developed rapidly in recent years, which is digitizing learning processes and use internet to store in a database to help recording, searching, organizing, and analyzing the learning portfolio (Chen, 2002). Learning portfolio let students grasp learning processes, as well as help students reflecting and reviewing all learning processes and learning outcome. Furthermore, the learning portfolio gave appropriate feedbacks to support student learning (Chang, 2001). Hence, the Math Island integrates learning portfolio concept to give students immediate feedback and reflection. Moreover, the Math Island also provides teachers with information to focus students' problems. So the Math Island wishes to help students reaching in meaningful learning.

3. System Design: Math Island

3.1 Learning process

The object of this system mainly used in elementary school's mathematics learning. All students play the role of a master who is the owner of the "Math Island". In the system, every student must manage their virtual island and attracts other virtual resident to living in the island. The business model of the Math Island built from a new ground. Each ground has a variety of construction projects (or learning task). The learning process of the Math Island as showed in figure 2. Students can plan their own construction projects which indicate that students could choose a learning task by themselves. In other words, students can do a mathematical learning task to advance their house. Students will get reward form system when they are completing a learning task. Then, the building will grow up by their learning effect. The visible surface features on building represent a portfolio for students. Finally, the island will be personalized because students can purchase some unique building to develop theirs island.

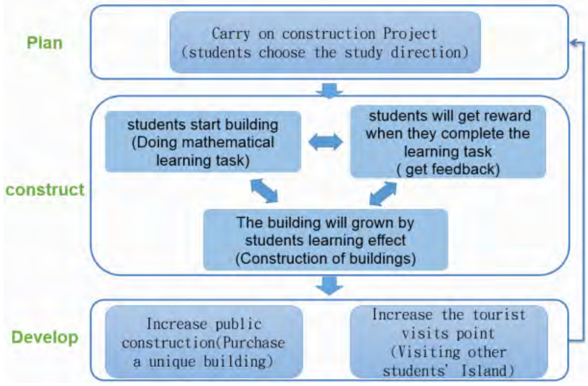

Figure 1. The Learning process of the Math Island system.

3.2 Learning content design

In recent years, the educational institution which called "Ministry of Education" promotes slight regulation for nine-year joint curriculum of elementary school and junior high school in Taiwan. The Ministry of Education indicators five-ability index of mathematics which are "Number and quantity", "geometric", "algebra", "Statistics and Probability", and "link". For this reason, the interface and learning content of the Math Island system is according to this five-ability index. However, the index about "algebra" and "link" are not adapted to be an index of the math island system. As a matter of fact, among the contents of the elementary school and junior high school, most of the "algebra" units are in the junior high school's curriculum. Furthermore, the index of "link" units contains many elements such as perceived transformation, problem solving, communication, and analysis. More specifically, it is difficult to define "link" and "algebra" be an index that these elements relate to many mathematic units. Accordingly, the index of "algebra" and "link" units are integrated with other units in this system. Besides, the index of "Number and quantity" in the system are divided into two indexes which called "Numeral and Computing" and "Quantity and Measure" because the "Number and quantity" are covering a wide range of curriculum in elementary school.

To this end, this study draws a mathematical knowledge map which was including four indexes: "Numeral and Computing", "Quantity and Measure", "geometric", and "Statistics and Probability" (see Figure 2). To begin with, these four indexes are depending on the nine-year joint curriculum and divided into a variety of units and sub-units. Then, each unit contains many sub-units and has principles to connect these sub-units. Finally, these units and sub-units have been classified into some roads in the system. Hence, there are many different roads which named by relate units in the math island system. Thus, the indexes of "Numeral and Computing" are containing a very large part of the Math Island because it plays an important role in the primary mathematic curriculums. Basically, the student can do learning tasks in different areas to perform mathematics learning. Table one show the design of knowledge map's structure on the Math Island. We are implementing a great amount of learning task in the system.

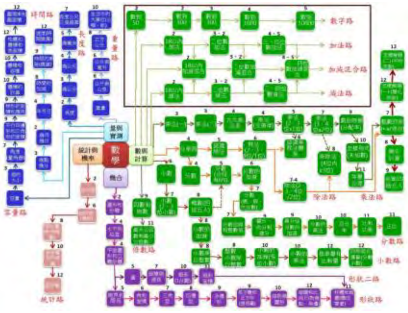

Figure 2. The knowledge map structure.

Figure 3. System interface in the system.

There are much different learning content in the math island. In the system, we design three types of task, such as prior concept review, concept teaching, and mastery learning for students' learning. However, the subject of mathematics learning was usually limited by student's prior knowledge (ex. If a student wants to learn" single-digit addition", he/she must understand the concept of "single-digit" and "addition"). Therefore, this course has been structured to operate in a self-paced manner. In addition, in order to confirm that students really learn a knowledge in self-paced, we set a mechanism which classified the prior concept review task and concept teaching task as "key task" to regulation on students learning. Students must have been completed the "key task" for fear that students have enough prior knowledge to do the next task. In other words, Students must get a passing "key task" to move to the next course.

Figure 4. Snapshot of the learning content interface.

The learning content of each task has referred to a variety of publishing house and re-design by many experts. The learning contents are included graph, text, and instructional videos to guide students learning. Besides, it provides a scratch paper and visual numeric keypad for students to answer questions. More specifically, the system also has a variety of materials which including crosswords, multiple choice, fill in the blank, matching, true or false of questions. These different kinds of questions can support students to learn different concepts. Finally, when students are answering a question, the system will calculate accuracy immediately. If students can get higher accuracy they will earn more rewards. Furthermore, the system will give students positive feedback when students respond a correct answer. Conversely, the system will give students hint to guide students when they respond a wrong answer. There are some learning content examples shown in the figure 4.

The other tasks are mastery learning task which using two digital games to appearing in the system. One is "Happy Farm", and the other is "Fishing Expert". These games have some game elements to enhance students' motivation for their learning. All of learning tasks in the math island develop in accordance with this mechanism.

Figure 5. Snapshot of A mastery learning games.

3.3 System mechanism

When students login into the system, an arrowhead would be displayed on the monitor and guide them to choose a learning unit (see Figure 6). In addition, if students click a building, the scenario will transfer to "learning lobby". The lobby will present many learning tasks for students to choose. The task with blue color means that it can be performed. On the contrary, the gray means students need to complete the prior key task to open the task.

Figure 6. Some arrowheads guiding students' learning.

Figure 7. A task list in the building.

In addition, as shown in figure 8, the system also provides immediate feedback mechanism to help students answer a question. More specifically, when students input a correct answer, the system will show "√" message to represent the correct answer. In contrast, when students input a wrong answer, the system will give immediate feedback or hints to help student's reflection. The rewards for students are according to their accuracy rate in the task. Besides, in the system, each student can construct the map individually and giving feedback for teacher on the level of understanding of every student. Within the option of individual construction of the map, the students can be allowed to visit the other student's island where students are able to share information. The system provides this mechanism for students to interact with others and enhance their learning motivation.

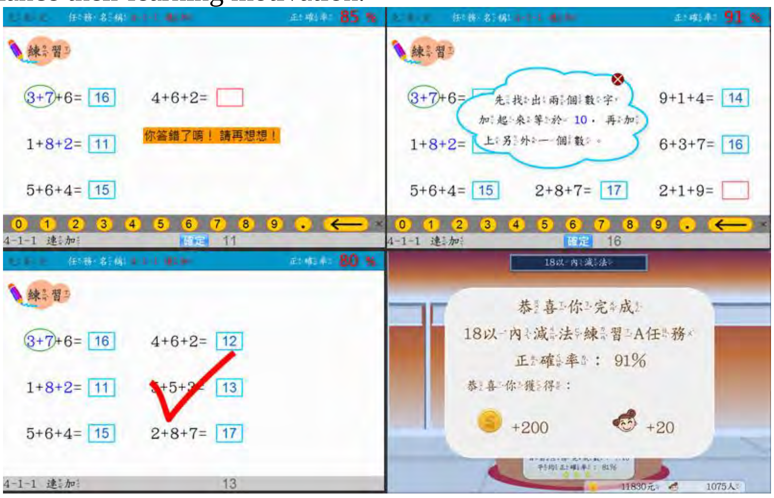

Figure 8. Snapshot of the learning task with immediate feedback.

According to task completion, the buildings can be divided into four grades in total. As show in figure 9, students' learning outcomes will be presented in these buildings to show students learning progress in the Math Island system. In addition, students can understand their learning situation and reflection themselves by their own-paced.

Figure 9. Four grades in the buildings.

4. Case Study

4.1 Participants and Data collection

The participants were 217 second-grade students of a primary school in Taiwan. All participants have a tablet PC to conduct a digital environment. At the beginning, we held a typing training program and system introduction course in order to make sure that all participants could control the prerequisite skill. At the end of the training program, the participants' can login the Math Island system to do a learning task by their own-pace. The systems will collection all user data in the database.

4.2 Preliminary results

According to the system data, some students not only reached the standard progress in semester 1 but also reached the second-grade progress by using the system. Furthermore, the data in Table 1 demonstrates the progress in different mathematic units of all students. The standard curriculum pace is 101-1 and more than 210 students can reached the next semester curriculum. The preliminary shows that some students have a good progress by self-learning but it also need to In-depth analysis in the further research.

Table 1: The results of the student's task data.

	2th Grade Class 1	2th Grade Class 2	2th Grade Class 3	2th Grade Class 4	2th Grade Class 5	2th Grade Class 6	2th Grade Class 7	2th Grade Class 8	Total
Participants	26	28	27	28	27	27	27	27	217
Complete task number	123	138.1	121.1	134.3	130	129.7	128.0	141.6	130.72
Average accuracy	88.26	90.28	88.33	89.52	87.83	88.26	89.16	87.97	88.701
Less than 101-1	1	2	3	0	0	0	0	1	7
Reached 101-1	25	26	24	28	27	27	27	26	210
Reached 101-2	9	22	11	17	18	15	16	22	130
Reached 102-1	1	1	0	2	0	0	0	4	8
Reached 102-2	0	0	0	1	0	0	0	1	2

5. Conclusion and discussion

In this study, the Math Island system with knowledge map and self-regulation design was developed for students in learning mathematics by their own-paced and self-reflection in an easier way. We produced 488 mathematics interactive materials, videos and games and conduct a management game to motivates students' learning. Meanwhile, the aims of this study not only examined whether the Math Island system is useful to improve students' learning motivation, but also investigated how students' learning progress in the system. The preliminary results show that elementary students may be able to learn in the self-regulation learning environment and learning well themselves. However, although students' progresses were increasing at this time, how the influence on the system should be further evaluated and discussed. In the future, we will do more detailed data analysis of the system, support more learning materials and implement a diagnosed mechanism in the system to help students learning.

Acknowledgements

The authors would like to thank the National Science Council of the Republic of China, Taiwan, for financial support (MOST 101-2511-S-008 -016 -MY3, MOST 100-2511-S-008 -013 -MY3) and Research Center for Science and Technology for Learning, National Central University, Taiwan.

References

Arter, J. A., & Spandel, V. (2005). Using portfolios of student work in instruction and assessment. *Educational Measurement: Issues and Practice*, *11*(1), 36-44.

Bandura, A. (1986). The explanatory and predictive scope of self-efficacy theory. *Journal of Clinical and Social Psychology*, 4, 359-373.

Barr, R. B., & Tagg, J. (1995). From teaching to learning—A new paradigm for undergraduate education. *Change: The magazine of higher learning*, *27*(6), 12-26.

Barlett, C. P., Anderson, C. A., & Swing, E. L. (2009). Video game effects confirmed, suspected and speculative: A review of the evidence. Simulation & Gaming, 40(3), 377-403.

Birgin, O., & Baki, A. (2007). The use of portfolio to assess student" s performance. *Journal of Turkish Science Education*, *4*(2), 75-90.

Casonato, R., Furlonger, J., & Harris, K. (1999). What Are the Steps Needed to Create a Knowledge Map? . GartnerGroup Research Note, 26(July).

Crawford, C. (1982). *The art of computer game design*. Retrieved from http://www.vic20.vaxxine.com/wiki/images/9/96/Art_of_Game_Design.pdf

Chang, C-C. (2001) “A study on the evaluation and effectiveness analysis of web-based learning portfolio”, *British Journal of Educational Technology*, Vol 32, No 4, pp 435-458.
Chen, D. L. (2002) .Design And Implementation of a Web-Based Portfolio Supporting System. (Doctoral dissertation or master's thesis). Retrieved from http://etd.lib.nsysu.edu.tw/ETD-db/ETD-search/getfile?URN =etd-0625102-190739&filename=etd-0625102-190739.pdf
Downes, S. (2005, October 17). E-learning 2.0. eLearn Magazine [Web blog message]. Retrieved from http://elearnmag.acm.org/featured.cfm?aid=1104968
Davenport, T. H., David, W., & Beers, M. C. (1998). Successful knowledge management projects. *Sloan management review*, *39*(2), 43-57.
Davenport, T. H., & Prusak, L. (2000). *Working Knowledge: How Organizations Manage What They Know*, Harvard Business Press.
Evans, C. (2008). The effectiveness of m-learning in the form of podcast revision lectures in higher education. *Computers & Education*, 50(2), 491–498. doi:10.1016/j.compedu.2007.09.016
Gartner Group (2000)."Mapping knowledge to the process: directions to success". Advisory Research Note.
Holsapple, C. W., & Joshi, K. D. (2002). Knowledge management: A threefold framework. *The information society*, (18), 47-64.
Huizenga, J., Admiraal, W., Akkerman, S., & Dam, G. ten. (2009). Mobile game-based learning in secondary education: engagement, motivation and learning in a mobile city game. *Journal of Computer Assisted Learning*, 25(4), 332–344. doi:10.1111/j.1365-2729.2009.00316.x
Hwang, G. J., Su, J.M. & Chen, N. S. E-learning: Theory & practice (pp. 2-29). Taiwan：Drmaste.
Kiili, K. (2005). Digital game-based learning: Towards an experiential gaming model. *The Internet and higher education*, *8*(1), 13-24.
Kiili, K., & Ketamo, H. (2007). Exploring the learning mechanism in educational games. *Journal of Computing and Information Technology*, *15*(4), 319-324.
Kember, D. (1997). A reconceptualisation of the research into university academics' conceptions of teaching. *Learning and instruction*, *7*(3), 255-275.
Liaw, S.-S. (2008). Investigating students’ perceived satisfaction, behavioral intention, and effectiveness of e-learning: A case study of the Blackboard system. *Computers & Education*, 51(2), 864–873. doi:10.1016/j.compedu.2007.09.005
Li, M.-C., & Tsai, C.-C. (2013). Game-Based Learning in Science Education: A Review of Relevant Research. *Journal of Science Education and Technology*, 22(6), 877–898. doi:10.1007/s10956-013-9436-x
Lin, P.J. & Tsai, W. H. (2001). Using research-based cases to enhance prospective teachers’ understanding of teaching mathematics and their reflections. In F. L. Lin (Ed.), *Common sense in mathematics education (pp. 231-272). Proceedings of 2001 the Netherlands and Taiwan Conference on Common Sense in Mathematics Education*, 19-23, November 2001. Taiwan: Taipei.
Liu, T.-Y., & Chu, Y.-L. (2010). Using ubiquitous games in an English listening and speaking course: Impact on learning outcomes and motivation. *Computers & Education*, 55(2), 630–643. doi:10.1016/j.compedu.2010.02.023
Novak, J. D. (1990). Concept maps and Vee diagrams: Two metacognitive tools to facilitate meaningful learning. *Instructional science*, *19*(1), 29-52.
Patterson, M. E., Dansereau, D. F., and Newbern, D. (1992). Effects of communication aids and strategies on cooperative teaching. J. Educ. Psychol. 84: 453–461.
Pintrich, P. R., & Schrauben, B. (1992). Students’ motivational beliefs and their cognitive engagement in classroom academic tasks. *Student perceptions in the classroom*, 149-183.
Prensky, M. (2001). *Digital Game-Based Learning*. New York: McGraw-Hill.
Papastergiou, M. (2009). Digital Game-Based Learning in high school Computer Science education:Impact on educational effectiveness and student motivationa. *Computers & Education*, *52*(1), 1-12.
Paraskeva, F., Mysirlaki, S., & Papagianni, A. (2010). Multiplayer online games as educational tools: Facing new challenges in learning. *Computers & Education*, 54(2), 498–505. doi:10.1016/j.compedu.2009.09.001
Tillema, H. H. (2001). Portfolios as developmental assessment tools. *International Journal of Training and Development*, *5*(2), 126-135.
Terborg, J.R.(1976). The motivational components of goal setting. *Journal of Applied Psychology*, 61, 613– 621.
Tüzün, H., Yılmaz-Soylu, M., Karakuş, T., İnal, Y., & Kızılkaya, G. (2009). The effects of computer games on primary school students’ achievement and motivation in geography learning. *Computers & Education*, 52(1), 68–77. doi:10.1016/j.compedu.2008.06.008
Van Eck, R. (2006). Digital game-based learning: It's not just the digital natives who are restless. *EDUCAUSE review*, *41*(2), 16.
Winne, P. H., & Hadwin, A. F. (1998). Studying as self-regulated learning. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 279-306). Hillsdale, NJ: Erlbaum.
Zimmerman, B. J. (1990). Self-regulated learning and academic achievement: An overview. *Educational psychologist*, *25*(1), 3-17.