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Digital Game-Based Learning as an Innovation to Enhance Understanding and Motivation for Mathematics and Sciences Classroom

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Abstract: Current, technology is the most important for the daily life. In education, technology is the most context in learning style. Game is one technology that previous study found that game can promote student learning because game have important property to engagement and funny. Therefore, the research has two studies. The first study, to design and development of digital game-based learning (DGBL). The second study, the objective of this study to evaluate of DGBL. Research found that DGBL's effectiveness in learning Science and Mathematics. DGBL motivated learners' motivation and supported their understanding of content, even though the nature of them is complex and hard to understand.

Keywords: Digital game; smart learning environments; model-based learning; technology enhance learning; STEM

1. Introduction

Technology plays important roles in daily life and its significant factors attributed to change the aspects of education in the 21st century. Almost new generations get involved in technology and applied it to support learning in the future. It stimulates learners to be automatically digital learners and assists them to acquaint with technological rapid technology. Education institutes have attempted to incorporate technology into the classroom to make changes and deliver learning and teaching. Technology enables to capture learners' attention and motivate digital natives as Gen Z. They develop their understanding and accommodate their misconception to learning, Mathematics, and Science, particularly (Kärrqvist,1985). The general natures of these subjects are absolutely complex and abstract. Students are lack of motivation and unwilling to participate in learning because of their difficulty. Additionally, It requires students' efforts to deal with intricate problem-solving. Learning Mathematics and Science context found that methodology mostly applied in teaching is implication and knowledge transfer. Learning content directly transfer to learner and students receive that knowledge. Especially, teaching Mathematics teachers provides questions and then students focus on the teacher's problem. Teaching science needs a laboratory room and experimental tools for the experiment, but they are built in some schools. Specialist teachers for teaching science and know how to apply the tools in the laboratory are sufficient. As a result, teaching is mostly orientation. Students miss opportunities to participate in the experiment, tool application, and full part of learning activities. These attributed to the lower average of learning Mathematics and Sciences achievement.

Digital game-based learning is a technological integration into translate content and concept of learning. It can help to promote student learning in classroom and promote student motivation in learning science (Liu, Cheng & Huang, 2011). The impact of games on learning have resulted in conflicting findings depending on what criteria for inclusion and exclusion of articles were used, and which outcome variables were considered. These decisions were influenced by the authors' theoretical approach to the use of digital games for learning. Among these approaches, two are particularly prominent: a cognitive perspective (Blumberg, 2011; Fletcher & Tobias, 2005; Mayer, 2005; Shute, Ventura, & Ke, 2014; Spence & Feng, 2009) and a sociocultural perspective (De Freitas, Rebolledo-Mendez, Liarokapis, Magoulas, & Poulovassilis, 2010; Shaffer, 2006; Squire, 2008, 2011; Steinkuehler, Squire, & Barab, 2012). Depending on which perspective is taken, games are considered either environments that are motivating but likely to require excess amounts of information to be processed by the learner (cognitive perspective) or, conversely, approaches that provide the rich contextual information and interactions needed for learning in the 21st century. Moreover, technology can help student to learn in a meaningful by linking their prior knowledge to new knowledge and can apply the new knowledge for daily life (Jonassen, 1997). In previous research found that technology can use to support learners to understand the concept of learning science in a more meaningful and understandable way. In term of physics technologies can improve student to understand in complicate and abstract content (Srisawasdi & Kroothkeaw, 2014). However, teachers' perspectives on digital game-based learning are entertainment purpose and students neglect to emphasize to its complex content. As a result, this research is to design methodology that integrates learning theory, brain theory, and technology characteristics to develop digital game-based learning. The design is to increase motivation and understanding of Mathematics and Science learning.

2. Theoretical framework

Researcher had reviews related literature to create a theoretical framework for designing digital game-based learning. The theory study revealed learning that is fun appears to be more effective (Lepper & Cordova, 1992). Also, Quinn (1994) argues that for games to benefit educational practice and learning, they need to combine fun elements with aspects of instructional design that include motivational, learning and interactive components. Nonetheless, the elements of instructional design not only focus on entertaining purpose, but it also aims to develop learners' higher thinking.

2.1 Constructivism Learning Environment

Learning theory is principles that describe human learning to acquire knowledge and abilities. Jonassen and others (2003) proposed that human has constructed knowledge when they are stimulated with certain conflicts, questions, and learners' curiosity. Knowledge construction is the process of cooperating between what is to be learned and what is observed in real life. In the other words, Teaching is not a vital process in which knowledge is constructed because learners are unable to expect what teachers know and their knowledge is not utter transferability to learners. Therefore, environment learning management is the important process to construct knowledge and knowledge representation. Meaningful models derived from learners' experiences, action and reasonable decision making. This concept is applied to develop learning Science and problem-solving mathematics (Looi, et al, 2005; Jonassen, et al, 2011*)*.

2.2 Model-Based Learning

The significant learning approaches with model comprised of 2 modelling: functional-pragmatic approach and a constructivist approach. These approaches are used to create a learning modeling because of their relevance to mental model. Modeling as a process is also important because it is one of the most concept engaging cognitive process that can be performed. Solving design problems are potentially more engaging, however, technology to date better afford modeling process than designing activities which are less constrained and more complex. Mayer (1989) assumed that learners have more opportunities to create a systematically mental model when they are treated with modeling instruction. Modeling is used as a clue to problem-solving and enables to connect to other contextual problems. The learning model has its effectiveness in understanding development and problem solution in learning complex and abstract subjects. According to more than 100 researches in mental model, it revealed that pre-learning and during learning information model preparation has substantial efficiency and effectiveness to assist learners creating a mental model (Mayer, 1989; Jonassen & Henning, 1999). Discovery-based modelling is a method and applied to develop a mental model in learning and teaching Mathematics and Science (Lehrer& Schauble, 2000; Penner, et al, 1997).

2.3 Brain-Based Learning

Brain-Based education applied the results of neuroscience and how the brain works to be an essential ground in learning design. Based-based research studies about sensory perception attention, memory and emotion that affects learning (Goleman, 1997; Sprenger, 1999). The significant findings are applied to be a ground of learning design. Learning atmosphere is created by compatibly integrating knowledge and emotions; positive emotion refers to happiness, self-confident and self-valued, for example. Amygdala enables to pass emotions to the hippocampus. The content design is necessary to connect learners' prior experience at easing understanding content. Another is learning management that needs to support learners' independent, feel free of controlling and promote to learn by doing (Caine, et al, 1994). The understanding of executive functions' working is also important. Executive functions (EFs) are brain-based cognitive skills that facilitate critical thinking and self-regulation. Executive functions call upon the prefrontal cortex of our brains to help with goal-setting and decision making. These skills include flexibility, focus, organization, planning, self-awareness, self-control, time management, and working memory (Diamond, 2013).

2.4 Game-Based Learning

Definitions of game-based learning mostly emphasize that it is a type of game play with defined learning outcomes (Shaffer, Halverson, Squire, & Gee, 2005). Usually it is assumed that the game is a digital game, but this is not always the case. A corollary to this definition is that the design process of games for learning involves balancing the need to cover the subject matter with the desire to prioritize game play (Plass, Perlin, & Nordlinger, 2010). This corollary points to the distinction of game-based learning and gamification. What exactly is meant by gamification varies widely, but one of its defining qualities is that it involves the use of game elements, such as incentive systems, to motivate players to engage in a task they otherwise would not find attractive. Similarly, there is an ongoing debate among scholars as to the exact definition of a game, and especially what is not a game. One definition defines a game as "a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome" (Salen & Zimmerman, 2004). Consider as an example the gamification of math homework, which may involve giving learners points and stars for the completion of existing activities that they consider boring. Game-based learning of the same math topic, on the other hand, even though it may also include points and stars, would involve redesigning the homework activities, using artificial conflict and rules of play, to make them more interesting and engaging.

3. Methodology

3.1 Research Framework

This research has designed the research as shown in the following diagram.

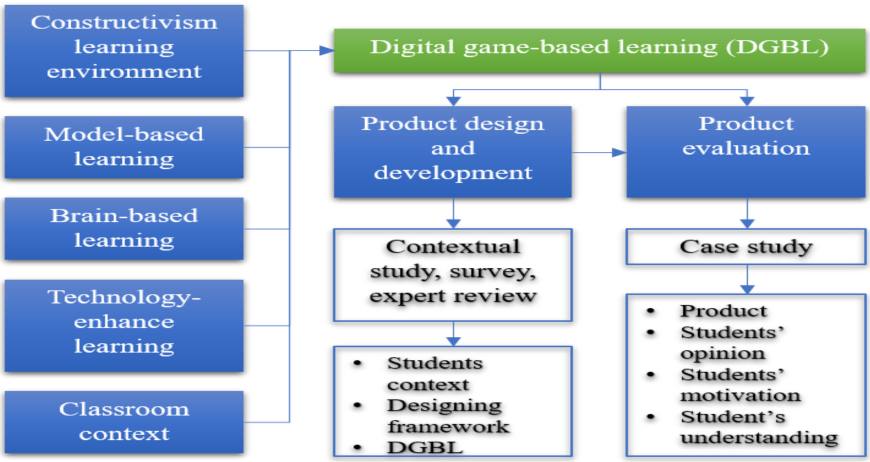


Figure 1. Research framework

3.2 Data Collection and Analysis

The study divided into 2 phases, (1) Product design and development: researcher design and develop the product by surveying learners' learning context and their characteristics in learning. The population of this study was Grade 6th students of Elementary School in the number of 90 people. A test and questionnaire used learning-based theory to design. Data derived from Learning achievement and perception and knowledge background of learning Science and Mathematics, being synthesized to be a design framework for game-based digital learning. A framework was scrutinized by 5 experts and then researcher created game-based digital learning. (2) Product evaluation: Researcher brought the product to experiment in the real classroom to evaluate with Grade 6th students of Elementary School in the number of 41 people. In organizing activities, DGBL is used as a learning tool in learning plan in the flipped classroom designed by teacher. DGLB was used in Pre-class and Post-class to review learners' content comprehension. The research tools comprised of opinion survey form, comprehension and motivation test form, experts' tool evaluation form. The data was calculated by statistics.

Figure 2. Illustrated data collection and students learning with digital game-based learning

3.3 Digital Game-Based Leaning

The conceptual framework of DGBL design consisted of 5 principles, namely Knowledge engagement, Constructivism learning engagement, Cognitive, social engagement, Model-based engagement, and Brain's executive function engagement. These principles were synthesized to be components of DGBL: (1(Context/task refers to problem representation to stimulate learners' curiosity and exploration. (2(Learning mechanic refers to path design of game based-learning which emphasized on knowledge acquirement through a mission setting. (3) Incentive system refers to mission design to motivate and arouse learners' emotion and challenge.)4(Scaffolding refers to assist design that learners apply to solve problems. (5(Aesthetic design refers to interface design to engage learner's attention in activities. (6(Knowledge resource refers to information source to support learning and problem-solving.

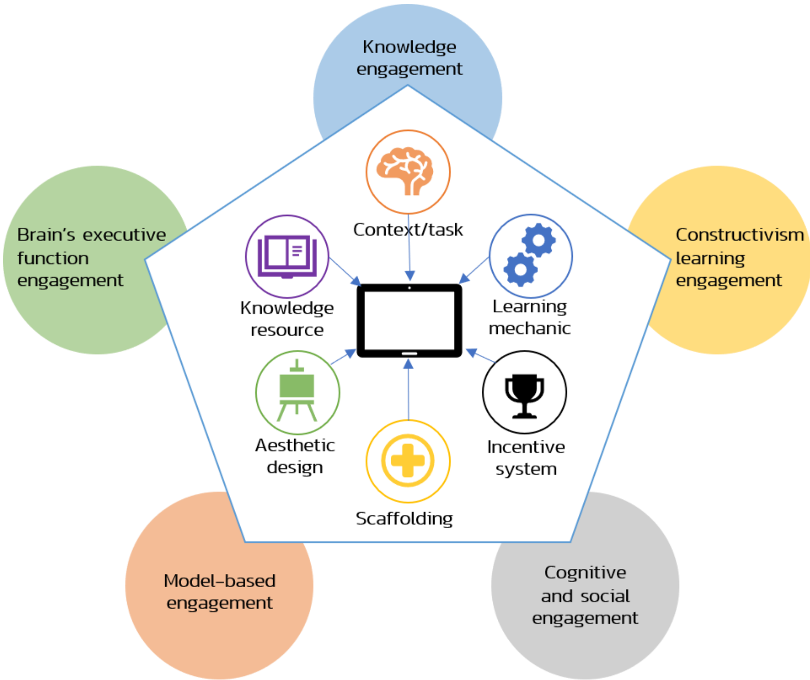
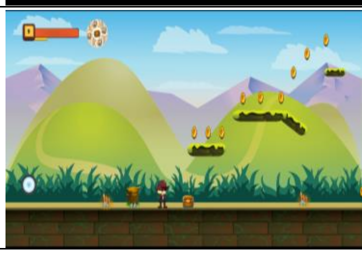


Figure 3. Illustrated Digital game-based learning (DGBL) framework

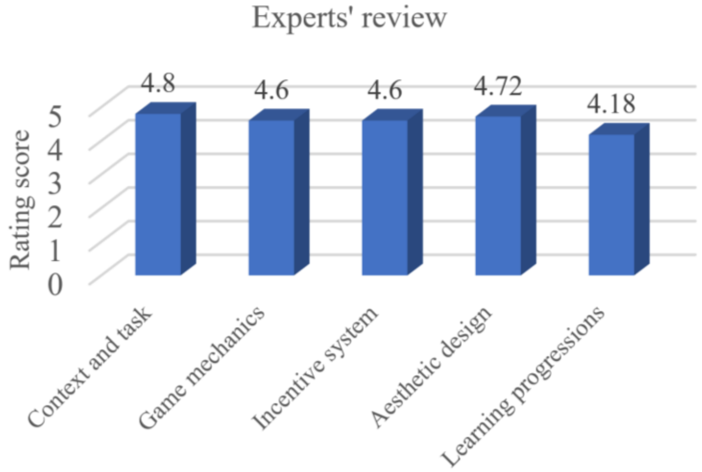
Table 1

An Example Screen Design of Digital Game-Based Learning

Description	*Example Screen Design*	
Illustrated DGBL interface for sciences and mathematics		
Illustrated context/learning task focused on the real context in order to motivate students to solve problems and inquiry knowledge.		
Illustrated DGBL Learning mechanic interface		

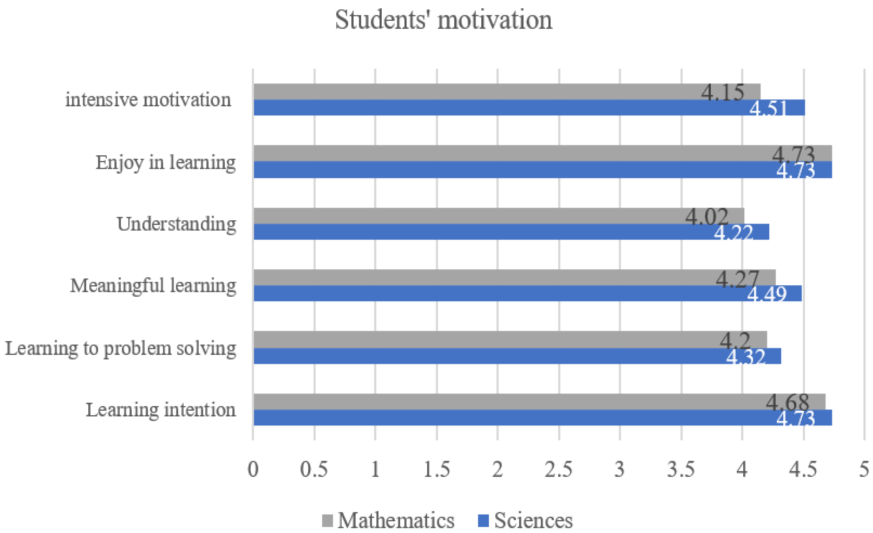
4. Result and Conclusion

4.1 Result of experts' evaluation



According to bar chart above, it illustrated that total quality of DGBL was the highest level with the average of)$\bar{x}$ =4.59, S.D. =0.20). Context and task were $\bar{x}$ =4. 80, Aesthetic design and music was $\bar{x}$ =4. 72 and learning progression was $\bar{x}$ =4.59 respectively.

4.2 Students' motivation on learning with DBGL



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4.3 Students' understanding on learning with DBGL

Table 2 The displayed mean and statistic deviation of learners' understanding assessment of learning Science.

Grade	Test	Number	Mean	Percentage	S.D.
Grade 6th	Pretest	41	7.54	18.84	2.85
	Posttest	41	21.17	52.93	3.65

From table 1.1 above, it showed that the average of pretest and posttest of Grade 6th students of elementary school in learning Science in the topic of electricity. The average pretest and posttest were significantly different. The pretest was $\bar{x}$ = 7.54, S.D = 2.85 and pretest was $\bar{x}$ = 21.17, S.D = 3.65. Importantly, the average of posttest increased.

Table 3 The displayed mean and statistic deviation of learners' understanding assessment of learning Mathematics.

Grade	Test	Number	Mean	Percentage	S.D.
Grade 6th	Pretest	41	13.41	33.54	4.94
	Posttest	41	22.76	56.89	5.20

From table 2 above, it showed that the average of Pretest and Posttest of Grade 6th students of elementary school in learning Mathematics in the topic of Algebra. The average pretest and posttest were considerably different. The pretest was $\bar{x}$ = 13.14, S.D = 33.54 and pretest was $\bar{x}$ = 22.76, S.D = 5.20. The posttest score increased when comparing to pretest score.

4.4 Discussion and Conclusion

According to the result above, it determined DGBL's effectiveness in learning Science and Mathematics. DGBL motivated learners' motivation and supported their understanding of content, even though the nature of them is complex and hard to understand. DGBL's design stimulated their challenge to problem-solving. These are consistent with research of Looi, et al, (2006), Jonassen & Marra (*2011*). Additionally, DGBL's system creation continuously motivated learners' curiosity and affected to their learning emotion (Sprenger, 1999; Caine, et al, 1994; Diamond, 2013). The alteration of content-oriented presentation applied a model to ease at processing information. The application of model-based leaning principles helps to create a mental model to understand difficult and complex content (Lehrer & Schauble, 2000; Penner, et al, 1997). Based on the findings, it can be insisted that DBGL is a tool that supports unconfident learners in learning Science and Mathematics and able to apply in activities for Flipped classroom. Students enable to study from DBGL before learning and it is also used as a tool for reviewing comprehension after classroom activities.

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References

Anderson, R. E. (1992). Social impacts of computing: Codes of professional ethics. *Social Science Computing Review*, *10*(2), 453-469.

Blumberg, F. C. (2011). Ramifications of video game play for academic learning and cognitive skill acquisition: Introduction. *Child Development Perspectives*, 5, 73–74.

Caine, G., Caine, R. N., & Crowell, S. (1994). *MindShifts: A brain-based process for restructuring schools and renewing education*. Arizona, Zepher Press.

Chan, T. W., Roschelle, J., Hsi, S., Kinshuk, Sharples, M., Brown, T. et al. (2006). One-to-one technology-enhanced learning: An opportunity for global research collaboration. *Research and Practice in Technology-Enhanced Learning*, *1*(1), 3-29.

Conger, S., & Loch, K. D. (1995). Ethics and computer use. *Communications of the ACM*, *38*(12), 30-32.

De Freitas, S., Rebolledo-Mendez, G., Liarokapis, F., Magoulas, G., & Poulovassilis, A. (2010). Learning as immersive experiences: Using the four-dimensional framework for designing and evaluating immersive learning experiences in a virtual world. *British Journal of Educational Technology*, 41, 69–85.

Diamond, A. (2013). Executive Functions. *Annual Review of Psychology*. 64:135-168.

Fletcher, J. D., & Tobias, S. (2005). The multimedia principle. In R. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 117–133). New York, NY: Cambridge University Press.

Goleman, D. (1997). *Emotional Intelligence*. New York: Bantam Books.

Jonassen, D. (1997). Instructional design models for well-structured and ill-structured problem-solving learning outcomes. *Educational Technology Research and Development*, 45, 65-94.

Jonassen, D. H., Peck, K. L., & Wilson, B. G. (1999). *Learning to Solve Problems with Technology: A Constructivist Perspective (2nd Edition)*. Columbus, OH: Prentice Hall.

Jonassen, D.H., & Henning, P. (1999). Mental model: Knowledge in the head and knowledge in the world. *Educational Technology*, 39(3), 37-42.
Jonassen, D.H., Howland, J., Moore, J., & Marra, R.M. (2003) *Learning to Solve Problems with Technology: A Constructivist Pperspective*, 2nd. Ed. Columbus, OH: Merrill/Prentice-Hall.
Jonassen, D. H., Howland, J. L., & Marra, R. M. (*2011*). *Meaningful learning with technology*. Boston, MA: Pearson Education.
Kärrqvist, C., (1985). The Development of Concepts by Means of Dialogues Centred on Experiments. In: R. Duit, W. Jung, C. von Rhöneck (Eds) , *Aspect of Understanding Electricity*, 73-83.
Lehrer. R., & Schauble, L. (2000). Modeling in mathematics and science. In R. Glaser (Ed.) Advances in instructional psychology: volume 5. *Educational design and cognitive science*,101-159. New Jersey: Lawremce Erlbaum.
Lepper M R and Cordova D I.(1992). A desire to be taught: Instructional consequences of intrinsic motivation. *Motivation and Emotion*. (16),187–208.
Liu, C., Cheng, Y. & Huang C. (2011). The effect of simulation games on the learning of computational problem solving. *Computer & Education*. C.-C. Liu etal. (57), 1907-1918.
Looi, C.K., Jonassen, D. H., & Ikeda, M. (2005). Towards sustainable and scalable educational innovations informed by the learning sciences: Sharing good practices of research, experimentation and innovation. *Proceedings from the 13th International Conference on Computers in Education (ICCE 2005)*. Singapore: IOS Press. 28 November-30 December.
Mackay, W. E. (1995). Ethics, lies and videotape. In I. R. Katz, R. Mark, L. Marks, M. B. Rosson, & J. Nielsen (Eds), *Proceedings of CHI'95* (138-145). Denver, Colorado: ACM Press.
Mayer, R. E. (1989). Models for Understanding. *Review of Educational Research*. 59 (1), 43-64.
Mayer, R. E. (2005). Cognitive theory of multimedia learning. In R. Mayer (Ed.), *The Cambridge handbook of multimedia learning*. (31–48).
Penner, D. E., Giles, N. D., Lhrer, R., & Tompsett, C. (1997). Building functional models: designing and elbow. *Journal of Research in Science Teaching*, 34(2), 125-143.
Pavlas, D., Heyne, K., Bedwell, W., Lazzara, E., & Salas, E. (2010, September). Game-based learning: The impact of flow state and videogame self-efficacy. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. 54 (28) 2398–2402. Thousand Oaks, CA: Sage.
Quinn C N .(1994). Designing educational computer games in Beattie K, McNaught C and Wills S (eds) *Interactive multimedia in University Education: Designing for change in teaching and learning* Elsevier Science BV, Amsterdam, 45–57.
Salen, K., & Zimmerman, E. (2004). Rules of play: Game design fundamentals. Cambridge, MA: MIT Press
Schwartz, M., & Task Force on Bias-Free Language of the Association of American University Press (1995). *Guidelines of Bias-Free Writing*. Bloomington, IN: Indiana University Press.
Shaffer, D. W., Halverson, R., Squire, K. R., & Gee, J. P. (2005). *Video games and the future of learning* (WCER Working Paper No. 2005-4). Madison: University of Wisconsin–Madison, Wisconsin Center for Education Research (NJ1)
Shaffer, D. W. (2006). Epistemic frames for epistemic games. Computers & Education, 46, 223–234.
Shute, V., Ventura, M., & Ke, F. (2014). The power of play: The effects of portal 2 and lumosity on cognitive and noncognitive skills. *Computers & Education*, 80, 58–67.
Sprenger, M. (1999). Learning and memory, *The brain in action*. Alexandria Virginia. ASCD.
Spence, I., & Feng, J. (2010). Video games and spatial cognition. *Review of General Psychology*, 14, 92–104.
Squire, K. D. (2008). Video games and education: Designing learning systems for an interactive age. *Educational Technology*, 48(2), 17–26
Squire, K. (2011). Video games and learning: Teaching and participatory culture in the digital age. *technology, education*—Connections (The TEC series). New York, NY: Teachers College Press
Srisawasdi, N., & Kroothkeaw, S. (2014). Supporting students' conceptual development of light refraction by simulation-based open inquiry with dualsituated learning model. *J. Comput. Educ*.
Steinkuehler, C., Squire, K., & Barab, S. (Eds.). (2012). *Games, learning, and society: Learning and meaning in the digital age*. Cambridge, MA: Cambridge University Press.