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Investigating Factors Affecting Conceptual Learning Progression when Playing Digital Game-based Inquiry Learning for Energy Education

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Abstract: One of the challenges of promoting students constructing knowledge on abstract topic as energy is helping them make the relationship between the theoretical-world and their life outside the classroom, through inquiry of the elements of energy consumption by daily used household electrical appliances in the digital game. Factors that increase students' conceptual learning progression in the digital game-based inquiry learning are challenged to be investigated. In this study, factors of Enjoyment, Inquiry, and Intention to Use were selected as important attitudes in learning game and promoting conceptual learning progression. To verify the effectiveness of the game, sixty-six secondary school students participated in the digital game-based inquiry learning for energy education. The results showed that the game impacted moderately on improving the students' conceptual understanding progression on energy consumption topic, students' inquiry of the game has a significant relation with their learning progression, and students' enjoyment and intention to use with the game do not significantly have a relation with their learning progression. Our results suggest that there are attitudinal factors affecting conceptual learning progression gained by the digital game-based inquiry learning.

Keywords: Game in education, learning progression, energy education

1. Introduction

It is known that school science subjects, like physics, chemistry and biology contain lots of theoretical concepts which students find difficult to understand and thus have misconceptions in it. Because of this, students rarely link the knowledge gained from those sciences in day-to-day life. This is all due to the narrow relation between how they are taught and what they learn (Kurt and Ayas, 2012; Ozmen, 2008). Normally in traditional teaching approach, teachers often over-rate the importance of their content and under-rate their impact in students' learning. Thus, attempts to teach students all that they need to know become ineffective because students forget much of the content that they memorize. Most of the time in traditional teaching, teachers concern much about time limitation for teaching vast content of the subjects so they rarely encourage students in class discussion, collaborative learning, and inquiry-based activities that often take time. However, for effective learning, teachers must develop learning activities that encourage students on how to use scientific knowledge to solve important queries and help in deep thinking rather than worrying about covering the content. Deep thinking is essential because understanding is the residue of thinking. To encourage thinking, learning should incorporate activities that create a joy, an excitement, and loves for learning so that the students will be impatient to run home, study, and contemplate– to real learning (DiCarlo, 2009).

In the recent years, there are varieties of resources developed and are available. Incorporating such resources can be the best appropriate instructions that can fit the goal of achieving active learning. This has been a challenge for science teachers especially to teach abstract concepts, such as energy to young children (Duit, 1981; Yuenyong, Jones and Sung-Ong, 2011). So there has been always hunt for better learning method(s) to inculcate this concept in students because energy education has become an

area of major importance for those who are responsible for school teaching. As per DeWaters and Powers (2011), energy education enables clients to identify the better ways to save energy. However, the study indicated that while almost everybody agrees that they want to conserve energy, this often does not translate into action. Further, the study also showed that domestic energy usages are invisible to the consumers most of the time. This is simply because most people have only a vague idea of how much energy they are using for different purposes and what sort of difference they could make by changing day-to-day behavior or investing in efficient methods. For this reason, energy consumption has not declined significantly in reality (Boyde, 2002; Yang, Chien and Liu, 2012). This difficulty may be due to the fact that users usually either do not know how much electricity is consumed by their household electrical appliances or do not have any idea of how to save electricity in an appropriate way. As stated by Bates (2003), to meet the consequences of the paradigm shift from industrial age to information age, the current approaches and methods of instructions are insufficient. Eventually, the instructional designers are facing with the challenges of making learning situation to fit an instructional design/ development of model rather than selecting suitable model to fit the needs of changing learning situations (Gustafson and Branch, 2002).

In recent years, there are many books and articles published, indicating various approaches for learning the different forms of energy, energy transformation, and the law of conservation of energy (Aggul, Yalcin, Acikyildiz and Sonmez, 2008). However, student's prevailing ideas about energy are still found to be different from the scientific perspective. These days, a number of active learning units employing simulations and games have been developed for educational purpose in many disciplines like mathematics, science, engineering, humanities, and social sciences (Cai, Lu, Zheng and Li, 2006; Eck, 2006). Many students prefer learning by using computer games as it has lots of benefits in students' habits and interests (Gee, 2006; Prensky, 2007). Games in education provide students to interact and gain learning experience from those activities that are closely relate to realistic situations that help students to apply their knowledge, skills and strategies to make decisions in their assigned task. Consequently, the students' intellectual capacities and expectations about learning are enhanced. Papastergiou (2009) viewed that games and simulations integrated with contents help in teaching concepts through the transformation of experiences. Thus, the computer games can be used as learning tool to teach the factual information as well as worksheet activities for teaching and learning process (Spraggins and Rowsey, 1986).

Therefore, this study develops a digital game incorporating with inquiry-based learning strategy called Digital Game-based Inquiry of Energy Education to assist students' learning in learning energy consumption. When playing the developed game, the students were encouraged to use electrical appliances for certain durations and to adjust the appropriate duration with each electrical appliance in a meaningful way of learning conceptual understanding of factors of energy consumption. In this study, we examined how much students' conceptual learning progression size after participating in the developed game. Moreover, the factors that increase students' conceptual learning progression in the game are challenged to be investigated to know the attitudinal factors affecting their conceptual learning progression.

2. Background and Motivation

According to National Research Council (2000), the authors summarized their research findings that students have different preconceptions about how the world works. If the teachers do not engage and link students' initial understanding into new concepts then, they may fail to grasp the new concepts and information that were taught, or they may land up learning for the purpose of test only. Such that, to develop competence in an area of inquiry, students must have a proper foundation of factual knowledge, comprehend facts and ideas in the context of a conceptual framework, and organize knowledge that facilitates retrieval and application. Therefore, it is vital to choose appropriate strategy to develop learning tools (Charsky and Ressler, 2011; Chuang and Chen, 2009; Wang and Chen, 2010).

Inquiry-based learning is a strategy to enhance learning by engaging students in authentic investigations, achieving a more realistic conception of scientific endeavor as well as providing a more student-centered and motivating learning environment (Kubicek, 2005). Teachers act as a facilitator who provides the opportunity for students to observing, examining books and other sources of information using tools to gather, analyze, and interpret data which students learn from their

explanation, predictions, and communicating the results. (Krajcik and Blumenfeld, 2006; Kuhn, Black, Keselman and Kaplan, 2000). Regarding to provide opportunity for students to observe, gather, analyse, construct their own conceptual knowledge; in this study, the inquiry-based learning strategy was chosen to design a digital game-based learning to assist students explore the factors of energy consumption by using electrical appliances for certain durations and adjusting the appropriate duration with each electrical appliance. These features of the game might help students to improve their conceptual knowledge on energy consumption. As such, we hypothesize that:

H1: Students' conceptual learning progression through Digital Game-based Inquiry Learning has medium gain size or high gain size when using concept of Hake (1998) normalized gain <g>.

When the digital game-based inquiry learning can help students to improve conceptual learning progression in medium gain size or high gain size; then, in our case, we can imply that it is successful digital game-based inquiry learning. Such that the students' attitudes toward the digital game-based inquiry learning are challenged to be investigated to know the factor(s) affecting their conceptual learning progression. In this study, the factors of Enjoyment, Inquiry, and Intention to Use were selected as important attitudes in learning game and promoting conceptual Learning Progression.

Enjoyment is the degree to which activity is perceived to be personally enjoyable (Davis, Bagozzi and Warshaw, 1992). When the students participate in a game, they are reduced anxiety and feel confident to construct knowledge. This is the sense of enjoyment in the game (Vorderer, Klimmt and Ritterfeld, 2004). We can imply that higher levels of enjoyment affect higher conceptual learning progression size. Moreover, as mentioned above, the inquiry-based strategy is the method to which learning sequence is perceived to be personal inquiry. The term of inquiry while the students learn through a game facilitate exploration and help students construct conceptual knowledge on specific concept. We can assume that higher levels of inquiry affect higher conceptual learning progression size. In addition, the intention of use is considered as common factor on most of the game acceptance studies (Ha, Yoon and Choi, 2007; Hsu & Lu, 2004; Venkatesh and Bala, 2008). The students' attitude toward playing or intention to use the game will facilitate the practical use of a digital game system. We can imply that higher levels of intention to use affect higher conceptual learning progression size. Hence, we have hypotheses as follow:

H2: Students' Enjoyment with the digital game-based inquiry learning has a positive relation with their Learning Progression size;

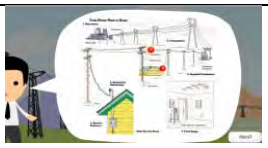
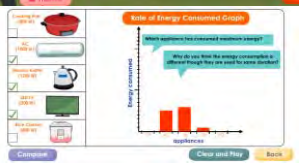
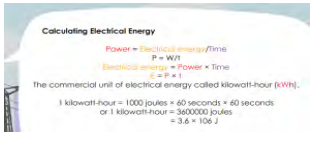
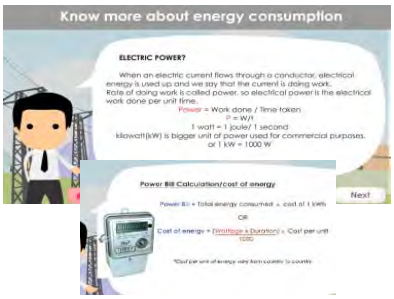
H3: Students' Inquiry with the digital game-based inquiry learning has a positive relation with their Learning Progression size;

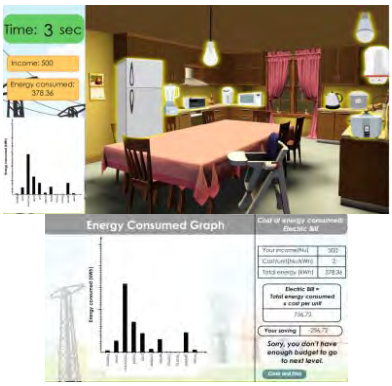
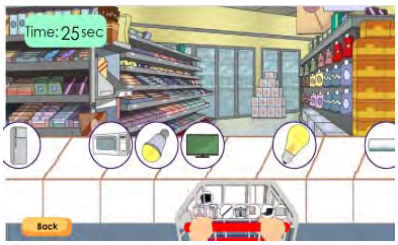
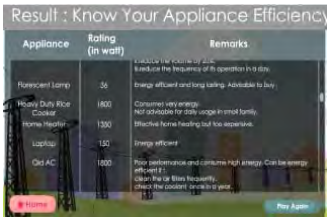
H4: Students' Intention to Use with the digital game-based inquiry learning has a positive relation with their Learning Progression size;

3. The Digital Game-based Inquiry Learning

For the purpose of our study, we developed the digital game-based inquiry learning. The main purpose of the developed game is to improve the conceptual knowledge of energy consumption. The developed game provides ways by which students can experience their subject in different manners. The game brings the world (reality) into the classroom and appeals to actively engaging students. While learning through the game, the students are provided opportunity to think more critically about their own progress and abilities. The developed game media follows the design rationale for the proposed game-based learning units that guide the students in transforming their knowledge on electrical energy consumption into their daily life applications. Furthermore, the learning game is embedded within inquiry-based learning approach. It helps students engaged in a new concept by relating their previous knowledge by exploring and explaining through their experiences, then elaborating on what they have learned, and finally evaluating their understanding on that new concept under the guidance of teachers. Eventually, this enhances students' conceptual understanding of subject. Table 1 shows the summary of the developed game.

Table 1: The learning activities in the digital game-based inquiry learning for energy education

Steps	Pictorial representation	Learning activities
1. Engagement		The lesson begins with scenario that commonly happens at our home. Example, father gets a monthly power bill claiming Nu. 6,500/- (Currency used in Bhutan). But his monthly salary is just Nu. 10,000/- now he has pay more than 50% of his income just on power bill. This arise curiosity and engage students to investigate the cause of power consumption. Teacher further encourages them with some common questions, like - list down electrical appliances operated at our home? - any idea how much energy is been consumed by those appliances? Eventually, teacher will link to learning unit.
2. Exploration	  	To investigate reason for high power bill; students explore the cases in "Energy Detective"- interactive simulated learning module to identify the factors for energy consumption. It also explains, elaborates and evaluate students understanding on transmission of electricity to our home, how power bill is calculated, unit of electrical energy is derived, etc. In the meanwhile, teacher keeps note of the findings and reinforce participants to find reasons to support their findings.
3. Explanation	 	After exploring through the interactive units to identify the factors for energy consumption, students solve problems provided in the worksheets and present their findings to the class. Teacher then displays and compares their findings, and ask them to summarize the findings in identifying the factors for energy consumption in electrical appliances. Subsequently, teacher introduces important formulas, relations and units related to energy consumption context.

Steps	Pictorial representation	Learning activities
4. Elaboration	 	Theoretical knowledge of energy consumption is then extended into the interactive game "Energy Efficiency Game: know your power bill". This provides students opportunity to apply the abstract concept of energy consumption to into practical, which help them to visual and understand clearly in a playful way. Students find ideas about rate of energy consumption and how to conserve it. Thus, the knowledge on energy consumption is elaborated into energy conservation. In the meantime, teacher ask the students the ways of saving more money while playing the game and encourage them to share the ideas with rest of the friends.
5. Evaluation	 	"Shopping: know your home electric applaince better" is an interactive game, students can interact and choose commonly used home electrical appliances from the list. This module evaluates students' self-awareness in using electrical efficient appliances to conserve energy. Further, teachers elaborate the context into daily life situations and provide additional information on it and provide opportunity to students to share their knowledge on energy saving at their home and school. Finally, the teachers summarize/ debrief on the learning unit.

4. Research Methodology

We will investigate the four research hypotheses of this study. In the first research hypothesis (H1), a Digital Game-based Inquiry Learning has improve students' conceptual learning progression in medium gain size or high gain size; results on H1 will lead us to the other three hypotheses (H2, H3, H4) in order to clarify which factors affect the students' conceptual learning progression.

4.1 Experiment Procedure and Participants

The research design was one group pre-posttest design. A total of 66 tenth graders of secondary school students (37 females and 29 males) in eastern Bhutan participated in this study. The students were asked to learn with the digital game-based inquiry learning environment; that is the game led the students to explore factors of energy consumption, and guided them to construct their own conceptual knowledge via asking questions during playing game. Before participating in learning unit/game, the students were asked to take pre-conceptual test of the topic. After finishing learning activities on the game learning environment lasted 90 minutes in a time, they were asked to take post-conceptual test followed by

attitude questionnaire. They were asked to respond questionnaire only one time after finishing post-conceptual test.

4.2 Research Tools

To examine the first research hypothesis (H1), the research tools were a pre-conceptual test and a post-conceptual test; both of them were designed by three experienced teachers teaching same subject. Each test contained 20 multiple-choice items, and one point was scored for each correct answer; therefore, the total score of the tests was 20. The pre-conceptual test was evaluated the validity by three experienced teachers, and had the reliability value 0.63, implying that the test was reliable. Similarly, the post-conceptual test was evaluated the validity by three experienced teachers, and had the reliability value 0.60, implying that the test was reliable.

To investigate the other three hypotheses (H2, H3, H4), the attitude questionnaire was adopt from Giannakos (2013). In this study, there were 10 items in three factors of the questionnaire: Enjoyment (four items), Inquiry (three items), and Intention to Use (three items) as shown in Table 2. This questionnaire was measuring using a 5-points Likert scale ranging from "1 = strongly disagree" to "5 = strongly agree". This questionnaire showed that the Cronbach's alpha reliability value was 0.74, implying that the questionnaire was reliable.

Table 2: The research factors and their corresponding items

Factors	Definition	Items
Enjoyment (ENY)	The degree to which the learning sequence of using the digital game-based inquiry learning is perceived to be personally enjoyable.	*Item1:* Participating is more interesting using the digital game-based inquiry learning. *Item2:* Using the digital game-based inquiry learning is fun. *Item3:* I like using the digital game-based inquiry learning. *Item4:* I enjoy those aspects of my studying that require me to use the digital game-based inquiry learning.
Inquiry (INQ)	The degree to which the learning activity of using the digital game-based inquiry learning is perceived to be personal inquiry.	*Item5:* Using the digital game-based inquiry learning does help me explore factors of energy consumption. *Item6:* Using the digital game-based inquiry learning does help me construct my own knowledge. *Item7:* Using the digital game-based inquiry learning does help me building confidence in finding conceptual understanding of energy consumption clearly.
Intention to Use (IU)	The degree of students' willingness to play the digital game-based inquiry learning.	*Item8:* I plan to use the digital game-based inquiry learning for studying in the future. *Item9:* I intent to continue using the digital game-based inquiry learning for studying in the future. *Item10:* I expect my use of the digital game-based inquiry learning to continue in the future.
Learning Progression (LPRO)	The level of students' conceptual knowledge gained using the digital game-based inquiry learning.	The conceptual tests

5. Results

5.1 Students' conceptual learning progression

The result of the first research hypotheses (H1): students' conceptual learning progression through Digital Game-based Inquiry Learning has medium gain size or high gain size is taken to be the average normalized gain <g> by analyzing the conceptual pre-test and post-test. Hake (1998) defined the <g> as "High gain, <g> ≥ 0.7", "Medium gain, 0.7 > <g> ≤ 0.3", and "Low gain, <g> < 0.3". From sixty-six students' conceptual pre- and conceptual post-test scores, the results show that there are 13, 34, and 19 students for high, medium, and low gains respectively. For overall result, as shown in Table 3, the conceptual score of pre- and post-test, the <g> is 0.46 indicating that the students have conceptual learning progression of their learning by gaining better conceptual knowledge after participating in the digital game-based inquiry learning environment. It is clearly that the progression of their conceptual knowledge has medium gain size which meets the H1.

Table 3: Learning progression of conceptual score by the average normalized gain <g>

Conceptual test (Total score = 20)	N	Mean	S.D.
Pre-test	66	7.56	2.30
Post-test	66	13.26	3.07
<g>	0.46		

According to Table 3 results, this result suggests that learning with the developed digital game-based inquiry learning impacted moderately on improving the students' conceptual understanding of energy consumption. As now we have proven the value of the digital game-based inquiry learning on conceptual learning progression. We will answer the other three hypotheses (H2, H3, H4) to identify which factors of the developed game influences students' conceptual learning progression.

5.2 Students' attitudes affecting conceptual learning progression

To examine the research hypotheses regarding the effect of ENJ, INQ, and IU on students' LPRO, we divided ENJ, INQ, and IU on high and low categories performing by progression size; then performing a *t*-test including students' LPRO as a dependent variable and the other three factors (ENJ, INQ, IU) as independent variables. As shown in Table 4, we can see that INQ has significantly effect on students' LPRO, with a significant level of 0.05, while ENY and IU have not.

Table 4: Research hypotheses (H2, H3, H4) testing using *t*-test

Dependent variable	Independent variable	Categories progression gain size		*T*
		Low Mean (S.D.), interpretation	High Mean (S.D.), interpretation	
Learning progression (LPRO)	Enjoyment (ENY)	4.46 (0.35), strong agree	4.63 (0.32), strongly agree	1.56
	Inquiry (INQ)	3.92 (0.64), strong agree	4.77 (0.44), strongly agree	3.81*
	Intention of Use (IU)	4.57 (0.42), strongly agree	4.67 (0.41), strongly agree	0.66

*$p < 0.05$

Although we notice that only INQ has the significant effect on students' LPRO, observing Table 4, we must acknowledge that there is higher effect of IU than ENY. This indicates that the decision of students to use a digital game is higher effect than the enjoyment experienced through a

digital game on influencing the learning progression. Overall, Figure 1 clearly shows the positive influence of ENY, INQ, IU on students' LPRO in which we can answer the research hypotheses (H2, H3, H4).

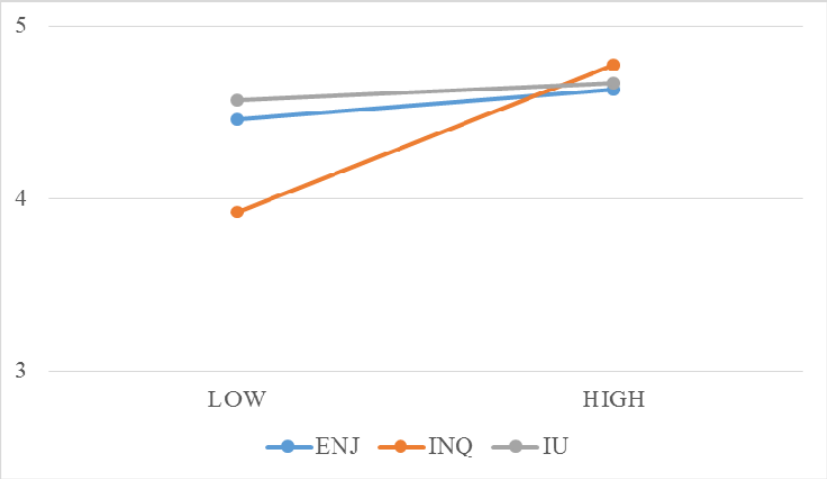


Figure 1. The effect of students' attitudes in their conceptual learning progression gain size when playing the digital game-based inquiry learning

We can see that the three factors (ENY, INQ, IU) affect the students' LPRO in the different way. As such to verify the strength of the relationship between factors, we used Pearson's coefficient as shown in Table 5. Clearly, there is relatively strong relation among three factors. This indicates that students reflecting high enjoyment are more likely to explore knowledge by themselves through the game; students reflecting high intention to use the game are more likely to be enjoyment during learning; and also a digital game reflecting high inquiry-based activity are more likely to influence decision of students to use a digital game.

Table 5: Pearson's correlation coefficient between factors (ENJ, INQ, IU)

Factors	ENY	INQ	IU
ENY	1		
INQ	.492*	1	
IU	.549*	.592*	1

*Correlation is significant at the 0.01 level

6. Discussion and Conclusion

This study examined the effectiveness of a digital game-based inquiry learning at the conceptual learning progression of energy consumption competences with the students of eastern Bhutan secondary school. From the conceptual tests, this study indicates that the developed digital game-based inquiry learning successfully improved students in Physics course. This result leds us to investigate the relationship between students' attitudes (Enjoyment, Inquiry, Intention to Use) and conceptual learning progression gain size regarding digital game-based inquiry learning. The findings indicated that Inquiry has a significant effect on students' conceptual learning progression. Thus, we could suggest that Inquiry: the degree to which the learning activity of using the digital game-based inquiry learning is perceived to be personal inquiry could play a very crucial role in acquiring conceptual knowledge of students. On the other hand, the hypotheses H2 and H4 are rejected. As such, students' enjoyment and intention to use indicate that there is no significant effect on students' conceptual learning progression. Our study is also similar with several studies (Sumak, Hericko and Pusnik, 2011; Giannakos, 2013) that also deal with the effect of students' attitudes (Enjoyment, Intention to Use) on learning performance when using digital games. Moreover, our study clearly

indicate the important roles of Enjoyment, Inquiry, Intention to Use in affecting the students' decision to use the digital game-based inquiry learning (Table 5).

The research findings revealed that students reflecting high inquiry are more likely to gain conceptual knowledge through the digital game. As such, educators, researchers, and practitioners should provide a learning environment where inquiry feature is supported and fostered in order to enhance successful conceptual learning progression with the digital game. If we overlook students' inquiry feature, it might have unfavorable effects on the conceptual knowledge constructing led to the conceptual knowledge progression.

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