Proposal of personalised mobile game from inquiry-based learning activities perspective: relationships among genders, learning styles, perceptions, and learning interest

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Abstract: This study is focused on the relationships among genders, learning styles, perceptions, and learning interest for physics learning supported by a digital game incorporated with scientific inquiry approach. Seventy-nine students participated in this experiment. The results of this study showed that perception about the digital game and learning interest are not significantly different among the different genders or learning styles; and there is significant association between genders and learning styles. Explanations and discussions of these results are offered. Although, this suggests the game need to provide the opportunities for interaction on game screen and with peers. The students showed the need of learning science in real phenomena by basing on the developed game corresponding their own prior-knowledge. In light of the previously mentioned, this paper extends the developed game and addresses the application proposal with the use of mobile devices to support personalised learning in authentic general science activities.

Keywords: interactive learning environment; individual differences; science education; mobile game-based learning.

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1 Introduction

In the past decade, inquiry-based learning were developed from conceptions of constructivism where learning involved meaning construction as students perceived and interpreted their experiences (Driscoll, 2000; Jonassen, 1994) and students interacted with the peers and tools of the educational environment (Brown et al., 1989; Lave and Wenger, 1991). In other words, scientific inquiry learning have been recognised as an excellent teaching and learning approach to engage students in constructing knowledge and to make learning more meaningful (Benson and Bruce, 2001; Pedaste and Sarapuu, 2006). Consequently, the inquiry-based learning can be an instructional approach for stimulating students’ thinking processes and promoting conceptual understanding (Lim, 2004; Looi, 1998).

In recent years, educational digital game has been recognised as highly impacted learning procedures, including enhancement of instruction (Shin et al., 2012). For example, Dorji et al. (2015a) reported that the digital game-based inquiry learning approach could enhance students’ learning in physics better than the traditional teaching approach. Kilili (2007) revealed that authenticity and learning by doing, which were the most important characteristics of effective educational games, could enhance students’ problem solving abilities. Sung et al. (2017) revealed that the experiential game-based approach could improve primary school students in learning motivation, deep learning strategy, and acceptance of the technology. Although, the digital game-based learning approach seems to be an effective tool. Researchers have pointed out that such approach could create drawback impact, such as less learning outcomes, when it has been designed without proper teaching strategies or learning process (Chang et al., 2012; Charsky and Ressler, 2011; Hoffman and Nadelson, 2010). Several researchers indicated that one great challenge of educational computer game development is to provide support and to guide the students while keeping the balance between learning and gaming and between challenge and individual learners’ abilities (Kickmeier-Rust and Albert, 2010; Charsky and Ressler, 2011). It is important to provide suitable learning strategies when developing digital game for educational purposes. Therefore, this study has incorporated components of scientific inquiry-based learning into the digital game and implemented into the force and motion topic in a general science course for primary school students.

Although, there are a number of researchers that developed the educational game integrated inquiry-based learning approach showing that the game could help students improve learning performance, promote perceptions, learning motivation (Dorji et al., 2015b; Lin et al., 2012), and learning interest (Hwang and Chang, 2011). There are human factors affecting students’ learning performance and attitudes in technological learning environments. For example, learning style differences influenced students’ perceptions in e-learning environment (Lu, 2012) and affected learning performance in digital game learning (Hwang et al., 2015a). In addition, males showed more interest in digital game than females (Unlusoy et al., 2010). Obviously, human factors affecting learning performance in technological learning environment have been becoming challenge and important issue; moreover, the findings could be served as reference for technological researchers or teachers to provide additional supports to students with individual differences (Hwang et al., 2015a). However, the students’ individual differences (i.e., genders and learning styles), which are the key factors affecting their perceptions and learning interest through the digital game integrated inquiry-based
learning approach, have not well addressed yet. Therefore, this study aims to cope un-
investigated area of educational digital game integrated inquiry-based learning approach
by empirically evaluating there is interaction between learning styles (i.e., visual and
verbal learners) and genders (i.e., female and male) of students’ perceptions and learning
interest about the developed digital game. In addition, with the benefits of the educational
digital game, personalised learning, and mobile learning, the developed game is extended
and the application proposal is proposed by using personalised mobile learning
environment to be a guideline of authentic force and motion activities of physic course in
this paper.

2 Relevant research

2.1 Computer-supported inquiry-based science learning

The classroom environment using the traditional approach might not be suitable to
facilitate student collection of the necessary information to carry an inquiry activity (Lee
and Butler, 2003). Scientific inquiry-based learning approach is a method, which
provides opportunity to students to carry out investigation to test their ideas and construct
their own knowledge, make inquiries through experiment of science. It is based on
constructivism theory of John Devery and Jean Piaget. This approach could help students
to acquire scientific process skills. When engaging in inquiry, student describes objects
and events, asks questions, constructs explanations, test the explanations against current
scientific knowledge, and shares ideas with peers. The students are asked to identify their
assumptions, use critical and logical thinking, and consider attractive explanations. In
this way, they actively develop their understanding of science by combining scientific
knowledge with reasoning and thinking skills (NRC, 1996). Inquiry-based learning could
promote students to conceptualise a problem and then search for possible explanations
related to that problem (Olson and Loucks-Horsley, 2000), so as for enhance their high-
order thinking abilities and problem-solving skills. Ikpeze and Boyd (2007) indicated that
it could encourage students to participate in explanations, reflections, and reinforcement
of critical thinking abilities. Therefore, appropriate learning situation are needed for
students to perform task effectively (Endsley, 2000). In other words, inquiry-based
learning approach can be in the form of task, which is a piece of scientific work, for
triggering student’s scientific investigation, explanation, and knowledge conclusion.

The inquiry-based learning character, thus, has been more focused as it is originated
in the scientific inquiry practices. It has been used to engage student to investigate the
scientific oriented questions, perform experiment, create explanations from evidence,
evaluate the explanation, analyse the result possibility, justify and summarise the output
(American Association for the advancement of Science, 1993). Several researchers
suggested the different levels of inquiry-based learning approach, such as confirmation,
structured inquiry, guided inquiry, open inquiry, and authentic inquiry (Buck et al.,
2008). For example, the guided inquiry-based learning approach has been characterised
to be the guideline that teachers provide problem/question, setup background, and
determine the procedure/design; and students have to perform the experiment based on
the specified design, make the communication, and conclude scientific knowledge.
In conventional classroom based on the inquiry learning approach, it is remaining a
dilemma to afford students in the situations required to conduct meaningful inquiry
activities (Lim, 2004). The progress of computer network technologies has provided the
potential benefits of the inquiry-based learning environment (Ucar and Trundle, 2011).
Many previous studies demonstrated positive impacts of technology integrated inquiry-
based learning environment on learning performance and conceptual understanding. For
example, Hwang et al. (2012) stated that students who learn in an authentic learning
environment with Ubiquitous Scientific Device Trainer (USDT) significantly benefited
the student more than learning in the traditional method. Simsek and Kabapinar (2010)
revealed that inquiry-based learning has a positive impact on students’ conceptual
learning. Linn et al. (2014) employed a computerised automated guidance to support
scientific inquiry activity to improve Science learning performance of students. Moore et
al. (2013) utilised interactive online simulations to scaffold and support students’ guided-
inquiry learning through exploration and experiment in general chemistry class.

With the benefits of guided-inquiry approach, in this study, it will be used as the
guideline to create and design the digital game environment. Because in the game,
teacher has to ensure if student have enough information to perform and summarise all
information and concept from playing themselves. The game stage and environment have
to be designed to guide and help students to gain information until completing goal of the
game.

2.2 Digital game and students’ learning outcomes

Game, which consisted of challenge, control, curiosity, and fantasy, could be created
persistence and enjoyment (Toro-Troconis and Patridge, 2010). According to the game’s
functions, many educational researchers and game developers have developed
educational games for teaching and learning in the following three goals: (1) students can
learn from playing the game; (2) the component of game can be supported the learning’s
abilities; and (3) students are motivated to learn via playing the game. Digital game-
based learning (DGBL), which is one of student-centred instructional approaches,
incorporates learning content or learning principle into the computer game for engaging
students to achieve the educational goals. In an educational game, learners are situated in
gaming scenario to complete a series of task individually, collaboratively, or even
competitively (Nelson et al., 2011). The players need to be challenging enough to
compete while acquiring educational goals according to specific rules and principles,
contributing to the development of their cognitive skills and their construction of
knowledge, and promoting their learning motivation (Erhel and Jamet, 2013; Huang
et al., 2010). Moreover, DGBL can afford a meaningful environment for developing
students’ problem-solving abilities (Kiili, 2007; Kim et al., 2009).

In recent years, many studies have developed and reported that DGBL was able to
promote students’ learning interest and motivations (Ebner and Helzinger, 2007; Huang
et al., 2010). For example, Huang et al. (2010) surveyed 264 undergraduate students
about playing online game, and found potential relationship between intrinsic motivation
and extrinsic rewards. Inal and Cagiltay (2007) further investigated the flow experience
of children in an interactive game environment and found that the challenge and
complexity elements of the games had a greater effect on the children’s flow experiences
than did clear feedback. Dickey’s study (2011) investigated the impact of narrative
design in a game-based learning environment and found that intrinsic motivation,
curiosity, and plausibility were benefited from game-like environment.
In addition, researchers have investigated the impact of DGBL from many aspects. For example, Lee and Chen (2009) studied the impact of different prompts and levels of prior knowledge on problem solving in non-routine mathematical situations, and reported that prior knowledge and comprehensive mathematical ability were important and further related to the problem-solving effect. Kili (2007) indicated that authenticity, collaboration, and learning by doing were the key factors of effectively conducting education game. Paraskeva et al. (2010) and Dorji et al. (2015b) reported that the gender differences play the important role when playing digital game effecting the learning performance. Hwang and Chang (2011) revealed that after participating the digital game based learning via mobile phone in the learning activity, the student improved in their learning interest and attitudes. Unlusoy et al. (2010) reported that males show more interest in digital game than females. In addition, the DGBL has more attractive method than the traditional one. It seems to be more interesting to learners. From the previous mentioned, students’ feedback toward use of DGBL, (i.e., perceptions, attitude, learning interest) has been a challenge to be investigated (Chen et al., 2008).

2.3 Learning styles

Learning styles have been recognised as an important factor for better understanding students’ learning preference (Filippidis and Tsoukalas, 2009), and reflected causes of individual learning behaviour (Keefe, 1987). In other words, learning style is used to analyse a student characteristic indicating how a student learns and likes to learn (Keefe, 1991). Moreover, learning styles are likely to influence how students learn, how instructors teach, and how they interact (Reiff, 1992). Researchers further suggested that teachers and course designers pay attention to students’ learning styles and design teaching and learning interventions accordingly (Coffield et al., 2004).

In the past decade, several researchers revealed studies on the relationship between learning style and learning performance. For example, Buckley and Doyle (2017) used Felder-Silverman learning style questionnaire to examine the impact that different learning styles and personality traits on students’ perceptions, engagement, and performance during learning in a gamification using a prediction market. It was found that the students with the different learning styles had the different impression of gamification. Khenissi et al. (2016) used Felder-Silverman learning style questionnaire to reveal that students with the different learning styles preferred the different genres of computer games. Moreover, Soflano et al. (2015) revealed that the learning style of Felder-Silverman model fluctuated during the learning process in game-based learning environment. These results suggests that learning styles affecting on learning performance. However, which type of digital game designs best suits the different learning styles is not firmly specify yet (Wang et al., 2006).

3 Research framework and hypothesis

3.1 Research framework

Based on the discussion of related works above, the research framework for this study is shown as Figure 1. The principal objectives of this study are to investigate the relationships among genders, learning styles, perceptions, and learning interest through
playing the digital game embedded with scientific inquiry approach. In the task of science learning supported with the game, we expect to understand which genders and learning styles yield promoted statistically significant perceptions and learning interest.

**Figure 1  Research framework**

![Research framework diagram]

In light of game-based learning approach, we take the gender and learning style component as important factors in the digital game with scientific inquiry. These components might affect students’ perceptions and learning interest through playing the game. The active/reflective, visual/verbal, sensing/intuitive and sequential/global learning style dimensions, which were proposed by Felder and Silverman (1988), have been widely adopted in technology-enhanced learning systems (Filippidis and Tsoukalas, 2009; Hwang et al., 2013). Because the four dimensions are highly related to the computer-based interface or the digital learning material presentation design (Hwang et al., 2015b). According to the game in this study, it allows students to receive pictures, animations, and text. Therefore, in this study, the visual/verbal dimension of Felder and Silverman’s (1988), which refers materials in which students prefer to receive, is adopted as a self-assessment tool for determining a student’s learning preference.

3.2 Hypothesis

According to the research framework and to the previous studies, we submit the following three hypotheses about science learning supported by the digital game integrated scientific inquiry approach:

- **H1**: Different genders and learning styles significantly influence perceptions.
- **H2**: Different genders and learning styles significantly influence learning interest.
- **H3**: Genders are significantly related to learning styles.

4 The development of the digital game embedded with scientific inquiry approach

In this study, a digital game-based learning has been developed by incorporating the guided inquiry-based learning approach into gaming scenario for encouraging and promoting students’ learning performance in physics of science course. The game has been implemented with Flash Maker. MySQL has been used as the system database. The
Proposal of personalised mobile game

2D role-playing game has been chosen in this study because it is enough for presenting the game scenarios. It requires less computer power, which is supported in the most elementary school in Thailand. Moreover, researcher avoid situating elementary school students in a complex 3D interface, which may increase the difficulty for them to learn with the game (Hwang et al., 2015a). The role-playing is selected as the gaming type because it is to situate students in the authentic phenomena of force and motion. Moreover, the students will be enabled to realise that the knowledge they have learned can be applied to some real-world phenomena from this approach.

With the benefits of the scientific inquiry approach and the digital game, the incorporation of scientific inquiry learning into digital game will be studied. The educational digital game has been developed to make students understand the force and motion basic concepts with the characteristics of force and motion, the force composition, the direction of force, the same direction of forces calculation, and the calculation of resultant force. The digital game embedded with scientific inquiry approach consists of five components as following:

Component 1 Open-Ended Inquiry Question: Before starting learning activity, teachers were asked to provide the inquiry question by using the management control interface of the database system. Consequently, at the beginning, the game provides a question, for example “What will happen with key box when the knight is pulling the key box from the dragon?” as shown in Figure 2. It is a task to trigger students to explore scientific phenomena of the calculation of resultant force and find out the answer by playing the game.

Component 2 Scientific Background Information: This component displays scientific background and necessary information for students before playing and meeting target of the game. The information was prepared and setup by teachers in the management control interface of the database system. The teachers need to make sure that all required information has been provided in this component. For example, in the calculation of
resultant force task, the game provides information as “The dragon is hiding the key box. The knight need to get that key by using rope and clicking for more knights to get the key box. Don’t forget that pulling will let the object go backward and pushing will let the object go forward.” as shown in Figure 2.

Component 3 Procedure/Design: Students are triggered by scientific tasks in the game. Teachers designed the game story and structure. They guide the students with meaningful information for exploring scientific phenomena during playing the game. Figure 3 shows that the students play the role of the knight who is challenged to carry out the mission of completing the task and winning the competition with the dragon. In this task, the students will play tug of war game, which is a game that directly puts two teams (i.e., knight and dragon teams) against each other in a test of force strength. Teams pull on opposite ends of a rope, with the goal being to bring the rope and key box a certain distance in one direction against the force of the opposing team’s pull. That is the students use keypad on the screen to pulling and click to add more knights against the force of the dragon team. During playing tug of war, the game has force meter and force direction for showing net force and force direction as guidance. To win the game, the knight team has to do is to prove stronger than the dragon team by pulling the rope over to their side; that is resultant force refers to the single force acting on a key box along with the knights’ direction. Moreover, when finishing each chance, the pop-up table with drop-down list will display for asking the students to record data of scientific phenomena, such as total force of knights, total force of dragons, net force, and direction of key box. That is the data is the text format and is automatically saved into the database. The data will be used as input for the next component.

Figure 3   Illustrated interfaces of component 3
Component 4 Data and result analysis: During playing the game, students are asked to collect or note some information. All collected or noted information from Component 3 will be re-displayed and some key actions that the student did during playing the game will be re-run for student’s data analysis as shown in Figure 4. The hint buttons will be displayed and the space was provided to ask students to collect or note some information with the provided questions, such as “What happen with key box when the knight pulled the key box from the dragon?”

**Figure 4** Illustrated interfaces of component 4

**Figure 5** Illustrated interfaces of component 5
Component 5 Result communication and conclusion: For this component, the communication interface arranges some questions for students to deal with for enhancing the collaboration among peers and teachers. The interface will pop up and display other information/answers given by other students in Component 4 including hints or message from teachers as shown Figure 5. That is the students are able to see more information for analysing and to recheck their answer submitted in Component 4 for concluding the game result corresponding to scientific concept.

5 Research design

5.1 Participants

A total of 79-fourth and fifth graders of elementary school under Office of the Basic Education Commission in the central part of Thailand were recruited in this study. The students individually participated in the developed game, and shared the results in the game with their friends to construct their own scientific knowledge about force and motion. After finishing learning activities in the game, they were asked to respond questionnaires to clarify the degree of their perceptions about the game and show the degree of their learning interest.

5.2 Measurement tools, reliability, and validity

The perception questionnaire was adopted from Teo’s (2009) questionnaire and translated to Thai language. It consists of 11 items with a five-point Likert rating scale. There are four dimensions in the questionnaire, such as perceived usefulness (3 items), perceived ease of use (3 items), attitude towards digital game-based learning use (3 items), and behavioural intention to use digital game-based learning (2 items). Perceived usefulness refers to which a person believes digital game-based learning will help him or her to complete a certain task in an efficient and productive manner. In contrast, perceived ease of use refers to which a person thinks that the use of digital game-based learning will be relatively free of effort. Attitude refers to which a person has opinion and feeling toward the digital game-based learning. In addition, behavioural intention to use refers to which a person desires to use the digital game-based learning. In this questionnaire, students have to respond each item within 5-point rating scales (i.e., 1-strongly disagree; 2-disagree; 3-neutral; 4-agree; 5-strongly agree). The Cronbach’s α value of the questionnaire in Thai version was 0.91, showing acceptable reliability in the internal consistency. Moreover, the composite reliability values for the perceived usefulness, perceived ease of use, attitude towards digital game-based learning, behavioural intention to use were 0.84, 0.79, 0.76, and 0.82, respectively, showing good internal consistency of each construct.

In addition, the learning interest questions were adopted from Hwang and Chang’s (2011) questionnaire and translated to Thai language. It consists of 4 items with a five-point Likert rating scale. It is used to investigate students’ interest during learning in the developed game. In this questionnaire, the students have to respond each item within 5-point rating scales (i.e., 1-strongly disagree; 2-disagree; 3-neutral; 4-agree; 5-strongly agree). The Cronbach’s α value of the questionnaire in Thai version was 0.83 showing acceptable reliability in the internal consistency.
In this study, Felder and Silverman’s (1988) learning style is used as a self-assessment tool for determining a student’s learning style. The Felder and Silverman’s questionnaire used in this study was the Thai translation version. In addition, according to the game in this study, it allows students to receive pictures, animations, and text, which refers materials in which students prefer to receive; visual-verbal dimension was adopted for determining learning preferences.

5.3 Data collection procedure

The experiment was conducted with an elementary school in a general science course. Before conducting the learning activities through the developed digital game, the students were introduced the game and story line by the authors, and the basic functions of the game. Following that, the students played the game and took questionnaires of demographic, learning styles, perceptions, and learning interest. During the learning activity period of 40 minutes, the students were monitored and facilitated by teachers. Moreover, the students were asked to response the questionnaires for a period of 25 minutes.

6 Hypothesis testing results

In this analysis, three statistical methods are applied for hypothesis testing. A two-way multivariate analysis of variance (two-way MANOVA) was used to test for significant differences in students’ perceptions among the different learning styles and genders. A two-way analysis of variance (two-way ANOVA) was used to test the differences in learning interest among the different learning styles and genders. A Pearson’s chi-square test was used to examine the relationships between learning styles and genders. SPSS Version 20 for MS Windows was used as the software analysis tool for this study.

6.1 The description of participants

A total of 79 elementary-school students participated in this experiment, and a final count of 79 students completed filling out the demographic question and the learning style questionnaire, perceptions and learning interest questionnaires. Following visual-verbal dimension of Felder and Silverman’s learning style questionnaire, sample in this experiment contained the following learning styles: 12 verbal-learners and 67 visual-leaners. In addition, this experiment obtained the following distribution of student genders according to demographic question: 44 females and 35 males.

6.2 Perceptions among gender and learning style differences

Hypothesis H1 assumes that a student’s perceptions, when learning the digital game embedded with scientific inquiry approach, is influenced by the student’s gender and learning style. This research applied a two-way MANOVA to test H1. In this study, the two independent variables (i.e., gender and learning style) together with the dependent variables (i.e., perceived ease of use, perceived usefulness, attitude, and intention to use), were simultaneously declared and designed.
In prior to undergoing conducting the two-way MANOVA test, the analysis of equality of covariance matrices BOX’s M test was executed. The result showed that the equality of covariance matrix did not violate with one another, $F = 1.580 \ (p > .062)$. Consequently, the two-way MANOVA test could be effectively used to analyse the questionnaires rating scales of students’ perceptions. It was also found that there is no statistical significance interaction effect, $F_{(4,72)} = 0.898, p = 0.470$, Wilks’ Lambda = 0.952, between genders and learning styles. Regarding the effects of genders and type of learning styles. Therefore, a student’s perceptions, when learning a digital game embedded with scientific inquiry approach, is not influenced by the student’s gender and learning style. Thus, hypothesis H1 was no statistically supported, meaning that the different genders and learning styles were not associated with different levels of perceptions.

Table 1 show the descriptive data on the questionnaires rating scale of students’ perceptions in the digital game embedded with scientific inquiry approach. It clearly demonstrated that both genders with different learning styles similarly perceived the design interaction on usefulness, ease of use, attitude, and their intention to use the developed game.

### Table 1

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Gender</th>
<th>Learning style</th>
<th>N</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perceived Ease of Use (PEU)</td>
<td>Females</td>
<td>Verbal</td>
<td>7</td>
<td>13.86</td>
<td>1.069</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visual</td>
<td>37</td>
<td>13.62</td>
<td>1.320</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>Verbal</td>
<td>5</td>
<td>14.60</td>
<td>.548</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visual</td>
<td>30</td>
<td>14.03</td>
<td>1.829</td>
</tr>
<tr>
<td>Perceived Usefulness (PU)</td>
<td>Females</td>
<td>Verbal</td>
<td>7</td>
<td>12.71</td>
<td>2.059</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visual</td>
<td>37</td>
<td>13.92</td>
<td>1.920</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>Verbal</td>
<td>5</td>
<td>14.20</td>
<td>1.095</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visual</td>
<td>30</td>
<td>13.83</td>
<td>1.533</td>
</tr>
<tr>
<td>Attitude (ATT)</td>
<td>Females</td>
<td>Verbal</td>
<td>7</td>
<td>13.00</td>
<td>1.155</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visual</td>
<td>37</td>
<td>12.92</td>
<td>2.191</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>Verbal</td>
<td>5</td>
<td>13.60</td>
<td>2.191</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visual</td>
<td>30</td>
<td>13.53</td>
<td>2.224</td>
</tr>
<tr>
<td>Intention to Use (ITU)</td>
<td>Females</td>
<td>Verbal</td>
<td>7</td>
<td>7.43</td>
<td>1.134</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Visual</td>
<td>37</td>
<td>8.43</td>
<td>.987</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>Verbal</td>
<td>5</td>
<td>8.80</td>
<td>1.304</td>
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<tr>
<td></td>
<td></td>
<td>Visual</td>
<td>30</td>
<td>8.73</td>
<td>1.484</td>
</tr>
</tbody>
</table>

### 6.3 Learning interest among gender and learning style differences

Hypothesis H2 posits that, in the tasks of the digital game embedded with scientific inquiry approach, learning interest is influenced by the student’s gender and learning style. This research applied a two-way ANOVA to test H2. In this study, the two independent variables (i.e., gender and learning style) together with the dependent variable (i.e., learning interest), were simultaneously declared and designed. The results
of the two-way ANOVA test showed genders and learning styles were not significant different with the average of the learning interest levels \( F(3,75) = 0.052, p = 0.950 \). Therefore, student’s learning interest, when learning in a digital game embedded with scientific inquiry approach, is not influenced by the student’s gender and learning style. Thus, hypothesis H2 was no statistically supported, meaning that the different genders and learning styles were not associated with different levels of learning interest.

Table 2 shows the descriptive data on the questionnaire ratings scale of the students’ learning interest in the digital game embedded with scientific inquiry approach. It clearly demonstrates that when learning with the digital game embedded with scientific inquiry approach, female and male students are similarly interested in the designed learning activities.

Table 2

<table>
<thead>
<tr>
<th>Gender</th>
<th>Learning style</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>Verbal</td>
<td>7</td>
<td>18.4286</td>
<td>1.51186</td>
</tr>
<tr>
<td></td>
<td>Visual</td>
<td>37</td>
<td>18.0541</td>
<td>1.77867</td>
</tr>
<tr>
<td>Male</td>
<td>Verbal</td>
<td>5</td>
<td>18.6000</td>
<td>2.07364</td>
</tr>
<tr>
<td></td>
<td>Visual</td>
<td>30</td>
<td>18.3000</td>
<td>2.03673</td>
</tr>
</tbody>
</table>

6.4 Relationship between gender differences and learning styles

Hypothesis H3 posits that genders and learning styles are significantly associated with each other. This hypothesis aims to ensure whether genders can use to represent learning styles, or vice versa. Therefore, in this study, a Pearson’s chi-square test for independence is used to discover if there is a relationship between two categorical variables (i.e., genders: male and female, learning styles: verbal and visual). The results of test hypothesis H3 were Pearson Chi-Square = 80.040, DF = 4, \( p \)-value = 0.000 < 0.05. This suggests that learning style and gender have a statistically significant association. Thus, these findings offer statistical support for hypothesis H3. Table 3 shows the descriptive data on the gender and learning style. It clearly demonstrates that, both female and male students were more visual leaners than the verbal ones.

Table 3

<table>
<thead>
<tr>
<th>Gender</th>
<th>Learning style</th>
<th>N</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>Verbal</td>
<td>7</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>Visual</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>Verbal</td>
<td>5</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Visual</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

7 Discussions

In this study, we hypothesised that, when physics learning is supported with a digital game embedded with scientific inquiry approach, the different learning styles and genders could influence perceptions about the game and physics learning interest. A
summary of our findings is shown in Table 4. Our results support the notion that genders and learning styles do not significantly influence perceptions about the game and learning interest. Learning styles are significantly associated with genders, and thus, we can use genders as substitute for learning styles, or vice versa.

Table 4 Hypothesis test result summary

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1 Different genders and learning styles significantly influence perceptions.</td>
<td>Reject</td>
</tr>
<tr>
<td>H2 Different genders and learning styles significantly influence learning interest.</td>
<td>Reject</td>
</tr>
<tr>
<td>H3 Genders are significantly related to learning styles.</td>
<td>Support</td>
</tr>
</tbody>
</table>

Following Table 4, and according to hypothesis H1, we see that both learning styles and genders of students do not differ significantly with respect to perceptions about the game. It showed that the different learning styles and genders of students produce similar perceptions with the assistance of the digital game embedded with scientific inquiry approach for physics learning. Although, some previous research (e.g., Lu, 2012) revealed that the different learning styles influenced perceptions in technology of e-learning environment. Our results showed that all students were satisfied with their experience with the digital game as a technological tool to physics learning. This finding has meaningful implications for designing digital game-based learning environment that can help teachers to understand and use scientific inquiry approach for different genders and learning styles to promote students’ perceptions. For example, this type of digital game was designed by role-playing. It situated students in the authentic phenomena of force and motion on physics course. Such that they were encouraged to explore elements in the game, to collect or note some information, and to conclude phenomena for constructing scientific knowledge, such as characteristics of force and motion, the force composition, the direction of force, the same direction of forces calculation, and the calculation of resultant force. The game also allowed all students to receive pictures, animations, and text related to scientific phenomena. All students, thus, believed that this type of digital game would help them to complete a scientific task effectively. Moreover, the game was developed by Flash Maker and 2D interface, which required less computer power and decrease the difficulty for students to play. It led to all students though that the use this type of the game was free of effort. Consequently, they had positive feeling toward the game and desired to use this type of game for physics learning.

The results of testing hypothesis H2 showed that the different learning styles and genders produce similar degree of physics learning interest with the assistance of the digital game embedded with scientific inquiry approach. It is inconsistent with Unlusoy et al. (2010) who reported when playing the digital game, males showed more learning interest than females. Our results showed that all students interested their physics learning with the digital game embedded with scientific inquiry approach as a technological tool to physics course. For example, all students were provided the opportunity to interact with virtual scenario and graphical simulation within the game leading to the female and male students were promoted learning interest similarly.

Following hypothesis H3, we conclude that genders and learning styles are significantly associated with each other. There is, thus, correspondence between genders and learning styles, and we can use learning styles (i.e., visual and verbal learner) to represent genders, or vice versa. Obviously, the results of testing hypothesis H3 provide...
statistical evidence for using learning styles (i.e., visual and verbal learner) to represent genders (i.e., males and females). According to Table 3, the number of females (44) which is greater than the highest number of learning style (37 visual leaners), and the number of males (35) which is greater than the highest number of learning style (30 visual leaners). This result has implications for digital game design, because more visual materials, such as pictures, animations, graphical simulations, and demonstrations with scientific inquiry process, in a digital game can lead to positive degree of perceptions and of learning interest, reminding us to do not just focus on the gender characteristic aspects. Indeed these findings could provide a basic for the design of physics learning environment within the digital game embedded with scientific inquiry approach.

Based on the research findings of this study, it revealed that the development of digital game embedded with scientific inquiry approach is suitable digital game design for deceasing gap of learning style and gender differences. While, it is significant learning performance in the personalised learning support system (Bojilov et al., 2010; Schiaffino et al., 2008). Moreover, mobile devices with wireless communication have been widely used to support cognitive and affective domain (Georgiev et al., 2004; Liu and Hwang, 2010; Hwang et al., 2011). Consequently, a personalised mobile game-based learning environment based on such approach is then proposed in the next section.

8 An application proposal of personalised mobile game learning environment

Information and Communication Technology (ICT)-supported constructivist learning was first described in Hannafin et al.’s (1999) open learning environments, which used technological tools to support information manipulation, problem visualisation, and metacognition as students worked with authentic problem. Educational researchers indicated a good interplay between the usage of ICT and the instructional practice of constructivism (Mikropoulos and Natsis, 2011). The principles underlying ICT-supported constructivist learning were carefully developed by Jonassen et al. (2008). Their dimensions of meaningful learning stated that constructivist learning with ICT was firstly active: students are manipulating objects in the learning environment and observing its results. Secondly, it was constructive: teachers are engaging students to reflect and articulate their personal understanding of their observations. Thirdly, it involves the students in authentic phenomena. Next, the students were intentional about their own learning as they set their learning goals and plan their problem-solving processes. Finally, it was described as a social process that involved collaborative problem solving within a classroom community. It was proposed that ICT tools supported these five dimensions as “engagers and facilitators of thinking” (Jonassen et al., 2008, p.7).

In recent year, the digital game-based learning has been increasingly focused by several researchers (Prensky, 2005). For example, the instructional content with gaming features (i.e., scoring, ranking, feedback), which was combined with meaningful learning activities, has been effective for engaging students and meeting the desired learning goals (Annetta, 2008). With the advancement of technologies, mobile devices have become easier to use and to develop digital content inside to learn in anytime and anywhere situation. Mobile learning has been developed to support the learning effective of students (Georgiev et al., 2004; Liu and Hwang, 2010), and promote the thinking skills
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(Hwang et al., 2011). The learners with mobile learning environment have been able to get experience of outdoor and indoor setting move with no time and space limitation (Hwang et al., 2010). In order to situate students in a classroom which refers to only virtual learning environment, it is better to take and access both authentic learning environment and virtual one (Hwang et al., 2015b). Moreover, a mixed-reality game with cooperative learning, which used a combination of physical and virtual artefact, explicitly improved critical thinking skill (Schrier, 2006). Facer et al. (2004) used augmented reality activity to promote cooperation. It was found that students played a role of pride of lionesses and try to survive in a virtual African environment. Each lionesses had some part of information from their area where they visited. Therefore, they had to encourage working together. Subsequently, in the classroom, the students, who played together, revealed more cooperative learning attitude in working and sharing their understanding from the game and were appreciate other students’ perspectives. Moreover, mobile inquiry-based learning could enhance students in field learning performance and learning activity (Hung et al., 2013). The computer simulated experiment and mobile-based field investigation with an open-inquiry based learning extend the students’ learning experience and facilitate their conceptual learning in science by an integration between simulation-based inquiry and mobile learning in outdoor classroom (Srisawasdi, 2012). Although digital game learning and mobile learning has been implemented in various subjects, only few studies have been unable firmly specify which type of mobile game-based learning designs best suits students’ personalised learning. With the positive effects of our design on the developed digital game and with the students’ need of learning Physics in real-world phenomena by basing on our game, it is challenging to apply our design onto personalised mobile learning environment. Therefore, in this section, an idea of the personalised mobile game learning environment has been displayed, while individual students’ conceptual learning status has been used, and the scientific inquiry learning activities have been enhanced and featured.

Figure 6  The system structure of personalised digital game based on inquiry learning approach
The proposing learning environment is used to enhance students’ learning in the authentic environment, by employing the advantages of personalised learning diagnosis, digital game, and mobile with wireless communication technology to drive their scientific inquiry learning process. Therefore, a mixed-outdoor game is designed and two-gaming modules will be developed as shown in Figure 6. Firstly, in the prior-knowledge testing and diagnosing module, individual students will be situated in the different scenario by answering fifteen multiple-choice questions about force and motion concept. Together with number of items answered incorrectly divided by number of all items associated with the concept, was calculated and diagnosed conceptual learning status (i.e., well-, partial-, and poorly-learn) using fuzzy logic. Currently, this information will be stored in the database, and used in the next module. Students receive gaming stage differently based on their initial diagnosed learning problems, meaning that students are asked to play only gaming stage corresponding partial- and poorly-learned concept. Secondly, in the scientific inquiry module, starting with the first gaming stage in the diagnosed learning problem database, each student will be asked to follow a virtual set of destination using GPS positions and the Google map API. Each destination will represent each gaming stage corresponding conceptual learning problems. The students will have their own map with different destinations on mobile device. Moreover, in each destination, the students are encouraged (while teacher can monitor) to complete gaming task basing on the development of the digital game embedded with scientific inquiry approach as mentioned in section 4. Such that, when playing the game, the student will navigate the location and experience each stage by logging into each destination. Each physical location will have the specific concept of force and motion, such as the characteristics of force and motion, the force composition, the direction of force, the same direction of forces calculation, and the calculation of resultant force. The mobile device will be retrieved the learning content and game structure from the server via wireless communication. The students will inquire and analyse information within the game. During playing the game, the students will be asked to create a video clip of a physical phenomenon in the reality situation related to the experiment and then they are asked to use mobile feature to upload the video clip into the system. Moreover, they will be allowed to discuss and communicate their findings with peers to draw the conclusion of scientific knowledge about force and motion for completing the gaming stage.

9 Conclusion

This study developed a digital game embedded with scientific inquiry approach. The approach mainly provided learning activities that encourage students to inquire scientific phenomena within the game for constructing their own knowledge about force and motion of physics course for elementary school students with the different learning styles and genders. This study sought to test experimentally on the relationships among learning styles, genders, perceptions about the game, and physics learning interest. It was concluded that, in the task of physics learning with digital game embedded with scientific inquiry approach, the different learning styles and genders do not influence perceptions and learning interest. Moreover, learning styles and genders have significant association with one another. This suggests that one can use genders to represent learning styles, or vice versa.
The contribution of this study includes the developed digital game embedded with scientific inquiry approach, which serves as the originality in enhancement of the digital game design and better understanding of the effects of individual differences onto such environment. In addition, the proposed personalised mobile game-based learning environment serves as a further step in enhancing individual conceptual learning problems and experience powered by the mobile device and wireless communication technologies. Moreover, it could enable a number of possible gaming stages corresponding personalised conceptual learning problems. It would make students’ physics learning more exploring scientific phenomena in authentic environment by using mobile game-enhanced activities. That led to future studies for examining the effects of the personalised mobile game embedded scientific inquiry learning on learning performance with respect to physics learning score and acceptance technology in the educational system. Moreover, network and learning pattern through the personalised mobile game embedded scientific inquiry learning will be analysed in the future works.

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References


Proposal of personalised mobile game


Proposal of personalised mobile game


