Using a “prediction–observation–explanation” inquiry model to enhance student interest and intention to continue science learning predicted by their Internet cognitive failure

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ABSTRACT

The development of information technology, such as iPad applications, facilitates the implementation of constructivist teaching methods. Thus, the present study developed a “prediction–observation–explanation” (POE) inquiry-based learning mode to teach science concepts using the iPad2. The study used the “attention-to-affect” model with a self-report measure to determine the antecedent factor—Internet cognitive failure—related to learning interest based on students’ continuance intentions to practice POE inquiry using the iPad2. A total of 96 elementary 6th grade students participated in the study and completed the questionnaires, of which 81 effective questionnaires were validated for the confirmatory factor analysis with structural equation modeling. The results of this study indicated that Internet cognitive failure was negatively associated with three types of learning interest as indicated by high levels of liking, enjoyment, and engagement. On the other hand, three types of learning interest were positively correlated to continuance learning through iPad2 interactions. The results suggested that the POE mode of inquiry is suitable for implementing at an intelligent mobile device to enhance young students’ interest and continuance intentions with respect to the learning of science.

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1. Introduction

Inquiry-based learning in science education encourages students to explore the world through the observation and classification of normal objects (National Research Council, 1996, p.123). Previous studies focusing on students’ exploratory behaviors reveal that students often fail to link their observations to the scientific theory that underlies those observations (Bianchini, 1997; Jimenez-Aleixandre, Rodriguez, & Duschl, 2000; Krajcik, Blumenfeld, Marx, Bass, & Fredricks, 1998). This finding aligns with Piaget’s (Piaget, 1952) understanding of knowledge construction through “perceptual exchanges and experimental interactions between subject and object” (Wrzesien & Alcaniz-Raya, 2010, p. 178). Moreover, Hammer (2004) and Hammer and van Zee (2006) suggested that adolescent student thinking is naturally impaired and that, as a result, there are many complex theories and ideas that they cannot grasp. Nonetheless, science classes today are primarily didactic, lacking opportunities for students to explore. Even after watching didactic programs, there are still signs of students failing to grasp the scientific theories presented (Nie & Lau, 2010). However, student interest is actively promoted through inquiry-based interaction and the solving of meaningful and relevant problems (Antonietti & Cantoia, 2000; Price & Rogers, 2004). Therefore, there is a need to develop a constructivist teaching method for elementary school students.

Constructive empiricists (e.g., Contessa, 2006) argue that natural phenomena can be differentiated into observable and non-observable types. According to Van Fraassen (2001, 2002), the constructive empiricists believe that the concept of mass experiences is equivalent to ‘what an eye can see makes it true’. However, the constructive empiricists also believe that visual and vocal observations can strengthen a
student’s understanding of natural phenomena. Moreover, cognitive psychologists believe that the ability of students to understand science is strongly related to his or her exploration of the causal nature of a scientific problem (Graesser, Lang, & Roberts, 1991; Riedl, 2004). In addition, Gilbert (2008) highlight the visual simulation of natural phenomena can improve students’ understanding of difficult scientific concepts. By understanding the cause of a problem in science, students can comprehend a science concept through the cognitive process. Accordingly, the present study develops a systematic learning platform for elementary school students that utilize an inquiry-based learning model: predict → observe → explain (POE) so that student understanding of scientific concepts can be facilitated by developing POE content using iPad2 applications.

In a digital context, e-texts are general examples of electronic books used in education (Stone & Baker-Eveleth, 2013). Electronic devices (e.g., Apple iPad) influence the access to digital resources by providing portability, search-ability, and content tagging to eliminate the cognitive strain (Weisberg, 2011). An issue affecting the use of e-text, however, is the resolution of the text as it contributes to eye strain and cognitive failure (Bennett & Landoni, 2005). van der Linden, Frese, and Sonnenstag (2003) define cognitive failure as “a psycho-physiological state resulting from sustained performance on cognitively demanding tasks and coinciding with changes in motivation, information processing, and mood” (p. 484). Because electronic texts are not static like printed books and magazines (Robinson, 2010), greater effort is required to grasp the information that is presented to them. However, the cognitive theory of multimedia learning (CTML) (Mayer, 2005) posits that multimedia facilitates meaningful contexts (Ertmer & Newby, 1993) as researchers advocate (e.g., Teo, Lim, & Lai, 1999) that Internet usage can enhance student interest by presenting well-designed instructional messages that support cognitive development.

According to the “attention-to-affect” model (Critcher & Ferguson, 2011; Satpute, Shu, Weber, Roy, & Ochsner, 2013), learning is an emotional and cognitive experience (Frijda, 1986). Emotions negatively or positively affect student motivation (Pekrun, Goetz, Titze, & Perry, 2002a), which, in turn, leads them to concentrate on cognitive resources (Giannakos, 2013). Despite their learning potential and the considerable learning interest in digital games, however, the uptake in a formal scientific learning context remains limited (Logar, Karba, Papic, & Atanasevic-Kunc, 2011). As a consequence, several studies have explored potential factors that inhibit the adoption of inquiry-based learning in the classroom (e.g., Ainley, Hidi, & Berndorff, 2002). While these studies have been crucial in identifying important determinants, additional research that pays special attention to the relations between individual cognition abilities and learning determinants and how these relations are associated with the intention of students to use iPad2 in learning science concepts is required. Thus, the purpose of this study was to determine how student attitudes relate to learner Internet cognitive failure, learning interest, and continuance intention to learn POE inquiry scientific content using emerging technologies known as mobile applications.

2. Theoretical background

Inquiry is defined as the process of self-correction and self-adjustment in the process of “discovering or creating a problem-solving method to a specific topic” (Lipman, 2003, p. 184). The term inquiry is often used in studies related to science education. After decades of educational innovation, a new trend emerges whereby didactic teaching methods have been replaced with constructivist teaching methods that emphasize inquiry-based learning (Nie & Lau, 2010). Inquiry-based learning allows students to understand the nature of knowledge, and it is a powerful way for students to develop strategic thinking and to master scientific content (Bell, Blair, Crawford, & Lederman, 2003).

As the CTML may provide an explanation for the interest in inquiry-based interaction as a means to enhance student interest (Mayer, 2005), the present study employed a motivation theory that focused on a behavioral intention model developed and researched by Fishbein and Ajzen (1975). Furthermore, based on the attention-to-affect model, this study included intrinsic motivation – learning interest – as a virtual interactive psychology variable (Admiraal, Huizenga, Akkerman, & Dam, 2011) to explore another individual crucial construct, Internet cognitive failure to establish the research model.

2.1. Continuance intention toward inquiry-based learning

According to Fishbein and Ajzen (1975), the motivation to pursue a certain behavior is a function of the weighted sum of the beliefs about that certain behavior (attitude). There is an important factor in the theory of reasoned action known as behavioral intention, which is an important element in the process of persuasion. However, Fishbein and Ajzen (1975) also recognize that there are situations (or factors) that limit the influence of attitude on behavior, and in recent decades, research defines those factors that affect beliefs in learning systems (Bourgonjon, Valcke, Soetaert, & Schellens, 2010). Ultimately, one’s interest toward a behavior can lead to an intention to act, and this intention may or may not lead to a particular behavior.

Continuance refers to a form of post-adoption behavior. In the literature, post-adoption is often used as a synonym for continuance (Karahanna, Straub, & Chervany, 1999). Jasperson, Cater, and Zmud (2005) define post-adoptive behavior as a “myriad of feature adoption decisions, feature use behaviors, and feature extension behaviors made by an individual user after an IT application has been installed, made accessible to the user, and applied by the user in accomplishing his/her work activities.” As many examinations of continuance intention have been developed around the derivation of learning interest (e.g., Bhattacherjee, 2001), the present study included learning interest to examine continuance intentions; however, no study on user intention to remain with an inquiry-based learning environment using an iPad2 device has been conducted.

2.2. Determinants of learning interest: Internet cognitive failure

An overview of the relevant literature shows that possible issues impacting the adoption decision can be categorized into beliefs, skills, experience and curriculum related concerns. Apart from explicating these categories, this study focused on Internet cognitive failure regarding relevant adoption determinants for research factors. A cognitive failure can be defined as a mistake in the performance of an action that the person is normally capable of completing (e.g., Wallace, Kass, & Stanny, 2002). Cognitive failure indexes individuals’ self-reported absent-mindedness and failures of attention (Forster & Lavie, 2007; Tipper & Baylis, 1987). Previous studies indicate participants with high cognitive-failure scores are found to be more impaired by the presence of peripheral distractors than participants with low
cognitive-failure scores (Forster & Lavie, 2007; Kramer, Humphrey, Larish, Logan, & Strayer, 1994). This finding is interpreted as evidence that post-perceptual levels of selective attention are less efficient in participants with high cognitive failure (Forster & Lavie, 2007).

Consistent with this, cognitive failure may equally well reflect a decrease in the efficiency of perceptual levels of selective attention (i.e., defocused perceptual resources) and reflect a decrease in the deployment of cognitive resources.

At present, there is no evidence to indicate how resultant cognitive failure in Internet usage is manifested physiologically, subjectively, or behaviorally in relation to e-text (Liu, 2005). However, the present study considered the possibility that cognitive-affect mechanisms exert interacting effects on the interest in an inquiry-based learning environment. Specifically, Internet cognitive failure may modulate the recognition of the spatial focus of perceptual resources to manipulations of perceptual load, which would be reflective of learning interest. To capitalize on the participants’ interest, prior research suggests that feelings such as “like” and “enjoyment” may influence a person’s interest and that a heightened psychological state accompanies “engagement” with content over a given period of time (Roese & Peck, 2009). In this sense, this study considered the three factors: “like”, “enjoyment” and “engagement” as the components of learning interest to realize the association with Internet cognitive failure in relation to human-iPad 2 interactions to access the POE application. Then three hypotheses were proposed to guide this study as follows.

H1. Internet cognitive failure is positively correlated with like.
H2. Internet cognitive failure is positively correlated with enjoyment.
H3. Internet cognitive failure is positively correlated with engagement.

2.3. Determinants of continuance intention: learning interest

Interest in a familiar topic would be considered individual interest because the topic interest involved would likely be a stable and enduring preference of the reader (Schiefefe, 2009). Ultimately, it is important to recognize that individual interest is thought to positively influence learning (Hidi, 1990). One study yields informative findings in which topic interest is found to increase levels of positive affect, which increased persistence, and subsequently increased learning from texts (Ainley et al., 2002). However, this explanation does not answer the question of what cognitive process explains the positive association between interest and learning from texts (Clinton & van den Broek, 2012).

In the present study, the term ‘interest’ referred to the degree to which an individual enjoys or likes or engages in specific activities. Prior research suggests that feelings such as preference and enjoyment may influence a person’s interest and that a heightened psychological state accompanies engagement with content over a given period of time (Roese & Peck, 2009). Thus, the present study expected that preference, enjoyment and engagement will be associated with interest when participating in the activity.

Knowledge about changes in preference over repeated exposure is important for product development (Hetherington, Bell, & Rolls, 2000; Stolzenbach, Bredie, Christensen, & Byrne, 2013) as the initial rating of preference is found to be a predictor over repeated consumption (Vickers & Holton, 1998). According to Dewey (1933), conditions for learning are maximized when an activity is both playful and serious. The essential condition for learning is that enjoyment and the effect of interest be generated in response to the learning activity. Enjoyment is classified as a positive activity that focuses emotions and involves thoughts and cognitions concerning the process of working on an achievement activity. Hence, enjoyment involves experiencing pleasure during an activity (Ainley & Ainley, 2011). From a constructivist’s perspective, learning is not a replication or reproduction of knowledge and skills but an active meaning-making process in which the learner actively engages (Dewey, 1913). In this sense, engagement is considered as a defining aspect of topic interest; if one is interested in a topic, then one is engaged in that topic (Frick, 1992). Venkatesh and Bala (2008) reveal that perceived enjoyment (PE) is a vital determinant for tasks that are entertainment-oriented. On the other hand, mobile gaming is an enjoyment-oriented usage of information technology as defined by Llorens, Schaufeli, Bakker, and Salanova (2007). Hence, it is expected that learning interest will enhance users’ continuance intentions to adopt computer-supported learning. Thus, another three hypotheses guided this study were proposed as follows.

H4. Like is positively correlated with continuance intention.
H5. Enjoyment is positively correlated with continuance intention.
H6. Engagement is positively correlated with continuance intention.

2.4. Research model

According to the attention-to-affect model (Critcher & Ferguson, 2011; Satpute et al., 2013), the present study proposed research hypotheses that indicated Internet cognitive failure played an antecedent role in predicting that learning interest would lead to continuance intention using the iPad2 and the POE inquiry based learning platform. Consistent with this proposition and the literature review, the present study proposed that Internet cognitive failure will correlate with learning interest: preference, enjoyment and engagement. Moreover, these sub-constructs of learning interest will be associated with continuance intention to practice the POE mode of science inquiry. Henceforth, the following research model (Fig. 1) was proposed:

3. Research design

The present study encompassed an experimental research with questionnaire survey based on a POE inquiry-based learning design. The POE design and research procedure were elaborated as follows.
3.1. POE inquiry-based learning design

Reiff, Harwood, and Phillipson (2002) and Joolingen and De Jong (1997) use the scientific discovery as dual search (SDDS) model to reveal how the interactions between learner and the simulation model can facilitate the transfer of knowledge. Learners show increased opinions and display mastery of relevant knowledge after operating in the SDSS-based model (Lazonder, Wilhelm, & Hagemans, 2008). Pegg (2006) categorizes inquiry-based learning modes as follows:

- Inquiry mode 1: prediction, observation, data collection, and explanation (POCPE).
- Inquiry mode 2: prediction, observation, and explanation (POE).
- Inquiry mode 3: prediction, data collection, measurement, graph making, and explanation (PCMGE).

In virtual inquiry learning (Lazonder et al., 2008), the aim is for students to generate hypothetical-deductive explanations of natural science phenomena, which could add new concepts to the learner’s domain knowledge or disprove the learner’s assumptions. This study applied Inquiry mode 2 (prediction, observation, and explanation) to create an inquiry-based plot. The design mode is presented in Fig. 2. Marchionini, Dwiggins, Katz, and Lin (1993) view domain knowledge as the basis for learning. This domain can be expanded by means of various media. In addition to positing a question, many more tools are required to complement a learner’s lack of knowledge (De Jong, 2006a, 2006b). Because domain knowledge is particularly important, our study focused on inquiry-based learning of scientific knowledge.

Physics examples: 20 units, including buoyancy of fluids, pressure of gases, inflation of materials, and so forth.
Biology examples: 8 units, including camels, spiders, figs, and so forth.

To increase the effectiveness of the POE mode in future applications, a storyboard was created for use with the POE mode by a professional group. As an example, three frames from the “Balanced Bird” storyboard are shown in Fig. 3:

3.2. Research procedure

Research participants were directed to visit the POE platform on iPad2 for 15 min once per week, for a total of 8 times over two months in an elementary school computer lab. Students were permitted to pursue the scientific topic of their choice, but they were not allowed to discuss their work or collaborate with their classmates. In order to prevent students to discuss with each other, they were regulated with an incentive to encourage them to keep silence during the experiment. At the end of the two-month period, they were asked to complete a questionnaire.

3.3. Data collection and participants

According to Piaget (1978), understanding science concepts requires learners to understand cause–effect relationships (Riedl, 2004). Feldman (2004) proposes that children over 10 years of age can understand cause–effect relationships. Therefore, 6th grade students were chosen as study subjects. A total of 96 questionnaires were returned, 81 of which replied all items completely. Of the respondents, 44.4% were female and 55.6% were male. Approximately 66.7% of the participants had prior experience using digital learning software from iPad2 applications, while 55.6% had no prior experience.

4. Research instruments

The present study adapted some measurements from previous studies for instrument formation and confirmatory factor analysis. All constructs were measured using multiple items, and they all used fully anchored, five-point, Likert-type scales that ranged from “strongly disagree” to “strongly agree.”
4.1. Research questionnaire

4.1.1. Learning interest measure

Learners’ attitudes can be categorized into emotional preferences and reasoned preferences, or by “want” and “should” (Bazerman, Tenbrunsel, & Wade-Benzoni, 1998). Such categorizations are consistent with the hedonic/utilitarian dimensions of value. Hedonism embraces flow or playfulness in an activity (O’Brien, 2010). To capitalize on the novelty effect in sustaining participants’ interest, the present study deployed Lusk’s (2008) situational interest questionnaire. In the emotional preferences (see Pekrun, Goetz, Titz, & Perry, 2002b), task-related positive enjoyment is distinguished as a process (i.e., activity) and feeling of joy regarding success. From a constructivist perspective, engagement refers to the extent to which students are attending to and expending mental effort in the learning tasks (Chapman, 2003). Thus, to evaluate the 6th grade participants’ interest, the questionnaire was divided into three sections: like, enjoyment, and engagement. There were three items in each section.
4.1.2. Continuance intention measure

The measuring items were adapted from previously validated research by Chiu, Chiu, and Chang (2007). The original instrument was translated into Chinese and modified to reflect the context of the POE mode related to the IT/IS continuance context to investigate the relationships among factors that affect the intention to continuously use. There were 5 items adapted from the Cognitive Failures Questionnaire or CFQ by Broadbent, Cooper, Fitzgerald, and Parkes (1982) and were used to assess Internet cognitive failure (ICF). This study adapted the method outlined by Broadbent et al. (1982) for validation purposes, as it is an established measure for assessing slips inattention that occur in everyday life, a factor that was assessed through the questionnaire.

4.2. Reliability and validity analyses

Confirmatory factor analysis was applied to test composite reliability, convergent validity, discriminative validity, internal reliability, and construct validity of this research instrument. First, internal consistency was determined by examining the composite reliability (CR) of the constructs (Fornell & Larcker, 1981). As all composite reliability values in the present study ranged from .805 to .885, they surpassed the suggested threshold value of .7 (Hair, Black, Babin, & Anderson, 2009; Nunnally, 1978). Second, convergent validity in the present study was evaluated by verifying whether (1) the average variance extracted (AVE) values were lower than .5 (Fornell & Larcker, 1981) and (2) the factor loadings of all items were significant and higher than .5 (Nunnally, 1978). As all of these conditions were met, acceptable convergent validity was confirmed. Third, the discriminative power of the scale was determined by its ability to discriminate the items of instrument, and was examined by independent t-test to explain the discriminative power of each item. One frequently used technique for assessing whether an item is properly discriminating is to select those people in the top and bottom 27% of the subscale score distribution (Cureton, 1957), then to test whether there is a statistically significant difference between the two groups’ mean scores on the item to yield a t-value as the critical ratio (Himmerlfarb, 1993). If the critical ratio (t-value) is larger than 3, the discriminative power is significant, Table 1 shows that all critical ratio (t-values) were larger than 3 (p < .001**) indicating the subscales also all reached significance, thus suggesting that all items were discriminative (Green & Salkind, 2004).

Forth, to evaluate the consistency of the variables, a reliability analysis of the questionnaire was conducted using Cronbach’s α. According to Nunnally (1978), a Cronbach’s α value above .5 indicates that a measure of internal reliability is acceptable. The Cronbach’s α value is shown in Table 2, and the reliability coefficient for the entire questionnaire was .861. Fifth, the construct validity of the research instruments was established using confirmatory factor analysis (Byrne, 2001). Table 2 shows that the means of each dimension ranged from 3.179 to 3.942 and the standard deviations were small, thereby indicating that the degree of dispersion was low.

5. Research results

The analysis was run in two steps. In the first step, the degree of linear relationship between each construct was calculated using Pearson’s r coefficient of correlation. In the second step, we adopted the visual partial least squares (PLS) 1.04 to path model over the covariance-based SEM. We used the PLS 1.04 as an analysis tool to develop the measurement and structural models, and we used bootstrapping to estimate the sampling distribution and the path coefficients. Additionally, the model explanatory power for the measurement model was tested.

5.1. Correlation analyses

Pearson product–moment correlation coefficients are presented in Table 3. Table 3 shows that there were significant positive correlations among ICF, preference, enjoyment and engagement and that there was a certain degree of correlation among these continuous variables. All

**Table 1**

<table>
<thead>
<tr>
<th>Items</th>
<th>Mean</th>
<th>SD</th>
<th>Loading</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICF: AVE = .517, CR = .843</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. I often misinterpret the messages’ meaning so that I must read again.</td>
<td>2.63</td>
<td>1.336</td>
<td>.767</td>
<td>5.709</td>
</tr>
<tr>
<td>2. I often have difficulty to find the information I need on the webpage.</td>
<td>2.05</td>
<td>1.192</td>
<td>.717</td>
<td>4.636</td>
</tr>
<tr>
<td>3. If there are too many messages on the screen, I always have experienced in missing information but it is there.</td>
<td>2.31</td>
<td>1.328</td>
<td>.799</td>
<td>5.204</td>
</tr>
<tr>
<td>4. I often miss the location what I post on the Internet.</td>
<td>2.48</td>
<td>1.370</td>
<td>.669</td>
<td>4.973</td>
</tr>
<tr>
<td>5. I often forget what message I posted.</td>
<td>2.30</td>
<td>1.239</td>
<td>.731</td>
<td>5.322</td>
</tr>
<tr>
<td>Like: AVE = .593, CR = .805</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. After my last use of the POE mode, I still liked using it.</td>
<td>3.96</td>
<td>1.042</td>
<td>.710</td>
<td>4.280</td>
</tr>
<tr>
<td>2. After my last use of the POE mode, I am still eager to use it again.</td>
<td>3.80</td>
<td>1.249</td>
<td>.981</td>
<td>4.853</td>
</tr>
<tr>
<td>3. Even though I didn’t score well the last time I used the POE mode, I still want to use it.</td>
<td>4.06</td>
<td>1.258</td>
<td>.558</td>
<td>4.148</td>
</tr>
<tr>
<td>Enjoyment: AVE = .673, CR = .859</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. The last time I used the POE mode, I still felt excited.</td>
<td>3.01</td>
<td>1.383</td>
<td>.667</td>
<td>5.773</td>
</tr>
<tr>
<td>2. The last time I used the POE mode, I still felt focused.</td>
<td>3.80</td>
<td>1.166</td>
<td>.866</td>
<td>6.567</td>
</tr>
<tr>
<td>3. The last time I used the POE mode, I still felt enjoyed.</td>
<td>3.69</td>
<td>1.281</td>
<td>.908</td>
<td>6.662</td>
</tr>
<tr>
<td>Engagement: AVE = .715, CR = .885</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. The last time I used the POE mode, I lost track of time.</td>
<td>3.74</td>
<td>1.149</td>
<td>.836</td>
<td>7.329</td>
</tr>
<tr>
<td>2. The last time I used the POE mode, I still felt focused.</td>
<td>3.46</td>
<td>1.215</td>
<td>.912</td>
<td>9.506</td>
</tr>
<tr>
<td>3. The last time I used the POE mode, I still felt attracted.</td>
<td>3.17</td>
<td>1.282</td>
<td>.792</td>
<td>8.148</td>
</tr>
<tr>
<td>Continuance intention (CI): AVE = .624, CR = .867</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. I would recommend the POE mode to other students.</td>
<td>3.21</td>
<td>1.330</td>
<td>.817</td>
<td>8.608</td>
</tr>
<tr>
<td>2. I would like to continue using the POE mode.</td>
<td>3.37</td>
<td>1.239</td>
<td>.930</td>
<td>9.867</td>
</tr>
<tr>
<td>3. I would gradually increase my POE mode use frequency in the future.</td>
<td>3.12</td>
<td>1.269</td>
<td>.733</td>
<td>7.277</td>
</tr>
<tr>
<td>4. I would participate immediately when the POE mode offers new lessons.</td>
<td>3.01</td>
<td>1.392</td>
<td>.653</td>
<td>6.276</td>
</tr>
</tbody>
</table>
coefficients were moderate to large. As predicted, the variables for ICF and Liking, Enjoyment and Engagement were negatively correlated, and the sub-constructs of learning interest were positively correlated with continuance intention.

5.2. Structural model analysis

After testing the reliability and validity of the PLS measurement model, this study estimated the prediction and explanatory abilities of the PLS structural model. As shown in Table 4 and Fig. 4, Hypotheses 1, 2, 3, 4, 5 and 6 were supported. These results indicated that the ICF had a direct significant positive correlation with preference, enjoyment and engagement ($\beta = -0.348, t = 2.398^*; \beta = -0.471, t = 3.186^{**}; \beta = -0.403, t = 2.962^{**}$). Furthermore, preference, enjoyment and engagement had direct significant positive correlations with IU ($\beta = 0.249, t = 2.844^{**}; \beta = 0.422, t = 3.990^{***}; \beta = 0.522, t = 5.180^{***}$). Moreover, applying the square of the multiple correlation coefficients ($R^2$), the explained variance of the ICF on preference was 12.1%; the explained variance of the ICF on enjoyment was 22.1%; the explained variance of the ICF on engagement was 16.3%; the explained variance of the ICF, preference, enjoyment and engagement on IU was 66.7%. Thus, we determined that the dependent variables used in this research demonstrated good reliability.

6. Discussion

The results of this study provided insight into the attention-to-affect relationships among Internet cognitive failure, learning interest, and the continuance intention to use the POE science learning model on the iPad2. These findings offered three theoretical contributions. (1) They showed that continuance intention using the iPad2 was derived from a mix of learning interest. (2) They emphasized the interrelatedness of learning interest and Internet cognitive failure. (3) They offered a more system-specific insight into the antecedents of Internet cognitive failure, specifically, the importance of the continuance intention of a new device for science learning. Consistent with the initial hypotheses that cognitive failures mediate the association with learning interest and reflect continuance intentions regarding the iPad2 to practice POE science inquiry learning, the confirmatory analyses showed high predictable power of Internet cognitive failure to learning interest, and furthermore, Internet cognitive failure accounted for virtually all the shared variance among the preference, enjoyment, engagement and continuance intention. These findings were consistent with other previous findings regarding the associations between learning interest and low cognitive failure (e.g., Cheyne, Carriere, & Smilek, 2006).

By analyzing the data obtained, the present study affirmed the relative independence of Internet cognitive failure, and it also confirmed that continuance intention was mediated by a high level of learning interest. In fact, a confirmatory model advocating a possible convergence of all measures around a single construct presented an adequate level of structural adjustment, though the existence of independent general dimensions was supported. This result was significant considering that the correlation between the latent constructs may be predicted from previous constructs. That is, lower Internet cognitive failure correlates with higher learning interest with respect to the POE inquiry-based science learning using the iPad2 application. This result was supported by Myers’ (1937) view that feelings of cognitive failure

<table>
<thead>
<tr>
<th>Construct</th>
<th>Number of items</th>
<th>Mean</th>
<th>SD</th>
<th>Cronbach’s α</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>18</td>
<td>3.545</td>
<td>.752</td>
<td>.861</td>
</tr>
<tr>
<td>Internet cognitive failure (ICF)</td>
<td>5</td>
<td>2.354</td>
<td>.993</td>
<td>.825</td>
</tr>
<tr>
<td>Like</td>
<td>3</td>
<td>3.942</td>
<td>.932</td>
<td>.689</td>
</tr>
<tr>
<td>Enjoyment</td>
<td>3</td>
<td>3.502</td>
<td>1.116</td>
<td>.844</td>
</tr>
<tr>
<td>Engagement</td>
<td>3</td>
<td>3.456</td>
<td>1.093</td>
<td>.881</td>
</tr>
<tr>
<td>Continuance intention (CI)</td>
<td>4</td>
<td>3.179</td>
<td>1.152</td>
<td>.904</td>
</tr>
</tbody>
</table>

Notes: **p < .01, *p < .05.

### Table 3

**The correlation matrix.**

<table>
<thead>
<tr>
<th></th>
<th>ICF</th>
<th>Like</th>
<th>Enjoyment</th>
<th>Engagement</th>
<th>CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICF</td>
<td>1</td>
<td>–0.201*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Like</td>
<td>–0.254*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enjoyment</td>
<td>.639**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Engagement</td>
<td>–0.211*</td>
<td>.731**</td>
<td>.858**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>CI</td>
<td>–0.294**</td>
<td>.619**</td>
<td>.781**</td>
<td>.810**</td>
<td>1</td>
</tr>
</tbody>
</table>

*p < .05, **p < .01.

### Table 4

**Path coefficient β, t-statistic, $R^2$ of the PLS measurement model.**

<table>
<thead>
<tr>
<th>Path</th>
<th>Path coefficient β</th>
<th>t-statistic</th>
<th>Construct</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICF → Like</td>
<td>–0.348</td>
<td>2.398*</td>
<td></td>
<td>.121</td>
</tr>
<tr>
<td>ICF → Enjoyment</td>
<td>–0.471</td>
<td>3.186**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICF → Engagement</td>
<td>–0.403</td>
<td>2.962**</td>
<td>Like</td>
<td>.221</td>
</tr>
<tr>
<td>Like → Continuance intention</td>
<td>0.249</td>
<td>2.844**</td>
<td>Engagement</td>
<td>.163</td>
</tr>
<tr>
<td>Engagement → Continuance intention</td>
<td>0.422</td>
<td>3.990**</td>
<td>Engagement</td>
<td></td>
</tr>
<tr>
<td>Engagement → Continuance intention</td>
<td>0.522</td>
<td>5.180***</td>
<td>Continuance intention</td>
<td>.667</td>
</tr>
</tbody>
</table>

Notes: **p < .001, *p < .01, *p < .05.
may serve as the cause, rather than the consequence of performance regarding the affective processes as well as the conscious and unconscious behaviors (Myers, 1937, p. 29). According to the assertion that Internet-based learning tasks constitute a particularly popular use of the Internet (Farley-Gillispie & Gackenbach, 2006), the correlation between Internet cognitive failure and learning interest was supported and was similar to the cognitive failure effect on individual learning interest (Itti & Koch, 2001).

According to Roeser and Peck (2009), enjoyment and engagement form the sub-constructs of a person’s interest and it is this interest that heightens his/her affective state over a given period of time. However, this study showed that continuance intention regarding the POE application was determined by learning interest. Similarly, Teo and Noyes (2011) find that perceived enjoyment has a significant direct influence on continuance intention to use new technological devices.

7. Conclusion

According to the “attention-to-affect” theory to explain learning as an emotional and cognitive experience (Frijda, 1986; Satpute et al., 2013), the learning interest is affected negatively or positively by students’ motivation (Pekrun et al., 2002a). In turn, they lead them to concentrate on cognitive resources (Giannakos, 2013). The results confirmed that learning interest was a strong and direct determinant of user continuance intention to practice the POE application. It further showed that virtual world users derived a mixture of interest from Internet cognitive failure via inquiry-based interaction.

7.1. Contributions

Taken together, the findings of our study suggested three principal contributions. First, this study supported an expanded perspective on the cognitive failure to Internet cognitive failure as a characteristic that affects students in interacting with POE contents and indicated that ICF has been a predominance of articulating the effects of individual differences as an antecedent of three types of learning interest. Where prior research is limited to produce results for individual-centered explanations of cognitive failure, this study showed that ICF explained how individuals differ in learning interests, i.e., asserting distinctiveness and enhancing an understanding of ICF in the e-learning environment.

Second, this study offered a novel, identity perspective to explain learning interest. Specifically, this study divided learning interest into three dimensions with which a person identifies with aspects of liking, enjoyment, and engagement that predict willingness to continue using POE inquiry learning. As prior research established the importance of learning interest in continuance intention relationships, this study advanced our understanding of relational dynamics to show how the three learning interest components promote or inhibit the relationship between Internet cognitive failure and willingness to continue inquiry learning. Accordingly, the results lead to a better understanding of the attention-to-affect model using science inquiry-based learning on the iPad2 platform with the POE model.

Third, this study provided a strong example of the importance of POE approaches on the inquiry scientific concept in a digital learning environment. From the integration of the components of POE with elements of the scientific contexts in which iPad2 devices allow learners to execute and inquire about science knowledge, moreover, this study developed explanations that underscored the power of multilevel learning interest relevant as inseparable from the inquiry situation. In this way, the integration of POE into new technology is seen to have a meaningful combinative influence on scientific inquiry learning than has been demonstrated in other POE research.

7.2. The theoretical implications

This theory underscored the importance of relational dynamics in inquiry-based learning research. Our study yielded significant results for the three factors named above to suggest that relational connectedness to continuance intention, i.e., when students with a low level of ICF have a high degree of learning interest in POE learning, then they are more willing to continue using the device to learn scientific concepts. Moreover, the three types of learning interest had important implications for the extent to which inquiry-based learning is expected to enhance self-directed learning. From this, the extent to which POE on an iPad2 device can be relational evaluation and the extent to which students can acquire other knowledge other than science in POE, then, it will allow students to be more willing to make inquiries into concepts in common.
According to the highlights of "attention-to-affect", the results of this study showed that students were more interested to practice inquiry learning, if they perceived it as being strong in relevant ICF. Therefore, they were more willing to continue using it. This is, students with a high level of the "attention" may be more interested as an "affective" factor to practice POE lends the supporting of the perspective as suggested by the "attention-to-affect" theory. As such, it was becoming more connected to the effectiveness of inquiry-based learning through POE process.

7.3. The practical implications

Virtual course designers must consider new technological features that generate and maintain interest in course activities (Silvia, 2006), because interest influences goal setting and learning strategies (Hidi & Renninger, 2006). From a practical perspective, the outcomes of this study served to improve the guidelines for the design and development of learning programs that specifically stimulate the acceptance of the users. Designers, as well as users of POE applications, should adopt an inquiry-based approach to ensure that the attention-to-affect model drives the right priorities for student learning.

A second practical implication is that POE in science inquiry-based learning needs to be recognized and that students may vary in the importance they place on ICF. This study suggested that bringing together students with high levels of ICF may not result in a high level of learning interest. Therefore, the students who needed to be recognized might not benefit from receiving POE. This implied that meaningful knowledge inquiry may take place only for students who were perceived as highly learning interested to create a continuance intention to effective knowledge inquiry. In other words, to the science teacher, more consideration in the application of POE as an inquiry approach for those who could benefit most from the knowledge inquiry and who may be the least likely to have a high level of Internet cognitive failure.

7.4. Future study

Although correlational data cannot provide definitive knowledge about causation, the benefit of structural equation modeling is that it allows us to predict experimental outcomes. The results obtained in the present study suggested a clear need for additional research on the potential consequences of relevant cognitive processes and learning interest in using the iPad2 to learn science. While there is a growing literature suggesting attention failures can be costly in terms of human error (e.g., Robertson, 2003), the present results suggested that future research should also consider prior knowledge in relation to cognitive failure as it is assumed that if one has more prior knowledge related to the learning tasks, one will experience fewer problems related to concentration, thinking, and attention. Thus, the degree to which prior knowledge affects Internet cognitive failure in relation to the continuance intention related to the POE inquiry-based model can be the subject of future study.

The study solely focused on self-learning where group discussion was discouraged. While a number of studies examine the relationship between applications or software and collaborative learning, Anjewierden, Gijlers, Kolloffel, Saab, and De Hoog (2011) confirm a positive correlation between domain-related chat communication and learning improvement. On the other hand, Valtonen et al. (2013) discover variations in student experience on software applications, such as the suitability of the software and the ability to familiarize with it. As the result, POE inquiry model can be applied to collaborative learning in the future to examine the model effect on a group basis.

A recent study of the brain areas active during mind wandering (Mason et al., 2007) suggests a "default network" of cortical areas that could be examined further in future studies of the effects of mind wandering on one’s affective state. Using these studies as a basis for future research could allow the neural underpinnings of the causal role of basic cognitive mechanisms in affective state, such as learning interest, to be more easily discovered. Moreover, such studies may provide valuable insight into new treatment methods for understanding the effectiveness of new informational technology devices with POE as the pedagogical design.

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References


