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Developing Web-based assessment strategies for facilitating junior high school students to perform self-regulated learning in an e-Learning environment

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ABSTRACT

This research refers to the self-regulated learning strategies proposed by Pintrich (1999) in developing a multiple-choice Web-based assessment system, the Peer-Driven Assessment Module of the Web-based Assessment and Test Analysis system (PDA-WATA). The major purpose of PDA-WATA is to facilitate learner use of self-regulatory learning behaviors to perform self-regulated learning and in turn improve e-Learning effectiveness. PDA-WATA includes five main strategies: 'Adding Answer Notes,' 'Stating Confidence,' 'Reading Peer Answer Notes,' 'Recommending Peer Answer Notes' and 'Querying Peers' Recommendation on Personal Answer Notes'. Using these strategies, examinees are allowed to add answer notes to explain why they chose a certain option as the correct answer and state their confidence in their own answer and answer notes, for peers' reference. In addition to reading peer answer notes, examinees can also recommend peer answer notes as valuable references. The recommendation information can also be queried by all examinees. Quasi-experimental design was adopted to understand the effectiveness of PDA-WATA in facilitating learner use of self-regulatory learning behaviors to perform self-regulated learning and in improving learner e-Learning effectiveness. Participants were 123 seventh-grade junior high school students from four classes. These four classes were randomly divided into the PDA-WATA group ($n = 63$) and the N-WBT group ($n = 60$). Before e-Learning instruction, all students took the pre-test of the Learning Process Inventory (LPI), used to understand how often learners use self-regulatory learning behaviors in the learning process, and the pre-test of the summative assessment. After a two-week e-Learning instruction, the students all took the post-test of the LPI and the summative assessment. Results indicate that students in the PDA-WATA group appear to be more willing to take the Web-based formative assessment than students in the N-WBT group. In addition, PDA-WATA appears to be significantly more effective than N-WBT in facilitating learner use of self-regulatory learning behaviors to perform self-regulated learning and in improving their e-Learning effectiveness. Moreover, this research also finds that in the PDA-WATA group, there is no significant difference between the learning effectiveness of students with a low level of self-regulated learning and students with a high level of self-regulated learning, but similar result cannot be found in the N-WBT group.

1. Introduction

As Internet communication technology (ICT) grows in sophistication, teaching and learning behaviors in e-Learning environments are undergoing rapid change. These changes have gradually begun to impact the educational paradigm (Flake, 2001), making research on e-Learning an important focus in the educational realm. Compared with traditional learning environments, e-Learning environments provide learners with more abundant and diverse learning resources (Wang, 2008). According to Wang (2008), the main advantage of e-Learning is that it overcomes the limits of time and space and provides learners opportunities to perform self-directed learning. However, it also lacks the teacher supervision of traditional teaching and makes learners feel isolated and disconnected (Wang, 2007). Thus, learners in an e-Learning environment must be highly self-regulated and independent, otherwise their e-Learning effectiveness may be low (Kauffman, 2004). If an e-Learning environment offers strategies to encourage learners to become highly self-regulated, it will help them enjoy better learning effectiveness.

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The major characteristic of self-regulated learners is that they can use self-regulatory learning behaviors to perform self-regulated learning (Gordon, Dembo, & Hocevar, 2007). Self-regulated learning means that learners intentionally make an effort to manage and direct complicated learning activities (Kauffman, 2004). This involves interactions between cognitive strategy, meta-cognition, and motivation (Butler & Winne, 1995; Perry, 2002; Zimmerman, 2000). Heikkilä and Lonkab (2006) believed that self-regulated learners could set task-oriented and reasonable goals, be responsible for their own learning, and maintain learning motivation. Self-regulated learning is important in improving student learning effectiveness (Gordon et al., 2007; Law, Chan, & Sachs, 2008; Pintrich, 2003; Schunk, 2005a, 2005b).

Though self-regulated learning plays an important role in both traditional and e-Learning environments, researchers have argued that self-regulated learning is more important in e-Learning environments than in traditional learning environments (Jonassen, Davidson, Collins, Campbell, & Haag, 1995; King, Harner, & Brown, 2000; Puzziferro, 2008). Zimmerman, Bonner, and Kovach (1996) made several suggestions about how to facilitate learner use of self-regulatory learning behaviors to perform self-regulated learning. Zimmerman et al. argued that learners' self-regulated learning ability could be taught and improved by learners' own efforts. They suggested that teachers could facilitate learners to perform self-regulated learning by making them use self-regulated learning strategies to perform self-regulated learning and experience the benefits of self-regulated learning. In other words, if teachers exploit the proper strategies in teaching environments and encourage learners to use self-regulatory learning behaviors to perform self-regulated learning and experience its benefits in the environments, learners' self-regulated learning ability will be improved and they will be motivated to perform self-regulated learning. Based on the suggestions of Zimmerman et al., this research develops strategies in an e-Learning environment to facilitate learners in using self-regulatory learning behaviors to perform self-regulated learning and improve their e-Learning effectiveness.

Paris and Paris (2001) argued that self-assessment was closely related to self-regulated learning and could include all dimensions of self-regulated learning. Therefore, this research develops self-regulated learning strategies that incorporate self-assessment in an e-Learning environment. Using the Web-based Assessment and Test Analysis (WATA) system (Wang, Wang, Wang, Huang, & Chen, 2004; Wang, Wang & Huang, 2008; Wang, 2010; Wang, 2011) as the platform, this research develops the Peer-Driven Assessment Module of the WATA system (PDA-WATA) (see Sections 2.2 and 3.2.3). Some modules in the WATA system, Formative Assessment Module (FAM-WATA; Wang, 2007) and Game Assessment Module (GAM-WATA; Wang, 2008), can successfully facilitate spontaneous performance of self-assessment in an e-Learning environment. Referring to the strategies of FAM-WATA, GAM-WATA and related literature, this research develops strategies which are expected to facilitate learner use of self-regulatory learning behaviors to perform self-regulated learning. In addition to developing PDA-WATA, this research also evaluates the effectiveness of PDA-WATA in facilitating learning in an e-Learning environment. Thus, this research seeks answers to the following three questions:

1. In an e-Learning environment, how effective is PDA-WATA in facilitating spontaneous participation in Web-based formative assessment, compared to a Normal Web-based Test (N-WBT)?
2. In an e-Learning environment, how effective is PDA-WATA in facilitating learner use of self-regulatory learning behaviors to perform self-regulated learning, compared to a Normal Web-based Test?
3. In an e-Learning environment, how effective is PDA-WATA in facilitating student e-Learning effectiveness, compared to a Normal Web-based Test?

According to the research questions stated above, this research has the following five research assumptions:

H_{01} Students in the PDA-WATA group and the N-WBT group are not significantly different in the number of times they spontaneously take Web-based formative assessment.
H_{02} Students in the PDA-WATA group and the N-WBT group are not significantly different in using self-regulatory learning behaviors to perform self-regulated learning.
H_{03} Students in the PDA-WATA group and the N-WBT group are not significantly different in their e-Learning effectiveness.
H_{04} In the PDA-WATA group, students with a high level of self-regulated learning and with a low level of self-regulated learning are not significantly different in their e-Learning effectiveness.
H_{05} In the N-WBT group, students with a high level of self-regulated learning and with a low level of self-regulated learning are not significantly different in their e-Learning effectiveness.

2. Literature review

2.1. Self-regulated learning

Self-regulated learning has become an important paradigm in the realm of educational research (Azevedo, Guthrie, & Seibert, 2004; Boekaerts, Pintrich, & Zeidner, 2000; Zimmerman & Schunk, 2001). In recent years, researchers have begun to emphasize the importance of self-regulated learning (Heikkilä & Lonkab, 2006; Perels, Dignath, & Schmitz, 2009; Schunk, 2005b). One of the main reasons that self-regulated learning has received research attention is that a learner with good learning achievement is often self-regulated (Kauffman, 2004). In other words, self-regulated learning is closely related to learning effectiveness (Gordon et al., 2007; Law et al., 2008; Pintrich, 2003; Perels et al., 2009; Schunk, 2005a, 2005b). Winne and Perry (2000) observed that self-regulated learners were often active and could effectively manage their own learning in various ways. Heikkilä and Lonkab (2006) further argued that a learner who was capable of self-regulated learning was also capable of setting a task-oriented and proper goal, being responsible for their own learning, and maintaining his/her own learning motivation. In addition, a learner capable of self-regulated learning is also capable of using many cognitive and metacognitive strategies to perform learning and monitoring their own learning to modify learning strategies based on learning tasks (Butler & Winne, 1995; Zimmerman, 2000).

Self-regulated learning is also important in an e-Learning environment (Hu & Gramling, 2008; King et al., 2000; Puzziferro, 2008; Vighnarajah, Wong, & Abu Bakar, 2009). According to Kauffman (2004), learners are required to learn independently in an e-Learning environment, which means they have to perform self-regulated learning. According to Hu and Gramling, in an e-Learning environment, it is

necessary to use self-regulated learning strategies to improve learner motivation and understanding for online learning. Puzziferro also argued that online courses often demanded a high degree of peer interaction and teamwork and learners needed to guide themselves to participate. Moreover, in addition to reading learning materials independently, learners also need to structure their own learning process, pace and strategies. In other words, if learners cannot use self-regulatory learning behaviors to perform self-regulated learning, they will not have good e-Learning effectiveness.

However, it is not easy for learners to spontaneously perform self-regulated learning (Pintrich, 1999). Several researchers have proposed methods for facilitating learner use of self-regulatory learning behaviors to perform self-regulated learning. According to Pintrich, learners can perform effective self-regulated learning only when they are highly-motivated and persistent in their learning tasks. Teachers also need to integrate strategies into teaching environments to facilitate learner use of self-regulatory learning behaviors to perform self-regulated learning (Zimmerman et al., 1996). Making learners understand the benefits of self-regulated learning is also an important way to facilitate learner performance of self-regulated learning (Zimmerman et al., 1996). Based on the above, this research develops strategies in an e-Learning environment aiming at enabling learners to become highly motivated to use self-regulatory learning behaviors to perform self-regulated learning and in turn improve their e-Learning effectiveness.

2.2. Self-regulated learning strategies in an e-Learning environment- PDA-WATA

e-Learning environments require learners to learn independently. Thus, e-Learning effectiveness is determined by whether learners can perform self-regulated learning in an e-Learning environment (Hu & Gramling, 2008; Jonassen et al., 1995; Kauffman, 2004; King et al., 2000; Puzziferro, 2008). One of the most important ways to improve e-Learning effectiveness is to enable learners to spontaneously use self-regulatory learning behaviors to perform self-regulated learning in an e-Learning environment, while one of the most important ways to make learners spontaneously use self-regulatory learning behaviors to perform self-regulated learning is to integrate self-regulated learning strategies into the learning environments, enabling them to experience the benefits of self-regulated learning (Zimmerman et al., 1996).

Paris and Paris (2001) argued that self-assessment was highly related to self-regulated learning since self-assessment included the main dimensions of self-regulated learning. Paris and Paris further pointed out that self-assessment involved the internalization of standards so that students could regulate their own learning more effectively. When students are able to interpret their own accomplishments with pride, their perceptions of ability and efficacy increase (Paris & Paris, 2001; Zimmerman, 2000). Following the suggestions above, this research takes self-assessment as the basis to develop self-regulated learning strategies in an e-Learning environment, PDA-WATA. By integrating PDA-WATA into an e-Learning environment, this research expects to facilitate learner use of self-regulatory learning behaviors to perform self-regulated learning, improving their e-Learning effectiveness.

This research is based on the self-regulated learning strategies proposed by Pintrich (1999) to develop the self-regulated learning strategies in PDA-WATA. Many earlier researches on self-regulated learning are therapeutic, aiming to teach participants to adjust dysfunctional behaviors (aggression, addictions and behavioral problems) (Schunk, 2005b). However, more and more recent researches try to apply the self-regulated learning theory in education.

Paul R. Pintrich is a leading theorist, researcher, and advocate of self-regulated learning in education (Schunk, 2005b). This research takes Pintrich's self-regulated learning theory as its basis. According to Pintrich (1999), there are three kinds of self-regulated learning strategies: cognitive strategies, metacognitive and self-regulatory strategies (self-regulatory strategies to control cognition), and resource management strategies. This research has used Pintrich's threefold division to develop five main strategies, 'Adding Answer Notes,' 'Stating Confidence,' 'Reading Peer Answer Notes,' 'Recommending Peer Answer Notes' and 'Querying Peers' Recommendation on Personal Answer Notes', for PDA-WATA. Detailed explanations are given below:

Cognitive strategies include rehearsal strategy, elaboration strategy, and organizational strategy (Pintrich, 1999; Weinstein & Mayer, 1986). Rehearsal strategy means repeating and reciting learning materials (Arsal, 2010; Pintrich, 1999). Rehearsal strategy helps learners identify important knowledge and retain the knowledge in short-term memory (Arsal, 2010). Elaboration strategy means summarizing and paraphrasing learning materials (Pintrich, 1999). Elaboration strategy helps learners create analogies and make connections and reorganization of ideas (Lloret, Aguilar, & Lloret, 2009). Organizational strategy means highlighting the main ideas of learning materials and outlining them (Pintrich, 1999). Organizational strategy helps learners develop deeper understanding (Lloret et al., 2009). PDA-WATA includes the 'Adding Answer Notes' strategy as the design for cognitive strategy. The 'Adding Answer Notes' strategy enables learners to add notes to explain why they chose a certain option as the correct answer when performing self-assessment. This involves learners in the process of rehearsal, elaboration and organization. In addition to repeating and recollecting the learning materials they learn in the e-Learning environment, they also summarize and outline the main ideas of learning materials and review the reasons why they chose a certain option as the correct answer.

There are three metacognitive and self-regulatory strategies: planning strategy, monitoring strategy, and regulating strategy, which are highly interrelated (Pintrich, 1999). Planning strategy means goal setting, in which learners set a learning goal and make plans to achieve it (e.g. Pintrich, 1999). Planning strategy allows learners to plan cognitive strategies they themselves want to use and activates learners' previous knowledge (Arsal, 2010). With this strategy, learners can more easily understand the learning contents and more effectively complete tasks (Lloret et al., 2009). Monitoring strategy is the next step after goal setting (Zimmerman, 1999). This means guiding the monitoring process by evaluating learning based on goals, standards, or criteria to achieve self-regulation (Pintrich, 1999). In other words, learners evaluate their own learning and understanding against the goals they set (Lloret et al., 2009; Weinstein & Mayer, 1986). PDA-WATA presents the percentage of 'passed' items (see Section 3.2.3). This can help learners set the goal of passing all items. In addition, PDA-WATA also includes the 'Stating Confidence' strategy. In addition to explaining why they chose a given option as the correct answer, learners can also evaluate their own confidence in choosing the option and the reason for choosing it. PDA-WATA also provides 'Reading Peer Answer Notes,' 'Recommending Peer Answer Notes' and 'Querying Peers' Recommendation on Personal Answer Notes' strategies. With these strategies, learners can understand why their peers chose a certain option as the correct answer through peer answer notes, recommend peer answer notes and understand how peers recommended their own answer notes. These strategies consolidate the mechanism of creating, reading and recommending answer notes. This mechanism provides learners with planning strategy and monitoring strategy. By reading peer answer notes, learners can compare their own knowledge with that of peers to understand their own learning conditions. By

comparing the recommendation on their own answer notes and those of peers, learners understand whether their own answer notes are more valuable references than those of their peers, and evaluate whether they know more than their peers. The mechanism also helps learners set the goal of gaining peers' recommendation for their answer notes. Learners will be motivated to use cognitive strategies to learn and then make the effort to write answer notes that can serve as valuable references. As to regulating strategy, it is closely related to monitoring strategy (Pintrich, 1999). Pintrich argued that when learners monitored their own learning and performance based on goals or criteria, this monitoring process provided suggestions to help them modify their own learning behaviors through the regulation process, making the learning behaviors conform to the goals or criteria. According to Puzziferro (2008) and Zimmerman et al. (1996), the monitoring process includes self-evaluation. Learners evaluate their own performance and the results of self-evaluation can serve as references for self-regulation. PDA-WATA also provides learners with regulating strategy. In addition to the mechanism of creating, reading and recommending answer notes, PDA-WATA allows learners to perform self-evaluation through self-assessment. When taking Web-based formative assessment in PDA-WATA, learners can monitor their own learning conditions and perform self-assessment by checking whether they have answered items correctly.

The resource management strategies help learners achieve better management and control of time, effort, study environment, and other people, including teachers and peers, by using help-seeking strategies (Arsal, 2010; Pintrich, 1999). Paulsen and Gentry (1993) indicated that resource management strategies were used by students to self-regulate both personal and environmental resources for academic tasks. McKeachie, Pintrich, Lin, and Smith (1986) divided resource management strategies into four categories: time management, study environment management, effort management, and managing the support of others. 'Time management' includes setting study plans and goals. 'Study environment management' includes establishing and maintaining studying area. 'Effort management' includes positive mood maintenance, self-talk, persistence management and self-reinforcement. 'Managing the support of others' includes seeking help from teachers, tutors, peers, and peer groups (McKeachie et al., 1986; Paulsen & Gentry, 1993). In other words, resource management strategies are focused on learners' control, monitoring and management of study environment (Lloret et al., 2009), which includes 'peer learning', 'help-seeking', 'effort regulation' and 'organising time and study environment' strategies (Blom & Severiens, 2008; Pintrich, Marx, & Boyle, 1993). PDA-WATA includes 'Adding Answer Notes,' 'Reading Peer Answer Notes' and 'Recommending Peer Answer Notes' strategies. By using these strategies, learners can explain why they chose a certain option as the correct answer while peers can read and recommend the reasons other learners provide. The 'peer learning' is achieved by reading and recommending these answer notes. The 'Reading Peer Answer Notes' strategy is also a 'help-seeking' strategy. It helps learners when they have difficulties answering an item by allowing them to read peer answer notes and understand the rate at which each option is chosen (see Section 3.2.3). By integrating peer answer notes, the chosen rate of each option, and the learning materials in the e-Learning environment, learners can achieve learning, find the correct answers and lastly 'pass' the items. The interface and strategies of PDA-WATA are also designed to provide learners with mechanisms for 'effort regulation' and 'organising time and study environment'. The PDA-WATA interface can display the percentage of 'passed' items (see part K of Fig. 2). This design helps learners manage their time and answering progress so that all items can be 'passed' in time. The 'Querying Peers' Recommendation on Personal Answer Notes' strategy allows learners to know how their own answer notes are recommended by peers. This design helps learners plan effective ways of learning so that they are able to write answer notes that earn peers' recommendation. Moreover, 'Recommending Peer Answer Notes' and 'Querying Peers' Recommendation on Personal Answer Notes' strategies enable peer interaction. Peers' recommendation on answer notes is positive feedback. When learners feel that the value of their answer notes are recognized, they will not only maintain a positive mood and perform self-reinforcement but persist in providing answer notes as a valuable reference for peers.

In addition to the three kinds of self-regulated learning strategies discussed above, motivation is also closely related to self-regulated learning (Pintrich, 1999). Pintrich argued that it was not easy for learners to spontaneously perform self-regulated learning. Learners will spontaneously and effectively perform self-regulated learning only when they have high participation in learning and are willing to spend more time and put more effort into cognitive and self-regulatory strategies to perform self-regulated learning (Pintrich, 1999). Thus, making learners highly motivated and persistent in their learning tasks is an important way to help them spontaneously use self-regulatory learning behaviors to effectively perform self-regulated learning. According to McKeachie et al. (1986), 'effort management' is meant to help learners maintain a positive mood and persist in completing learning tasks, making them highly motivated in learning. Blom and Severiens (2008) also noted that self-regulated learners strongly relied on resource management strategies to engage in learning. In other words, resource management strategies affect student learning motivation. PDA-WATA not only provides resource management strategies to enhance learning motivation but refers to the statements proposed by Rozendaal, Minnaert, and Boekaerts (2005), Vogel, Greenwood-Ericksen, Cannon-Bower, and Bowers (2006) and Wang (2008). Vogel et al. (2006) and Wang (2008) argued that the interaction with computers itself could improve learning motivation. To enrich human–machine interaction designs, Wang added the 'all pass and then reward' mechanism to the Web-based formative assessment system, GAM-WATA (Wang, 2008). It is found that GAM-WATA can significantly improve learner motivation to spontaneously take Web-based formative assessment (Wang, 2008). The 'all pass and then reward' mechanism allows learners to repeatedly take Web-based formative assessment (Wang, 2008). Each time they take Web-based formative assessment, the system randomly provides five items at most for them to answer. If learners answer an item correctly three consecutive times, they will be counted as having 'passed' the item and do not need to answer the item again in future assessments (Wang, 2008). In other words, the more items they answer correctly three consecutive times, the fewer items they will need to answer in future assessments (Wang, 2008). By answering all items correctly three consecutive times, learners can pass the level and be rewarded with a level-passing Adobe Flash animation (Wang, 2008). This research integrates the 'all pass and then reward' mechanism proposed by Wang into PDA-WATA, with the expectation that it will improve learner motivation to spontaneously participate in Web-based formative assessment. Rozendaal et al. pointed out that during learning, mutual help among peers had positive effects on motivation. This research follows the suggestions of Rozendaal et al. and develops human-machine interaction strategies based on the idea of mutual help among peers, and integrates these strategies, which include 'Adding Answer Notes,' 'Reading Peer Answer Notes,' 'Recommending Peer Answer Notes' and 'Querying Peers' Recommendation on Personal Answer Notes' strategies, into PDA-WATA. These strategies consolidate the mechanism of creating, reading and recommending answer notes to enable mutual help among peers. This mechanism allows learners to provide their own answer notes for peers' reference and gain help by knowing the chosen rate of each option and reading peer answer notes when having difficulties answering items. Moreover, learners can recommend peer answer notes based on their reference value. The recommendation information

can serve as reference for learners who need to refer to answer notes to achieve learning and choose the correct answers. By integrating peer answer notes, chosen rate of each option and learning materials in the e-Learning environment, learners achieve learning and find the correct answers. This research expects that the mechanism for mutual help among peers can have a positive influence on learning motivation and enhance learner motivation to learn with PDA-WATA. This research also expects that the designs can be used as 'help-seeking strategies (Pintrich, 1999)' in an e-Learning environment and facilitate learners to spontaneously use self-regulatory learning behaviors to perform self-regulated learning.

Based on the three kinds of self-regulated learning strategies proposed by Pintrich (1999) and Pintrich's viewpoints on motivation, this research develops various strategies in PDA-WATA for implementation in an e-Learning environment of junior high school 'Science and Technology' course in Taiwan. This research investigates whether these strategies can better motivate learners to spontaneously participate in Web-based formative assessment and promote learners to spontaneously use self-regulatory learning behaviors to perform self-regulated learning in an e-Learning environment. Moreover, this research also investigates the effectiveness of PDA-WATA in improving learner e-Learning effectiveness.

3. Methodology

3.1. Participants

Participants in this research comprised 123 seventh-grade students in four classes and their teacher from one junior high school in Taiwan. The teacher had experience in Web-based instruction. The four classes were randomly divided into two different groups, PDA-WATA group ($n = 63$) and N-WBT group ($n = 60$). All students learned the same e-Learning materials. However, students in the PDA-WATA group took the Web-based formative assessment in the form of PDA-WATA. Students in the N-WBT group took the Web-based formative assessment in the form of normal Web-based test (see Section 3.2.3). All students had taken a related course, Introduction to Computers and Internet, to familiarize themselves with computers and the Internet.

3.2. Instruments

3.2.1. e-Learning materials

This research developed e-Learning materials (Fig. 1) for the topic of 'Evolution' in the junior high school 'Science and Technology' course in Taiwan. These e-Learning materials did not include lengthy text descriptions and the contents were mostly presented with pictures and Adobe Flash animations.

3.2.2. Web-based formative assessment and summative assessment

The contents of the e-Learning materials, 'Evolution', were divided into two lessons, with one Web-based formative assessment for each lesson. This research constructed the items based on the contents of each lesson. There were 15 items in each Web-based formative assessment. All items were reviewed by two Biology and educational assessment experts. Students in the two groups all took the same items. The only difference was the method of administering the Web-based formative assessment. In the PDA-WATA group, Web-based

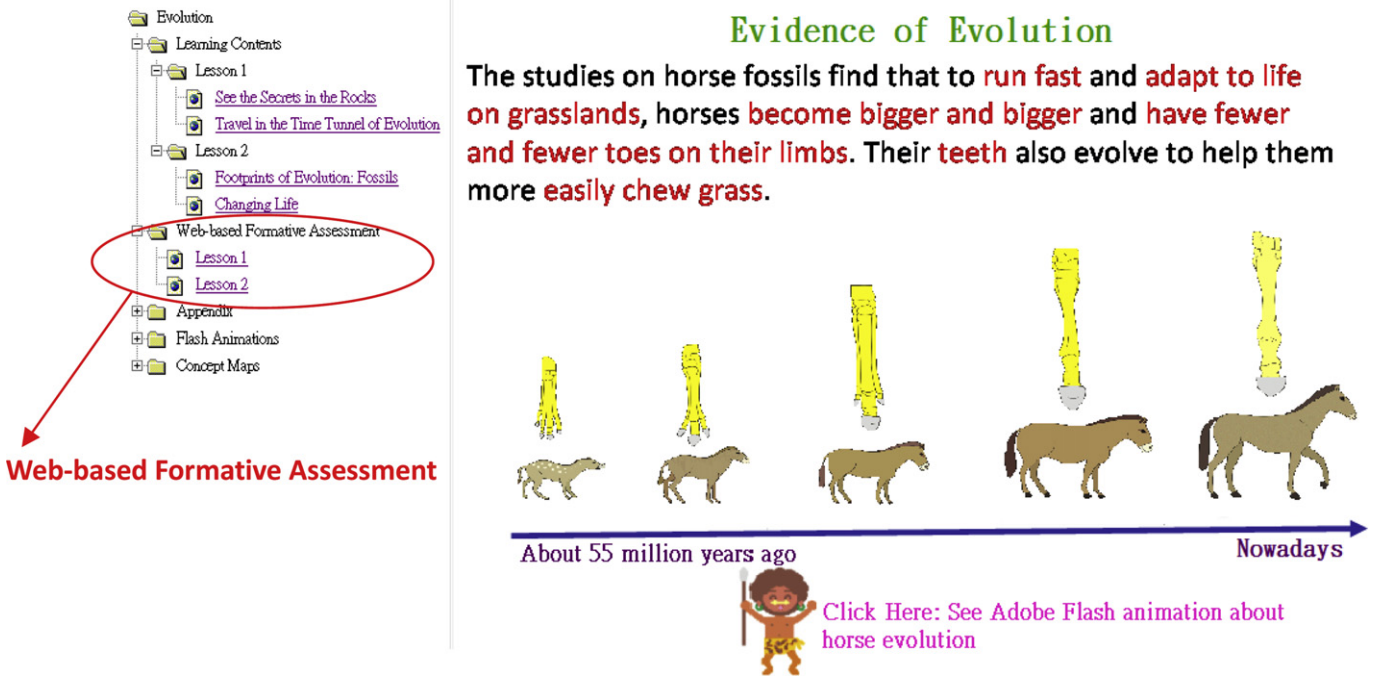

Fig. 1. e-Learning environment.

formative assessment was administered in the form of PDA-WATA. In the N-WBT group, Web-based formative assessment was administered in the form of normal Web-based test. See Section 3.2.3 for a more detailed discussion of PDA-WATA and N-WBT.

For the summative assessment, however, this research constructed items based on the contents of the entire e-Learning materials to evaluate learning effectiveness. The items in the Web-based formative assessment were not repeated in the summative assessment. The pre-test scores of the summative assessment were taken to represent entry behavior of learning, while the difference between the post-test scores and pre-test scores was taken to represent learning effectiveness. There were 30 items in the summative assessment. The items were constructed according to the Two-Way Chart and reviewed by two Biology and educational assessment experts to ensure validity. The average difficulty for the summative assessment was 0.525. Cronbach's α for the summative assessment was 0.833.

3.2.3. PDA-WATA & N-WBT

The main strategies of PDA-WATA include 'Adding Answer Notes,' 'Stating Confidence,' 'Reading Peer Answer Notes,' 'Recommending Peer Answer Notes' and 'Querying Peers' Recommendation on Personal Answer Notes' strategies. 'Adding Answer Notes' and 'Stating Confidence' strategies allow examinees to add answer notes to explain why they chose a certain option as the correct answer and state their level of confidence in their own answer and answer notes for peers' reference. 'Reading Peer Answer Notes' strategy allows examinees to read peer answer notes. In addition, 'Recommending Peer Answer Notes' strategy also allows examinees to recommend peer answer notes. The recommendation information can be queried by all examinees. Moreover, by using 'Querying Peers' Recommendation on Personal Answer Notes' strategy, examinees can query the recommendation information of their own answer notes. Each examinee was limited to using the 'Reading Peer Answer Notes' strategy 12 times in this research. To take the Web-based formative assessment, examinees have to answer at most five items randomly provided by PDA-WATA each time. After answering the items, examinees send the answers and the system immediately checks which items they answered incorrectly. However, the correct answers are not provided. Examinees can take the Web-based formative assessment repeatedly anytime, anywhere. If an item is answered correctly three consecutive times, it counts as 'passed' and does not appear again in later Web-based formative assessments. This process is iterated until no item is left for examinees to answer. The student is then counted as having 'passed' the whole assessment.

As shown in Fig. 2, part A ('Adding Answer Notes' strategy) allows examinees to add answer notes for the option they have chosen as the correct answer so that other examinees can refer to the answer notes. When examinees click part B ('Reading Peer Answer Notes' strategy), the telephone icon before the item, parts C, D, E, F and G will appear. Part C shows the chosen rate of each option, part D shows the answer notes peers add for the option, part E shows peers' confidence in their own answer and answer notes, part F shows how many peers recommended the answer notes, and part G ('Recommending Peer Answer Notes' strategy) allows examinees to recommend peer answer notes. Examinees can then refer to the information above to achieve learning and choose the correct answer. Part H ('Stating Confidence' strategy) allows examinees to rate their confidence in their own answer and answer notes. When examinees click part I ('Querying Peers' Recommendation on Personal Answer Notes' strategy), the eye icon before the item, the peers' recommendation information for the examinee's personal answer notes will be displayed (Fig. 3). In addition, part J shows the number of times remaining for the 'Reading Peer Answer Notes' strategy, while part K shows the percentage of 'passed' items. When the percentage shown in part K reaches 100%, it means that the examinee has 'passed' entire items.

Moreover, PDA-WATA includes the 'all pass and then reward' mechanism proposed by Wang (2007, 2008). This mechanism, in which an Adobe Flash animation is displayed as a reward when an examinee passes all items, is expected to improve examinee motivation to spontaneously take Web-based formative assessment. The design of the mechanism has been described in Section 2.2.

N-WBT changes traditional paper-and-pencil tests into normal Web-based tests. With N-WBT, examinees answer all items at a time. After they send out their answers, the system immediately checks which items have been answered incorrectly. Correct answers are then provided. Examinees can take the assessment as many times as they like.

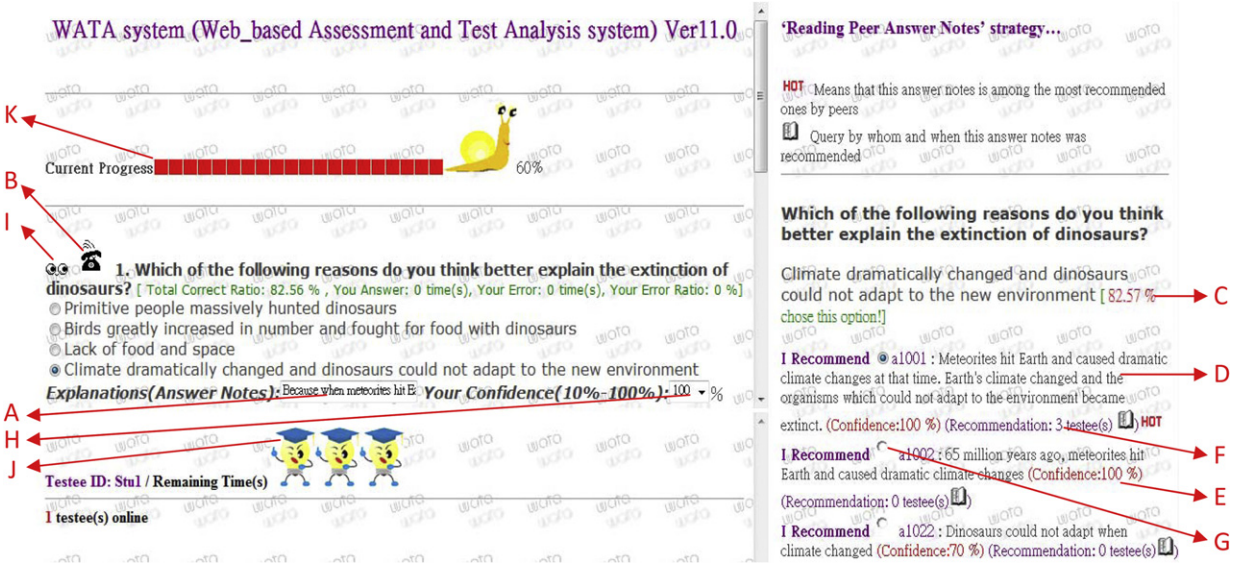

Fig. 2. PDA-WATA.

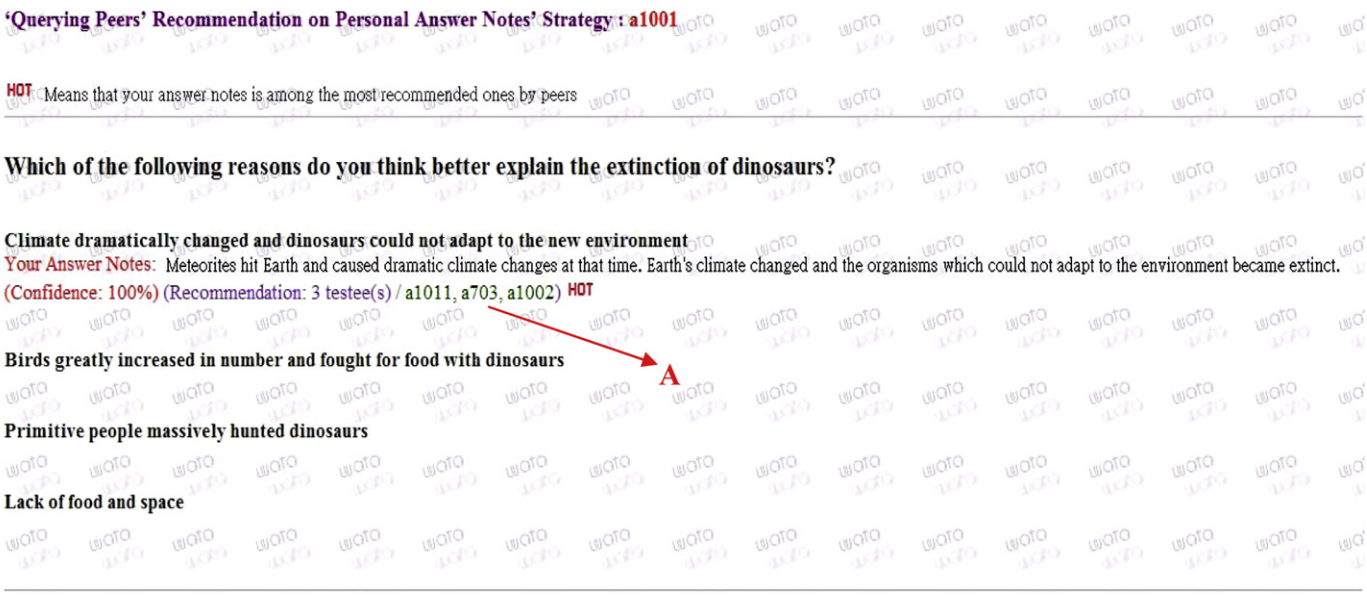

Fig. 3. 'Querying Peers' Recommendation on Personal Answer Notes' strategy. A: Three testees, a1011, a703 and a1002, recommended the answer notes.

3.2.4. Learning Process Inventory (LPI)

This research adopted the Learning Process Inventory (LPI) proposed by Gordon et al. (2007) to understand how often learners use self-regulatory learning behaviors in the learning process. Gordon et al. stated that the development of the LPI was primarily based on a questionnaire of Miller, Greene, and Montalvo (1996). It also includes several items from Gredler and Garavalia (2000). There are 26 items in the LPI, which are measured using a 7-point Likert scale (strongly agree: 7, agree: 6, slightly agree: 5, neutral: 4, slightly disagree: 3, disagree: 2, strongly disagree: 1) and includes four sub-scales: self-monitoring (monitoring) (9 items), deep strategy use (7 items), shallow processing (4 items), persistence (2 items), and environmental structuring (4 items) (Gordon et al., 2007).

The LPI is a kind of self-report scale. Gordon et al. (2007) argued that if a learner scored high on the LPI, it meant that he/she had a high level of self-regulated learning in the learning process. This research conducted the pre-test of the LPI and the post-test of the LPI on participating students. The pre-test of the LPI was conducted before the research. During the pre-test, students were asked to answer items according to how they had learned in the 'Science and Technology' course before. After the research, the post-test of the LPI was conducted and students were asked to answer items according to how they had learned during the research period. This research takes the pre-test scores of the LPI as an indication of how learners used self-regulatory learning behaviors to perform self-regulated learning prior to their participation in this research. The post-test scores of the LPI are taken as an indication of how learners used self-regulatory learning behaviors to perform self-regulated learning during this research. The differences between the pre-test and post-test scores of the LPI show how the design of the e-Learning environment in this research influences the way learners use self-regulatory learning behaviors to perform self-regulated learning.

Gordon et al. (2007) found that the reliability of each sub-scale of the LPI was between 0.63 and 0.80. This research gave the LPI to seventh-grade students in a junior high school in Taiwan, obtaining a Cronbach's α of each sub-scale as follows: self-monitoring : 0.930, deep strategy use: 0.925, shallow processing: 0.847, persistence: 0.671, and environmental structuring: 0.733.

3.3. Data collection and analysis

The data collected in this research were all quantitative data. Data collected included the number of times students took the Web-based formative assessment, the pre-test and post-test scores of the summative assessment, and the pre-test and post-test scores of the LPI. All data were analyzed using SPSS Ver12.0 (SPSS Inc., Chicago).

Five types of data analysis techniques were performed. First, to investigate whether PDA-WATA motivated students to take Web-based formative assessment spontaneously, an independent *t*-test was used to understand how students in the PDA-WATA group and in the N-WBT group differed in the number of times they spontaneously took the Web-based formative assessment (TIMES).

Second, to investigate how PDA-WATA and N-WBT influenced the way students used self-regulatory learning behaviors to perform self-regulated learning, ANCOVA (analysis of covariance) was performed. During ANCOVA, to regulate the effects of pre-test and entry behavior on the post-test scores, the 'pre-test scores of the LPI' was taken as the covariate, the 'post-test scores of the LPI' was taken as the dependent variable and the 'two different types of Web-based formative assessment (PDA-WATA and N-WBT)' was taken as the fixed factor when testing the relationship between the 'post-test scores of the LPI' and the 'two different types of Web-based formative assessment.' The Bonferroni post hoc test was also used to investigate the differences between students in the PDA-WATA group and students in the N-WBT group in using self-regulatory learning behaviors to perform self-regulated learning in the e-Learning environment designed in this research.

Third, a further analysis was also conducted. Students were divided into two types based on their pre-test scores of the LPI. Since LPI is a 7-point Likert scale, 4-point means 'neutral'. Hence, those students scoring higher than 104 points (26 items $\times$ 4 points) in the pre-test of the LPI are defined as more often using self-regulatory learning behaviors to perform self-regulated learning (students with a high level of self-regulated learning) before participating in this research. Those scoring lower than 104 points were defined as less often using self-regulatory learning behaviors to perform self-regulated learning (students with a low level of self-regulated learning) before participating in

Table 1
Independent *t*-test for students' TIMES in the PDA-WATA and N-WBT groups ($n = 123$).

Group	Mean of TIMES	SD	*t* value
PDA-WATA group ($n = 63$)	41.730	14.105	13.689**
N-WBT group ($n = 60$)	9.867	11.508	

**$p < 0.01$.
TIMES: Number of times students take the Web-based formative assessment.
SD: Standard deviation.

Table 2
One-way ANCOVA on the scores of the LPI ($n = 123$).

Variable	Level	Mean[a] (Std. error)	*F* value	Post hoc[b]
PRE			315.090**	
WFA	PDA-WATA	120.311(2.006)	12.313**	PDA-WATA > N-WBT**
	N-WBT	110.073(2.057)		

**$p < 0.01$.
[a] Covariates appearing in the model are evaluated at the following values: PRE = 113.260.
[b] Adjustment for multiple comparisons: Bonferroni.
PRE: Pre-test scores of the Learning Process Inventory (LPI).
WFA: Two different types of Web-based formative assessment.
PDA-WATA: PDA-WATA group.
N-WBT: N-WBT group.

this research. This research also used Cohen's *d* to evaluate the effect size (Cohen, 1988). The post-test scores of the LPI of students with a high level of self-regulated learning and of students with a low level of self-regulated learning were analyzed to understand how students used self-regulatory learning behaviors to perform self-regulated learning in the N-WBT and PDA-WATA groups. Based on the definition of Cohen, this research categorizes Cohen's *d* smaller than 0.20 as small effect size, Cohen's *d* ranging between 0.20 and 0.50 as small to medium effect size, Cohen's *d* ranging between 0.50 and 0.80 as medium to large effect size and Cohen's *d* larger than 0.80 as large effect size.

Fourth, to investigate how PDA-WATA and N-WBT influenced student e-Learning effectiveness, this research also used ANCOVA to test the relationship between the 'post-test scores of the summative assessment' and the 'two different types of Web-based formative assessment.' During ANCOVA, to regulate the effects of pre-test and entry behavior on the post-test scores, the 'pre-test scores of the summative assessment' was taken as the covariate, the 'post-test scores of the summative assessment' was taken as the dependent variable and the 'two different types of Web-based formative assessment' was taken as the fixed factor. The Bonferroni post hoc test was also used to test the differences between two different types of Web-based formative assessment in their effectiveness. Finally, this research also adopted ANCOVA to further investigate the effectiveness of PDA-WATA and N-WBT in facilitating the e-Learning of students with a high level of self-regulated learning and the e-Learning of students with a low level of self-regulated learning.

3.4. Research procedure

Before e-Learning, all 123 students (4 classes) were randomly divided into two different groups, the PDA-WATA group and the N-WBT group (each class as a unit). Further, all students took the pre-test of the summative assessment and the LPI. This research required 2 weeks in total (six classes). During the 2-week e-Learning instruction, students in the PDA-WATA and N-WBT groups could freely learn on the Web and take the Web-based formative assessment anytime, anywhere. The teacher did not perform any instruction of the course contents, only guiding the students in learning in the e-Learning environment. After the 2-week e-Learning instruction, all the students took the post-test of the summative assessment and the LPI.

4. Results

4.1. Analysis on the number of times students spontaneously take the Web-based formative assessment

The independent *t*-test was used to investigate the differences between students in the PDA-WATA group and the N-WBT group in the number of times they took the Web-based formative assessment (TIMES). Results of this analysis are shown in Table 1:

Table 1 shows that the TIMES of students in the PDA-WATA group is significantly greater than that of students in the N-WBT group ($t = 13.689$, $p < 0.01$). Based on this result, H_{01} is rejected. In other words, this result reveals that students in the PDA-WATA group appear to be more willing to take the Web-based formative assessment spontaneously than students in the N-WBT group.

Table 3
Effect size analysis on the LPI scores of students with different levels of self-regulated learning in the N-WBT and PDA-WATA groups.

Level of self-regulated learning	N-WBT group ($n = 60$)		PDA-WATA group ($n = 63$)		Effect size (Cohen's *d*)
	Mean	SD	Mean	SD	
High	124.091	24.201	135.979	20.220	0.533
Low	78.481	26.471	98.688	15.738	0.928

SD: Standard deviation.

Table 4
One-way ANCOVA on the scores of the summative assessment ($n = 123$).

Variable	Level	Mean[a] (Std. error)	*F* value	Post hoc[b]
PRE			150.849**	
WFA	PDA-WATA	58.625(1.426)	19.145**	PDA-WATA > N-WBT**
	N-WBT	49.610(1.462)		

**$p < 0.01$.
[a] Covariates appearing in the model are evaluated at the following values: PRE = 43.035.
[b] Adjustment for multiple comparisons: Bonferroni.
PRE: Pre-test scores of the summative assessment.
WFA: Two different types of Web-based formative assessment.
PDA-WATA: PDA-WATA group.
N-WBT: N-WBT group.

4.2. LPI analysis results

ANCOVA was used to investigate how students in the PDA-WATA and N-WBT groups are different in using self-regulatory learning behaviors to perform self-regulated learning in an e-Learning environment.

Before ANCOVA, the assumption of homogeneity of regression coefficients was tested ($F_{1,119} = 1.106$, $p > 0.05$). The result indicated that the homogeneity assumption was not violated. For the results of ANCOVA, please see Table 2.

Table 2 shows that the pre-test scores of the LPI have a significant impact on the post-test scores of the LPI ($F_{1,120} = 315.090$, $p < 0.01$), as does the WFA ($F_{1,120} = 12.313$, $p < 0.01$). H_{02} is thus rejected. In addition, the result of the Bonferroni post hoc test (Table 2) indicates that students in the PDA-WATA group have significantly more self-regulatory learning behaviors than those in the N-WBT group ($p < 0.01$).

Cohen's *d* (Cohen, 1988) was then used to analyze the post-test scores of the LPI of the students with different levels of self-regulated learning in N-WBT and PDA-WATA groups. Results of this analysis are shown in Table 3. Based on Table 3, a comparison of students with a high level of self-regulated learning in the PDA-WATA group with those in the N-WBT group shows that the effect size of the LPI score difference is medium to large (Cohen's $d = 0.533$). On the other hand, a comparison of students with a low level of self-regulated learning in the PDA-WATA group with those in the N-WBT group shows that the effect size of the LPI score difference is large (Cohen's $d = 0.928$).

The above results show that in promoting students to use self-regulatory learning behaviors to perform self-regulated learning, PDA-WATA is more effective than N-WBT. Moreover, the effect size of the LPI score difference between students in the PDA-WATA and N-WBT groups is larger for those students with a low level of self-regulated learning. This reveals that when originally learning in the e-Learning environment with N-WBT and later turning to learn in the e-Learning environment with PDA-WATA, students with a low level of self-regulated learning experience greater improvement in using self-regulatory learning behaviors to perform self-regulated learning than students with a high level of self-regulated learning.

4.3. Student e-Learning effectiveness in the PDA-WATA and N-WBT groups

In order to understand the effectiveness of the two different types of Web-based formative assessment (WFA), ANCOVA was used. Before ANCOVA, the assumption of homogeneity of regression coefficients was tested ($F_{1,119} = 1.114$, $p > 0.05$). The result indicated that the homogeneity assumption was not violated. For the results of the ANCOVA, please see Table 4.

Table 4 shows that the pre-test scores of the summative assessment have a significant impact on the post-test scores of the summative assessment ($F_{1,120} = 150.849$, $p < 0.01$), as does the WFA ($F_{1,120} = 19.145$, $p < 0.01$). According to the result, H_{03} is rejected. In addition, the result of the Bonferroni post hoc test (Table 4) indicates that students in the PDA-WATA group have significantly better learning effectiveness than those in the N-WBT group ($p < 0.01$). This result shows that PDA-WATA is significantly more effective in facilitating student e-Learning than the N-WBT.

ANCOVA was then used to separately investigate the learning effectiveness of students with a high level of self-regulated learning and students with a low level of self-regulated learning in the PDA-WATA and N-WBT groups. Before ANCOVA, the assumption of homogeneity of regression coefficients was tested (PDA-WATA: $F_{1,59} = 0.859$, $p > 0.05$; N-WBT: $F_{1,56} = 0.267$, $p > 0.05$). The result indicated that the homogeneity assumption was not violated. For the results of ANCOVA, please see Table 5.

Table 5 shows that for students in the PDA-WATA group, the pre-test scores of the summative assessment have a significant impact on the post-test scores of the summative assessment ($F_{1,60} = 64.364$, $p < 0.01$). However, the level of self-regulated learning (LSR) has no significant impact on the post-test scores of the summative assessment. Based on the result, H_{04} is accepted. In other words, the result shows that when

Table 5
One-way ANCOVA on the summative assessment scores of students with different levels of self-regulated learning in the PDA-WATA and N-WBT groups.

Group	Variable	Level	Mean[a] (Std. error)	*F* value	Post hoc[b]
PDA-WATA group ($n = 63$)	PRE			64.364**	
	LSR	High	62.259(1.710)	2.253	
		Low	57.115(2.950)		
N-WBT group ($n = 60$)	PRE			85.634**	
	LSR	High	49.625(1.794)	4.155*	High > Low*
		Low	44.161(1.984)		

*$p < 0.05$; **$p < 0.01$.
[a] Covariates appearing in the model are evaluated at the following values: PDA-WATA group: PRE = 45.979. N-WBT group: PRE = 39.945.
[b] Adjustment for multiple comparisons: Bonferroni.
PRE: Pre-test scores of the summative assessment.
LSR: Level of self-regulated learning.
High: Students with a high level of self-regulated learning.
Low: Students with a low level of self-regulated learning.

performing e-Learning in the PDA-WATA group, students with a high level of self-regulated learning and students with a low level of self-regulated learning are not significantly different in their learning effectiveness ($p > 0.05$). For students in the N-WBT group, the pre-test scores of the summative assessment have a significant impact on the post-test scores of the summative assessment ($F_{1,57} = 85.634$, $p < 0.01$), as does the LSR ($F_{1,57} = 4.155$, $p < 0.05$). Based on the result, H_{05} is thus rejected. In addition, the result of the Bonferroni post hoc test (Table 5) indicates that in the N-WBT group, students with a high level of self-regulated learning have significantly better learning effectiveness than students with a low level of self-regulated learning.

5. Conclusion and discussion

The effectiveness of PDA-WATA in an e-Learning environment is explored in this research. The five main strategies of PDA-WATA, including 'Adding Answer Notes,' 'Stating Confidence,' 'Reading Peer Answer Notes,' 'Recommending Peer Answer Notes' and 'Querying Peers' Recommendation on Personal Answer Notes' strategies, are designed based on the three kinds of self-regulated learning strategies proposed by Pintrich (1999): 'cognitive strategies,' 'metacognitive and self-regulatory strategies (self-regulatory strategies to control cognition)' and 'resource management strategies.' 'Adding Answer Notes' strategy is a cognitive strategy that allows learners to compose answer notes and explanations for their answers when performing self-assessment in an e-Learning environment. It requires learners to perform rehearsal, elaboration, and organization. In addition to repeating and recollecting the learning materials learned in the e-Learning environment, learners are also made to summarize the learning materials and generalize answer notes and explanations from them. 'Stating Confidence,' 'Reading Peer Answer Notes,' 'Recommending Peer Answer Notes' and 'Querying Peers' Recommendation on Personal Answer Notes' strategies are metacognitive and self-regulatory strategies. 'Stating Confidence' strategy allows learners to evaluate their own confidence in their answer and answer notes. 'Reading Peer Answer Notes,' 'Recommending Peer Answer Notes' and 'Querying Peers' Recommendation on Personal Answer Notes' strategies allow learners to read peer answer notes, recommend peer answer notes and know peers' recommendation of their own answer notes. By reading and comparing their own answer notes and recommendation information with those of their peers, learners can understand whether their own answer notes are more valuable references than the answer notes of their peers, and also evaluate whether they know more than their peers. The above mechanism helps learners monitor and regulate their own learning, as well as set the goal of composing answer notes which are recommended by peers. This can also facilitate learner use of cognitive strategies to learn and carefully compose answer notes. In addition, the interface and the main strategies of PDA-WATA provide resource management strategies, which allow learners to perform 'effort regulation', 'organising time and study environment', 'peer learning', and 'help-seeking' (Blom & Severiens, 2008; Pintrich et al., 1993). The interface of PDA-WATA shows information that enables learners to know how many more items they need to answer correctly before they can pass the assessment. This design helps learners manage their time and answering progress. The mechanism of creating, reading and recommending answer notes in PDA-WATA not only allows learners to exchange the knowledge they learn and perform peer learning but provides learners with the opportunity to perform 'effort regulation'. The 'Recommending Peer Answer Notes' and 'Querying Peers' Recommendation on Personal Answer Notes' strategies enable positive competition among learners, motivating them to plan effective ways of learning so that they are able to create answer notes that earn peers' recommendation. Recommendation on answer notes is positive feedback for learners, which helps them maintain a positive mood and perform self-reinforcement. They will also persist in providing answer notes as valuable reference for peers. Moreover, the mechanism follows the design of 'help-seeking strategy (Pintrich, 1999)'. When learners have difficulties answering items, the strategies can help them consolidate the reference information from peers and learning materials in the learning environment to achieve learning and find correct answers to the items.

This research finds that compared with N-WBT, PDA-WATA can better motivate learners to spontaneously take Web-based formative assessment in an e-Learning environment. This result can be explained by Blom and Severiens (2008), Hu and Gramling (2008) and McKeachie et al. (1986). Hu and Gramling argued that self-regulated learning strategies can promote online learner motivation. Blom and Severiens argued that resource management strategies could support learner engagement in learning, while McKeachie et al. argued that resource management strategies included 'effort management.' The maintenance of a positive mood and persistence management in 'effort management' are highly related to motivation. PDA-WATA includes resource management strategies. The 'Recommending Peer Answer Notes' and 'Querying Peers' Recommendation on Personal Answer Notes' strategies allow learners to provide positive feedback to peers by recommending answer notes. Learners whose answer notes are recommended also feel that the value of their answer notes are recognized and may maintain a positive mood and persist in providing answer notes as a valuable reference for peers. This is one of the reasons that PDA-WATA can improve learner motivation to spontaneously take Web-based formative assessment. In addition, Vogel et al. (2006) and Wang (2008) argued that enabling learners to interact with computers and adding more strategies to increase human-machine interaction, as PDA-WATA does, could improve learning motivation. PDA-WATA also includes strategies to enhance mutual help among peers. As noted by Rozendaal et al. (2005), mutual help among peers has positive effects on learning motivation. Using the 'Adding Answer Notes,' 'Reading Peer Answer Notes' and 'Recommending Peer Answer Notes' strategies, PDA-WATA constructs an e-Learning environment facilitating mutual help among peers. By using the 'Adding Answer Notes' and 'Reading Peer Answer Notes' strategies, learners can communicate their knowledge and understandings with peers. By using the 'Recommending Peer Answer Notes' strategy, learners can recommend answer notes that provide valuable references. This recommendation information in turn helps learners who need to refer to answer notes to read more valuable answer notes and find correct answers effectively. The mechanism of mutual help among peers is also a kind of help-seeking strategy. It enables learners to achieve learning by performing peer learning and seeking peer assistance when encountering difficulties. Help-seeking strategies and peer learning are also resource management strategies (Blom & Severiens, 2008; Pintrich et al., 1993). They also make learners motivated to use PDA-WATA to learn in an e-Learning environment.

Compared with N-WBT, PDA-WATA is also found to have better effectiveness in promoting learners to use self-regulatory learning behaviors to perform self-regulated learning. In addition, PDA-WATA also has better effectiveness in facilitating learner e-Learning effectiveness. The findings are consistent with the arguments of Pintrich (2003), Schunk (2005a, 2005b), Perels et al. (2009) and Zimmerman et al. (1996). The strategies of PDA-WATA designed to facilitate learner use of self-regulatory learning behaviors are based on the self-regulated learning strategies proposed by Pintrich (1999) and the idea of self-assessment proposed by Paris and Paris (2001). In addition, Pintrich's recommendation (e.g. Pintrich, 1999; Pintrich, 2003) that learning environments should be enriched with strategies to increase learner

motivation to effectively perform self-regulated learning is also followed in this research. Zimmerman et al. argued that if teachers integrated strategies that facilitated learner use of self-regulatory learning behaviors to perform self-regulated learning into teaching environments and allowed learners to experience self-regulated learning and its benefits, learners could be better motivated to perform self-regulated learning and in turn improve their own learning effectiveness. Pintrich (2003), Schunk (2005a, 2005b) and Perels et al. (2009) also pointed out that if learners could use self-regulatory learning behaviors to perform self-regulated learning, they would have better learning effectiveness. This research also finds that when learning in an e-Learning environment including N-WBT, students with a high level of self-regulated learning have significantly better learning effectiveness. However, when learning in an e-Learning environment including PDA-WATA, students with a low level and a high level of self-regulated learning are not significantly different in their learning effectiveness. The result can be explained by another finding of this research. Though both PDA-WATA and N-WBT provide learners with opportunities to perform self-assessment, it is found that PDA-WATA is more effective in promoting students to use self-regulatory learning behaviors to perform self-regulated learning than N-WBT. Moreover, the effect size of the LPI score difference between students in the PDA-WATA and N-WBT groups is especially larger for those students with a low level of self-regulated learning. This appears that when originally learning in the e-Learning environment with N-WBT and later turning to learn in the e-Learning environment with PDA-WATA, students with a low level of self-regulated learning experience greater improvement in using self-regulatory learning behaviors to perform self-regulated learning than students with a high level of self-regulated learning. Therefore, in the PDA-WATA group, the e-Learning effectiveness of students with a low level of self-regulated learning is statistically the same as that of students with a high level of self-regulated learning. In addition, the results also reveal that an e-Learning environment which does not incorporate suitable strategies to promote learners to use self-regulatory learning behaviors to perform self-regulated learning is less effective for students with a low level of self-regulated learning. However, the inference above still needs further investigation.

The foregoing discussion shows that PDA-WATA provides students with opportunities to perform self-assessment and includes the three kinds of self-regulated learning strategies proposed by Pintrich (1999). Compared with N-WBT, PDA-WATA more effectively facilitates learner use of self-regulatory learning behaviors to perform self-regulated learning, improves learner motivation to spontaneously take Web-based formative assessment, and raises learner e-Learning effectiveness when integrated into an e-Learning environment. This research recommends PDA-WATA for integration into e-Learning environments. In addition, this research finds that students with a low level and a high level of self-regulated learning are not significantly different in their e-Learning effectiveness in the PDA-WATA group, but similar result cannot be found in the N-WBT group. This research suggests that further research should more deeply investigate how PDA-WATA promotes learner use of self-regulatory learning behaviors to perform self-regulated learning and how PDA-WATA influences student e-Learning effectiveness. Additionally, future research should further explore how PDA-WATA improves learner motivation to spontaneously take Web-based formative assessment. The 'novelty effect' is an issue requiring attention when computers or other new technologies are integrated into education (Collis et al., 1996, p. 110; Krendl & Broihier, 1992). This effect makes it difficult for short-term research to uncover the real effects of computers and other new technologies on learning. Moreover, Arnold (n.d.) and Kerres (2001) pointed out that there was no clear empirical evidence showing that the new media improved learning motivation. They suggested that the benefits of new media should be examined more critically. In other words, integrating computers or other new technologies into education may have only temporary positive effects on student learning motivation. Following the arguments above, this research suggests that to better understand how PDA-WATA influences learning, longitudinal research and further research with extended research duration are necessary. Moreover, this research only investigates the e-Learning effectiveness of seventh-grade junior high school students on the topic of 'Evolution' in the 'Science and Technology' course. This research thus suggests that future research should be conducted across different grades and course contents. Since other factors may require attention, this research also suggests that new research designs and data analysis techniques should be adopted to understand how the effectiveness of PDA-WATA in facilitating learning is related to factors affecting the impact of integrating computers or other new technologies into education as identified in the literature (e.g. Clark, 2001). In addition, since this research uses a self-report scale to investigate how learners use self-regulatory learning behaviors to perform self-regulated learning, its measurement of student learning behaviors may not be able to fully reflect real learning behaviors. This research thus suggests that qualitative research methods should be used to collect more robust data. Qualitative data, such as interviewing and computer screen recording, can help researchers better understand not only how learners use self-regulatory learning behaviors to perform self-regulated learning but also the mechanisms by which PDA-WATA facilitates e-Learning effectiveness.

Many researchers have observed that the ability to perform self-regulated learning in an e-Learning environment determines e-Learning effectiveness (Hu & Gramling, 2008; Jonassen et al., 1995; Kauffman, 2004; King et al., 2000; Puzziferro, 2008; Vighnarajah et al., 2009). In other words, if learner use of self-regulatory learning behaviors to perform self-regulated learning in an e-Learning environment can be increased, improved e-Learning effectiveness will result. Therefore, this research suggests that researchers further explore theories and strategies of self-regulated learning, and develop a broader range of strategies based on the characteristics of e-Learning environments, along with self-assessment strategies, to facilitate learner use of self-regulatory learning behaviors to perform self-regulated learning in an e-Learning environment.

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