A cloud-based learning environment for developing student reflection abilities

Yen-Ting Lin, Ming-Lee Wen, Min Jou, Din-Wu Wu

Abstract

Students learn new knowledge effectively through relevant reflection. Reflection affects how students interact with learning materials. Studies have found that good reflection abilities allow students to attain better learning motivation, comprehension, and performance. Thus, it is important to help students develop and strengthen their reflection abilities as this can enable them to engage learning materials in a meaningful manner. Face-to-face dialectical conversations are often used by instructors to facilitate student reflection. However, such conventional reflection methods are usually only usable in classroom environments, and could not be adopted for distance learning or after class. Cloud computing could be used to solve this issue. Instructor guidance and prompting for initiating reflection could be seamlessly delivered to the students' digital devices via cloud services. Thus, instructors would be able to facilitate student reflective activities even when outside the classroom. To achieve this objective, this study proposed a cloud-based reflective learning environment to assist instructors and students in developing and strengthening reflection ability during and after actual class sessions. An additional experiment was conducted to evaluate the effectiveness of the proposed approach in an industrial course. Results show that the learning environment developed by this study is able to effectively facilitate student reflection abilities and enhance their learning motivation.

1. Introduction

Enhancing student reflection is important for the teaching and learning of new knowledge or skills because reflection affects how instructors and students interact with learning materials they encounter (McNamara, 2004). From instructors' perspective, student reflection often influence their best teaching (McNamara, O'Reilly, Best, & Ozuru, 2006). Reflection also influences how instructors plan teaching strategies for new classes in order to enhance student learning motivation and performance. From the students' perspectives, the lack of reflection abilities is a higher risk that new knowledge may be built upon faulty foundations (Boyd & Fales, 1983). Additionally, psychological investigations showed that good reflection abilities would improve learning because memory or mental storage capacity could be developed through association with pre-existing knowledge or experience (Schon, 1987). Studies also indicated that good reflection abilities would enhance student motivation, comprehension, and performance in learning new knowledge or skills (Boud, Keogh, & Walker, 1985; Kemmis, 1985; Paris & Ayres, 1994). Reflection abilities may also be a critical component in the acquisition, processing, and application of new information within other contexts (Chen, Kinshuk, Wei, & Liu, 2010; Chen, Wei, Wu, & Uden, 2008).

The reasons stated above suggest that it is important to develop and strengthen student reflection abilities to help them engage new learning materials in a meaningful manner. To induce student reflection in a classroom setting, instructors usually ask students certain questions to which the students reflect and provide feedback (Chi, de Leeuw, Chiu, & Lavancher, 1994; Davis, 2000). However, engaging students in face-to-face dialectical conversation in classroom settings is not possible for instructors during remote learning or after school sessions. Cloud computing and services could provide a solution. Prompts and activities helping to induce reflection could be seamlessly delivered to students' digital devices, allowing instructors to facilitate student reflective activities even when outside the classroom.

In order to assist instructors in developing student reflection abilities and to help students attain greater learning motivation and performance, a cloud-based reflective learning environment was proposed in this study. An experiment was also conducted in an industrial course in a Taiwanese university to investigate the effectiveness of the proposed approach.
2. Literature review

2.1. Reflection

Since information explosion leads students always browse through on Internet, this phenomenon could affect their thinking and further influence their learning performance. Therefore, promoting students' reflection on their learning and behavior is currently a major educational goal in higher education. The concept of reflection was first proposed by John Dewey in 1933 (Dewey, 1933), which is defined as repeated thinking, searching, observation, and understanding toward problems, surrounding environments, or causal relationships. Reflection is described as a process of active, persistent and careful consideration that aims to construct individual knowledge and meaning by using personal experiences, perceptions, and beliefs (Carver & Scheier, 1998). The process would be initiated through personal experience, thinking, comprehension and awareness, so that people would be able to survey, explore, and evaluate issues, opinions, feelings, and behaviors they encounter (Ward & McCotter, 2004). Reflection is also regarded as a useful learning process that can help students express and evaluate their attitudes and feelings, expand their learning cognition, and increase the comprehension of their own thinking (Chirema, 2007; Ladewski, Krajcik, & Palincsar, 2007). Through individual inquiry and socially interact with others, reflection can lead students' thinking from surface to deep level (Moon, 2004; van den Boom, Paas, & van Merrienboer, 2007).

From a teaching perspective, Schon (1987) divided reflection into two major frameworks, which are reflection-on-action and reflection-in-action. Reflection which occurs after teaching or during the interval before planning and thinking would be reflection-on-action. On the other hand, reflection-in-action would be the adjustments of personal teaching methods and feedback responses that occur during the teaching process. From the learning perspective, reflection would provide opportunities to stimulate students to examine knowledge they have learned (Etkina et al., 2010; Jou & Shiau, 2012).

To prompt and guide student knowledge construction, researchers recommended instructors to use different types of questions (Chen et al., 2008; Lee & Chen, 2009). King (1994) used three types of questions to help students construct individual knowledge, which are questions on memory, comprehension, and connection. Students would gradually enhance their cognition and comprehension as they progress from lower-level (memory) questions based on factual knowledge to higher-level (connection) questions based on reflective practices. The literature review also indicated that higher-level questions would facilitate reflection and could result in better understanding and higher learning performances (Redfield & Rousseau, 1981; Roscoe & Chi, 2008).

2.2. Cloud computing

During the last two years, cloud computing has become an increasingly popular phenomenon in every field. Cloud computing currently includes a series of hardware and software service provided via the Internet (Venters & Whitley, 2012). Since applications and user data would be stored remotely on cloud servers, users can seamlessly access cloud services and applications by using any digital device with an internet connection. In other words, cloud computing can enable users to access, process, share, and store information via the Internet from any location or device (Lin, Fu, Zhu, & Dasmalchi, 2009). In traditional IT systems, user productivity may be restricted since personal information was exclusive to specific applications, services or devices (Sang & Sung, 2012). However, these obstacles would be overcome by cloud computing since it can provide services to users seamlessly. Therefore, cloud services would make users more efficient, help facilitate collaboration with their peers, and give users seamless access to their information anytime and anywhere from any digital device (Marston, Li, Bandyopadhyay, Zhang, & Ghalsasi, 2011).

Cloud computing would be highly practical in education for both instructors and students. The technology allows instructors and students to access powerful services and massive computing resources wherever and whenever they needed, including various useful applications, services, and tools which are provided freely and openly to instructors and students (Jou & Wang, 2012). Since one of the feature of cloud computing is enable software as a service (SaaS), rather than as a standalone program. Therefore, the interconnectivity feature of cloud computing would allow instructors to administer entire learning processes easily and conveniently, allowing students to learn effectively (Paul, Chen, & Gloria, 2010). Additionally, cloud computing offers a potential way to enable instructors and students to conduct formal lessons even without a standard indoor classroom since the cloud services allow them to share their data with anyone, anywhere, and at anytime (Astrid, Paul, Carol, & Jordana, 2012).

2.3. Influence of web-based learning instrument on learning

Generally, the online learning environment is suitable to offer opportunities for reflection. It is useful for students to construct individual knowledge if appropriate learning services can be applied to assist them in concentrating on learning and guiding their engagement in reflection (Lamy & Goodfellow, 1999; Yang, 2010). To date, several web-based applications or services have been proposed to support various classroom activities including reflection activities (Huang, Lin, & Cheng, 2009; Jou, Chuang, & Wu, 2010; Lin, Tan, Kinshuk, & Huang, 2010). However, most of these services are novel or stand-alone programs. This means that users (instructors and students) have to spend additional time and efforts to familiarize themselves with these new tools. Users may be required to install additional programs on their own devices or register as a new user, which would negatively affect the motivation for using these services to support specific educational contexts (Lin, Lin, & Huang, 2011).

However, the age of cloud computing saw other web applications such as SkyDrive, Evernote, Dropbox, and Google Apps being developed. Different from traditional web pages and applications, such cloud computing applications offer SaaS to users who can use various digital devices to apply these services openly and freely. Users today are inundated with a myriad of web applications that provide friendly user interfaces and powerful functions in the cloud. Therefore, many instructors and students were already using these cloud applications in their daily lives (Lin & Jou, 2012). These observations compelled several researches to suggest that these modern web applications could be a new way of engaging participants in meaningful teaching and learning activities (Alexander, 2006; Hughes, 2009; Schneckenberg, Ehlers, & Adelsberger, 2011; Thompson, 2007; Wang, Woo, Quek, Yang, & Liu, 2012). Most of both instructors and students would be more motivated in using these applications in an educational context since they already have the necessary technical skills (Dohn, 2009). Therefore, they would only need to learn how to apply these applications in supporting educational activities for their classes (Pretlow & Jayroe, 2010). Previous studies also found that participants who take part in a web-enhanced class outperformed those who underwent traditional lectures (Crook & Harrison, 2008; Hamm & Wilson, 2003). Effective use of web applications can also blur the boundaries between formal and informal learning (Bennett, Bishop, Dalgarno, Waycott, & Kennedy, 2012).
With these in mind, this study integrated Google web applications as a set of teaching and learning tools within a reflective learning environment. The applications used are briefly described in the following:

- **Google plus:** This application is a free social networking service that can be accessed from various digital devices. Social networks between instructors and students can be established easily using Google plus. The social networks would allow users to share reflective thoughts, activities, and events effectively.
- **Google drive:** This web-based office suite allows users to create and edit documents online while collaborating with other users in real-time. Google drive allows instructors and students to immediately write down, view, and reply to ideas conveyed through any connected PC or mobile device.
- **Google sites:** This structured wiki- and webpage-creation application allows users to create dynamic web pages with their partners with the ease of writing a document. The use of Google sites can therefore assist instructors and students in consolidating and expressing their reflective thoughts.

3. **Cloud-based reflective learning environment**

A cloud-based reflective learning environment was developed in this study to assist instructors in administering reflective activities and help students develop reflection skills. The following paragraphs describe the development and content of the learning environment framework.

3.1. **The framework of cloud-based reflective learning environment**

Fig. 1 shows the framework of the cloud-based reflective learning environment with its three main components, namely the teacher side, student side, and cloud service.

The core component of the framework is the cloud service which includes the course website, web applications, and databases. The course website was developed to consolidate teaching and learning functions for instructors and students respectively. The web applications were used to assist instructors and students in administering and conducting reflective learning activities. The databases include a course database and a user profile database. The course database was built to store course information and resources, while the user profile database was utilized to store student personal information, learning profiles, and learning records.

Instructors can use the teacher side of the reflective-learning environment to administer course instructions and conduct reflective learning activities to help student learning reflection. Students can log into the learning environment on the student side and participate in various reflective learning activities during or after the course.

3.2. **The development of cloud-based reflective learning environment**

The primary aim of developing a cloud-based reflective learning environment is to find an appropriate approach to achieve this. The course website was created using ASP.NET 3.5 (C#) and the database was built using Microsoft SQL Server 2005. Google web applications were also integrated into the learning environment in order to facilitate participation in reflective activities.

An instructor interface based on the framework of the cloud-based reflective learning environment is provided for instructors on the teacher side of the course website. As shown in Fig. 2, instructors can gather and examine relevant information from the course archive to administer entire teaching and learning processes. They can also connect directly to each web application from the user function list to administer and conduct reflective learning activities via the course web site.

Students can log into the course website on the student side and obtain or browse course information using a student interface. They can also connect to the web applications from the user function list. Moreover, they can view and participate in particular reflective learning activities during or after the course, as shown in Fig. 3.

4. **Experiment**

An experiment was conducted to determine the effectiveness of the proposed cloud-based reflective learning environment on enhancing reflective practices and learning performance in an industrial course on product design.

4.1. **Research instruments, measures and goals**

To evaluate the effects of the proposed cloud-based reflective learning environment on reflective teaching and learning performance, various data sources were utilized, including questionnaires, pre-test/post-test results, and interviews. The questionnaires were designed to document student learning motivation and learning attitude. In addition, tests designed to assess the student reflective levels were implemented before and after the learning activities. Finally, the interviews were further used to investigate participant perception towards the entire teaching and learning process.

4.1.1. **Instrument of learning motivation survey**

To measure student learning motivation toward entire teaching and learning processes, the intrinsic value scale of the learning motivation questionnaire Motivated Strategies for Learning Questionnaire (MSLQ) was adopted to explore whether students' learning motivation had improved. The intrinsic value scale of MSLQ was recommended by researchers to measure student goals and beliefs about the importance and interest for class works, which are highly relevant to the aim of developing the cloud-based reflective learning environment. The scale of MSLQ included nine items based on a seven-point Likert scale (Pintrich & De Groot, 1990).

4.1.2. **Instrument of learning attitude survey**

Student learning attitude was surveyed using a learning attitude questionnaire that consisted of seven items scored using a four-point rating scale. The questionnaire has been previously used to measure student learning attitudes towards learning activities in other courses (Hwang & Chang, 2011; Hwang, Wu, & Chen, 2012).

4.1.3. **Instrument of reflection level evaluation**

Finally, the pre- and post-tests were designed to assess student reflective levels in the produce design course. The tests included memory, comprehension, and connection questions. The pre-test contained five multiple-choice test items (memory questions), such as “During a product design process, which one is not belong to the consideration of ergonomics?” and four short-answers test items (two comprehension questions and two connection questions), such as “What is different between innovation and invention?” and “Please give an example to explain how to apply ergonomics on product design.” that asked students the means of designing an industrial product according to their preliminary understanding. The post-test was similar in structure, with also five multiple-choice test items (memory questions) and four short-answer test items (two comprehension questions and two connection questions) that asked students the means of designing
an industrial product specifically for a hand-held device using knowledge acquired from the teaching activities. The maximum score for both tests were 50 points. In addition, three trained research members were assigned to evaluate student answers in both the pre- and post-tests. The inter-rater reliability of the pre-test and post-test were 0.931 and 0.902 respectively. The results indicated that the three research members have a concordance with regard to the pre- and post-tests.

4.2. Experimental design, participants and procedure

To investigate the effectiveness of the proposed cloud-based reflective learning environment, a quasi-experimental research was conducted on a product design course in a computer-aided classroom at a Taiwanese university. 70 university students (38 males and 32 females) from department of industrial education with an average age of 21 years and a course instructor participated in the experiment. All of the participated students were randomly and averagely assigned to an experimental group and a control group. The experimental group included 35 students who used the proposed learning environment to support their reflective learning activities. The remaining 35 students served as the control group and underwent similar activities as the experimental group, albeit with the aid of a discussion board instead of web applications.

The same learning and teaching activities were implemented by the instructor for both groups during class time. The activities included lecturing, engaging students in reflective learning activities, stimulating interaction and discussion, and consolidating the learning activity objectives. During the class, the course instructor would give lectures and engage students in reflective learning activities. Moreover, the students in the experimental group would apply Google drive to record personal learning status and reflective learning results. After class, the students in the experimental group would use Google plus to interact with peers and the instructor to continuously extend the discussions and reflective learning activities. On the other hand, the students in the control group would use a discussion board to carry out such activities after the class. Before the end of the entire course, the instructor would require the students of the experimental group to form seven groups to conduct and present a specific issue by using Google sites. With regard to the students in the control group, the students would be required to use Microsoft Office Word document to conduct and present a specific issue.

No matter the students in which group, in order to stimulate them to think reflectively, the course instructor would especially use real-life problems in the course to facilitate their discussions since there are few guidelines in their texts for the kind of problems (Brown, 1997). In other words, these problems are the kind
of ill-defined, messy, complex problems for which reflective thinking is needed anyway (Halpern, 1998; Kennedy, Fisher, & Ennis, 1991). Students have to continuously challenge their own ideas and argue among themselves about the problems and the solution to the problems.

Learning and teaching activities for both groups were conducted in five sections that had a total of 400 min as shown in Table 1. Students spent an average of 50% of the course time learning the course materials and used the remaining time to discuss and reflect on newly learned knowledge. The scheduling was a good balance between instruction and student interaction, the latter helping to verify that learning was achieved (Kong & So, 2008).

Fig. 4 shows the experimental process. All students took three pre-tests before undergoing the learning activities. The first test was on prior knowledge of product design and the second was a reflection level test. Thirdly, all students were then asked to fill out a learning motivation questionnaire before participating in the learning activities. After going through the learning activities, all students received a post-test, a second learning motivation questionnaire as well as a learning attitude questionnaire to reevaluate student reflection levels and learning motivation and to survey student learning attitude. Interviews were also carried out after the learning activities to investigate the participant perceptions on the entire teaching and learning process.

5. Results

5.1. The effect of prior knowledge

Prior knowledge tests with independently developed questions were used to determine whether knowledge level on product design were the same between the experimental and control groups. To conduct the analysis, a Kolmogorov–Smirnov Z test was firstly used to examine whether a t-test could be used in the prior knowledge tests. Results showed that the data satisfied the assumption of normality. Finally, a t-test was used to determine whether there were significant differences in prior knowledge of product design between the groups. Results showed that prior to the course, there were no significant differences between the experimental and the control groups (t = 0.081, p-value = 0.936). In other words, student abilities in both groups were statistically equivalent before the product design course.

5.2. Learning motivation survey

All students were asked to fill out an MSLQ questionnaire before and after the learning activities. The Cronbach’s alpha values of the questionnaire items were 0.815 and 0.865 for the experimental group and control group respectively. A one-way independent sample analysis of covariance (ANCOVA) was used to analyze the survey. In the ANCOVA, the post-test and pre-test scores of learning motivation were treated as the dependent variable and covariate respectively. Homogeneity of the regression coefficient was tested before performing ANCOVA. Results confirmed the homogeneity of the regression coefficient (F(1,68) = 3.628, p-value = 0.011 > 0.05). Table 2 shows ANCOVA results of the learning motivation post-test score for the two groups as well as the mean scores and standard deviations. The mean of the experimental group (46.543) was higher than that of the control group (40.800), implying that students whose learning was supported by the proposed cloud-based reflective learning environment had higher motivation. After eliminating the influence of the covariance on the dependent variable, post-test learning motivation scores between the two groups turned out to be significantly different (F(1,67) = 13.866, p-value = 0.00 < 0.05). Therefore, the proposed cloud-based reflective learning environment significantly benefited the students in terms of learning motivation.

5.3. Learning attitude survey

Students in both the experimental and control groups were required to fill out a learning attitude questionnaire after participating in the learning activities to survey their learning attitude. The Cronbach’s alpha value of the questionnaire items was 0.732. A t-test was performed to compare learning attitude scores between the two groups. The t-test results revealed significant differences in student attitudes between the experimental group and control group. (t(34) = 5.115, p-value = 0.00 < 0.05). In addition, to further survey
the differences of the students’ learning attitudes between the two groups, t-tests were used to analyze each questionnaire item. The statistical results are presented in Table 3.

More students in the experimental group reported having positive attitudes towards product design learning compared to students who did not use the cloud-based reflective learning environment. The t-test results revealed significant differences in student attitudes between the two groups. Students in the experimental group: (1) had better attitude for learning more about product design material, (2) had higher desires for product design knowledge and (3) were better motivated for actively searching information about product design.

However, no significant differences in student opinions were found on the importance of the course between the two groups. Most students in both groups felt that the product design learning was meaningful and useful, and expressed that they would like to learn product design well. Additionally, a vast majority of students in the experimental (94%) and control (90%) groups stated that learning about product design was important.

These results indicated that most students in both groups had a positive attitude towards the product design course. Nevertheless, students in the experimental group were significantly more positive in terms of attitude towards the course compared to those in the control group.

5.4. Pre-test/post-test evaluation of reflection level

To further evaluate student reflection levels, pre- and post-tests were administered before and after the product design learning activities. The test-sheet consisted of five multiple-choice test items (memory questions) and four short-answer test items (two comprehension questions and two connection questions).

A one-way independent sample analysis of covariance (ANCOVA) was used to analyze the tests. In the ANCOVA, the post-test and pre-test scores of reflection level were treated as the dependent variable and covariate respectively. Homogeneity of the regression coefficient was tested before performing ANCOVA. Results confirmed the homogeneity of the regression coefficient ($F(1,68) = 0.286$, $p$-value = 0.594 > 0.05). Table 4 shows ANCOVA results of the reflection level post-test score for the two groups as well as the mean scores and standard deviations. The mean of the experimental group (35.429) was higher than that of the control group (32.143), implying that students whose learning was

![Fig. 4. Experimental process.](image-url)

### Table 1

<table>
<thead>
<tr>
<th>Unit</th>
<th>Instruction activities</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design theory</td>
<td>1. Introduction of learning environment (10)</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>2. Instructor presentation (30)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Discussion (20)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Reflection (20)</td>
<td></td>
</tr>
<tr>
<td>Human factors engineering</td>
<td>1. Review of previous instruction (5)</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>2. Instructor presentation (35)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Discussion (20)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Reflection (20)</td>
<td></td>
</tr>
<tr>
<td>Ergonomics</td>
<td>1. Review of previous instruction (5)</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>2. Instructor presentation (35)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Discussion (20)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Reflection (20)</td>
<td></td>
</tr>
<tr>
<td>Product patent</td>
<td>1. Review of previous instruction (5)</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>2. Instructor presentation (35)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Product patent practice (20)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Reflection (20)</td>
<td></td>
</tr>
<tr>
<td>Creative design management</td>
<td>1. Review of previous instruction (5)</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>2. Instructor presentation (35)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Discussion (20)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Reflection (20)</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of students</th>
<th>Mean</th>
<th>S.D.</th>
<th>Adjusted mean</th>
<th>$F(1,67)$</th>
<th>$p$-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental group</td>
<td>35</td>
<td>46.543</td>
<td>3.559</td>
<td>46.463</td>
<td>13.866</td>
<td>0.00*</td>
</tr>
<tr>
<td>Control group</td>
<td>35</td>
<td>40.800</td>
<td>7.858</td>
<td>40.880</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number of students</td>
<td>70</td>
<td>43.671</td>
<td>6.711</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: S.D.: standard deviation. * $p < 0.05$. 

![Fig. 4. Experimental process.](image-url)
thought that only one fourth of students in the control group could
cepts in detail or interact with students. In contrast, the instructor
use of the modern web applications that could enable the students
reflection activities to after school sessions. This is because the
by the experimental group could easily extend discussion and
activity. He also felt that web application support used
demonstrated excellent performance in every discussion and
itionally, he was impressed that students in the experimental group
through the cloud-based reflective learning environment. Addi-
ter, share, and consolidate individual thoughts and knowledge
were more engaged in the learning events and activities during
learning during and after new things in a class because
follow the activities after class, while the rest were too unmo-
tivated to get involved.

For the student interviews, a small group of students in both
groups preferred more direct instruction from the course instruc-
tor since they thought that some of the concepts were difficult to
understand and hindered participation in discussion and reflection
activities. Nevertheless, majority of the students, especially those
from the experimental group, indicated that learning about prod-
duct design with reflection activities was interesting.

5.5. Interaction perspective

The instructor observed that students in the experimental
group often gave feedback and asked questions on product design
concepts. These students also had better discussions and reflec-
tions in each learning activity during and after the course. In con-
trast, students in the control group carried out fewer discussions
and reflections, especially after school. Therefore, the instructor
noted that adopting well-known web applications would posi-
tively influence student participation and responsiveness in their
learning.

5.5.3. Technology perspective

The instructor and the majority of students in the experimental
group indicated that the user interface of the cloud-based reflec-
tive learning environment was clear and straightforward. They
were already familiar with major learning tools before participat-
ing in the product design course. Most students actively used the
cloud-based reflective learning environment due to its conve-
nience, which also motivated them to carry out reflective learning
activities and strengthen their reflection abilities. This was possible
since the cloud-based reflective learning environment was inte-
grated with well-known web applications. Most students need
not install extra applications or register as a new user for using
the learning environment. The instructor, on the other hand,
thought that reflection learning was driven by the students them-
selves instead of the cloud-based reflective learning environment.
He also believed that students were willing to conduct reflection
learning during and after learning new things in a class because
it helped improve their learning, but were often unable to do so
as they lacked suitable means and tools. Therefore, the instructor
felt that the cloud-based reflective learning environment was pro-
vided effective tools that helped students to interact, discuss, and
share their individual thoughts and knowledge with their instruc-
tor and peers. The proposed learning environment facilitated
reflective practices and thus successfully addressed the issue of
improving student reflection abilities.

With regard to the control group, the instructor and most stu-
dents indicated that the discussion board is an older learning tool
than the web applications applied in this study. Therefore, it is not
suitable for the present student behaviors on Internet since the
information transmission and social interactions on the discussion

<table>
<thead>
<tr>
<th>#</th>
<th>Item</th>
<th>Experimental group</th>
<th>Control group</th>
<th>t(68)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The product design course is valuable and worth studying for.</td>
<td>3.771/0.426</td>
<td>3.600/0.497</td>
<td>1.549</td>
</tr>
<tr>
<td>2</td>
<td>It is worth learning about product design</td>
<td>3.829/0.382</td>
<td>3.714/0.458</td>
<td>1.133</td>
</tr>
<tr>
<td>3</td>
<td>It is worth learning the product design course well</td>
<td>3.857/0.355</td>
<td>3.686/0.471</td>
<td>1.719</td>
</tr>
<tr>
<td>4</td>
<td>It is important to learn more about product design, such as observing and learning about industrial products</td>
<td>3.429/0.502</td>
<td>3.000/0.485</td>
<td>3.632</td>
</tr>
<tr>
<td>5</td>
<td>It is important to know about novel design and new technologies relevant to product design</td>
<td>3.914/0.284</td>
<td>3.571/0.558</td>
<td>3.241</td>
</tr>
<tr>
<td>6</td>
<td>I will actively search for more information about product design</td>
<td>3.800/0.406</td>
<td>3.486/0.507</td>
<td>2.863</td>
</tr>
<tr>
<td>7</td>
<td>It is important for everyone to take the product design course</td>
<td>3.743/0.443</td>
<td>3.714/0.458</td>
<td>0.265</td>
</tr>
</tbody>
</table>

Note: S.D.: standard deviation.
* p < 0.05.

5.5. Interview investigation

The course instructor and students in both groups were inter-
viewed to understand their perceptions of the product design
course and investigated the differences of the teaching and learn-
ing experiences between the two groups. Instructor and student
responses were recorded and then transcribed for all the inter-
views. To clearly present the interview results, the transcript con-
tents were divided into three main topics of instruction, inter-
action, and technology according to the interview results.

5.5.1. Instruction perspective

The instructor stated that students in the experimental group
were more engaged in the learning events and activities during
and after the class as they could easily and conveniently adminis-
ter, share, and consolidate individual thoughts and knowledge
through the cloud-based reflective learning environment. Addi-
tionally, he was impressed that students in the experimental group
demonstrated excellent performance in every discussion and reflection activity. He also felt that web application support used
by the experimental group could easily extend discussion and reflection activities to after school sessions. This is because the
use of the modern web applications that could enable the students
to keep higher motivation and more positive attitude for contin-
uing their learning. Thus, more time could be used to address con-
cepts in detail or interact with students. In contrast, the instructor
thought that only one fourth of students in the control group could

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of students</th>
<th>Mean</th>
<th>S.D.</th>
<th>Adjusted mean</th>
<th>F(1,67)</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental group</td>
<td>35</td>
<td>35.429</td>
<td>5.736</td>
<td>35.378</td>
<td>5.173</td>
<td>0.026*</td>
</tr>
<tr>
<td>Control group</td>
<td>35</td>
<td>32.143</td>
<td>6.450</td>
<td>32.193</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number of students</td>
<td>70</td>
<td>33.786</td>
<td>6.281</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: S.D.: standard deviation.
* p < 0.05.

supported by the proposed cloud-based reflective learning envi-
nvironment had higher reflection levels. After eliminating the influ-
ence of the covariance on the dependent variable, post-test
reflection scores between the two groups turned out to be signifi-
cantly different ($F(1,67) = 5.173$, $p$-value = 0.026 < 0.05). Therefore,
the above results implied that students achieved higher reflection
levels after using the proposed cloud-based reflective learning
environment compared to those that did not.

Table 3
Students’ attitude towards product design learning.

Table 4
ANOVA results of the reflection level post-test score between the two groups.

5.5.3. Technology perspective

The instructor and the majority of students in the experimental
group indicated that the user interface of the cloud-based reflec-
tive learning environment was clear and straightforward. They
were already familiar with major learning tools before participat-
ing in the product design course. Most students actively used the
cloud-based reflective learning environment due to its conve-
nience, which also motivated them to carry out reflective learning
activities and strengthen their reflection abilities. This was possible
since the cloud-based reflective learning environment was inte-
grated with well-known web applications. Most students need
not install extra applications or register as a new user for using
the learning environment. The instructor, on the other hand,
thought that reflection learning was driven by the students them-
selves instead of the cloud-based reflective learning environment.
He also believed that students were willing to conduct reflection
learning during and after learning new things in a class because
it helped improve their learning, but were often unable to do so
as they lacked suitable means and tools. Therefore, the instructor
felt that the cloud-based reflective learning environment was pro-
vided effective tools that helped students to interact, discuss, and
share their individual thoughts and knowledge with their instruc-
tor and peers. The proposed learning environment facilitated
reflective practices and thus successfully addressed the issue of
improving student reflection abilities.

With regard to the control group, the instructor and most stu-
dents indicated that the discussion board is an older learning tool
than the web applications applied in this study. Therefore, it is not
suitable for the present student behaviors on Internet since the
information transmission and social interactions on the discussion
board were poorer than those on the modern web applications. Moreover, the discussion board was not convenient to users due to it is a standalone program that may not support various devices. However, a major advantage of the discussion board is that it had a low technical obstacle for each student to use.

6. Conclusion and discussion

This study developed a cloud-based reflective learning environment capable of supporting student reflective learning activities. The environment seamlessly provides a student-centered learning context to help students strengthen their reflection abilities. An experiment was also conducted in an industrial course to evaluate the effectiveness of the proposed approach.

The following paragraphs provide detailed discussions explaining how this research contributed to reflection learning, provided novel ideas and expanded upon current literatures. Further applications of the cloud-based reflective learning environment, research limitations, and proposals for further research on the development of reflective learning environments were discussed as well.

6.1. Contribution of the cloud-based reflective learning environment to reflection learning

In order to promote reflection learning, it is important to motivate and enhance learning motivation and participation for every student during and after a class. Students must receive reflective learning support from their learning environments when studying for a subject or course. However, student learning aids are often inadequate such as learning tools, which often confounds an instructor’s best efforts to deliver reflective instructions effectively. Conventional learning environments are often unable to provide effective teaching and learning tools for administering reflective learning activities after school for instructors and students. Therefore, the major contribution of this study is the proposed cloud-based approach that provides students appropriate learning tools to facilitate reflective motivation. In other words, the objectives of this study are to facilitate student learning participation and further promote learning motivation and reflection during and after a class by integrating modern web applications to the reflective learning environment. The improved reflection and motivation provided by the proposed learning environment also made teaching more successful.

The proposed cloud-based reflective learning environment was implemented experimentally in a product design course at a Taiwanese university. A series of evaluation processes that included tests, questionnaires, and interviews were used. Results verified that the proposed learning environment provided both instructor and students with effective supports. Students in the experimental group exhibited higher learning motivation and reflection performance as they could obtain adequate learning supports during and after the class. Despite the importance of reflection for students and instructors, reflective learning activities are usually not included in actual teaching due to limits on class duration. It is also difficult for instructors to induce student reflections or work with them effectively. Therefore, this study concluded that the cloud-based reflective learning environment is able to effectively assist instructors and students in administering and conducting reflective learning activities during and after a class.

6.2. Further applications of cloud-based reflective learning environment for educators

From a pedagogical perspective, although the proposed cloud-based reflective learning environment was implemented in a product design course, the proposed approach can also be used by educators in different educational contexts to achieve various pedagogical objectives. Educators can use the learning environment to interact with students and survey their opinions prior to a class to improve both teaching and learning. The environment can also be used during an instruction to conduct a formative assessment on student learning statuses and to identify learning problems. Finally, educators are able to use the environment to conduct post-instruction performance assessments to find out how well the students had acquired relevant knowledge taught during the learning process.

6.3. Limitations and future work

The proposed approach in this study was implemented in a computer-aided classroom. A limitation of the approach would be that it could not be easily implemented in standard classrooms since not every student owned a tablet PC or a smartphone. However, future progress and popularization of mobile devices would eventually solve this issue. Another limitation of this study would be that participants may have a limited understanding in the use of web applications to support their learning (Ng, 2012) even if the majority of them were already familiar with the web applications in their daily lives. Therefore, course instructors would be required to provide additional information and instructions on using these web applications for educational purposes.

Future directions of this study would be to apply appropriate cloud-based applications to strengthen the proposed learning environment and support the instruction of different subjects and disciplines. Further investigations on student learning effects may also utilize suitable cloud-based learning tools developed using application program interface (API) to support the reflective learning environment in various educational contexts.

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References

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