Universal Access in the Information Society (2020) 19:283–294
https://doi.org/10.1007/s10209-018-0640-6

LONG PAPER

Applying online competency-based learning and design-based learning to enhance the development of students' skills in using PowerPoint and Word, self-directed learning readiness, and experience of online learning

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Published online: 2 November 2018

Abstract
Online learning has been widely adopted in higher education, because it can help both teachers and students to achieve educational goals through better accessibility, flexibility, and interaction. As the Internet and educational technologies have evolved, however, educators indicate that online education and the related technology is more than just a technical consideration; thus, online educators and scholars should address the pedagogical perspectives of online learning. Therefore, this study attempts to provide an effective online teaching method and to investigate the effects of online competency-based learning (CBL) and design-based learning (DBL) on enhancing students' learning performance, self-directed learning readiness (SDLR), and experience of online learning in an online computing course. The experimental design in this study involved a 2 (CBL vs. non-CBL) × 2 (DBL vs. non-DBL) factorial pretest/posttest design. Four classes in a course titled "Applied Information Technology: Office Software" were chosen for this research. Students involved in this experiment were from non-computer field departments at a comprehensive university. Based on the analysis carried out in this research, students who received the intervention with online DBL showed significantly better skills in using PowerPoint. However, learners who received the intervention with online CBL and/or DBL did not have significantly better SDLR or experience of online learning. The potential reasons for this insignificance in students' SDLR and experience of online learning as well as their implications are reported in this paper.

Keywords Online competency-based learning · Online design-based learning · Online education · Skills in using PowerPoint and Word · Self-directed learning readiness · Experience of online learning

1 Introduction

Online and blended learning is growing in significance across the higher education sector with increasing demands for effective and flexible delivery of learning materials [63]. In online environments, learners can choose their learning objectives and learning time, select the learning tasks, and determine the learning contents. In addition, learners can choose their preferred method of learning based on their own learning ability, cognitive styles, and personality characteristics [26]. However, recently, educators have realized that online education is more than just a technical factor and that online teachers must address the pedagogical aspects as well [43]. Thus, the researcher in this study adopted innovative teaching methods and designed an appropriate online course considering modern students' specific needs and the needs of practical pedagogy for computing education.

1.1 Need for competency-based learning

Computer science and related technologies are at the core of the current information age [68]. Undergraduates should be prepared to develop the skills of using technologies, such as computing skills, to solve problems they may face. However, engineering and information technology graduates may

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perceive themselves as being unable to practice in the industry [12, 69], and this phenomenon raises concerns among academics and institutions regarding the intellectual complexities of, and resources for, computing education [84]. Upon graduating from university, people should ideally possess the essential technological skills to enter the workplace [46, 53]. To build their competitiveness, students need to develop information technology skills and learn to be adaptable, flexible, and oriented to solving problems [72].

Computing education in Taiwan is emphasized at each level and in each discipline [84]. Most undergraduates in academic universities in Taiwan have to take four to six compulsory computing courses, and pass the related certificate examinations before they graduate [82]. However, much application software education in Taiwan can hardly be regarded as practical in developing undergraduates' computing skills needed in the business environments [85, 86]. For instance, many inappropriate and disconnected examples are applied in the lectures of computing courses [54], which makes it difficult to strengthen students' computing skills for the workplace and may reduce their competence in future business environments [83].

To address students' competence for their careers, this study adopted competency-based learning (CBL) in an online computing course, because CBL focuses on the outcomes and levels of competence developed through students engaging in and performing real-world tasks [49]. Federal and state policymakers in the U.S. have expressed great interest in the expansion of competency-based learning in higher education [50]. Moreover, CBL can offer teachers sophisticated mechanisms for ensuring that students are prepared to meet the requirements of professional practice and public accountability [77], and has been conceived as the interplay of students' learning objectives, learning performance, skills, and competencies [24]. Thus, the researcher in this study adopted CBL in an online course to improve students' practical skills in using PowerPoint and Word, self-directed learning readiness (SDLR), and experience of online learning, and to further develop their competence for their future workplaces.

1.2 Need for design-based learning in computing education

The past decade has witnessed increasing industry demand for computing expertise, driven by the great expansion of computing use, the growing influence of computing on the economy, and the considerable influx of innovative technologies into modern life [23, 48]. Computing education is becoming increasingly important, as expressed by Wing [97] and Caspersen and Nowack [17]. However, in recent years, computing education in many countries (e.g., Korea and Taiwan) has not been appropriately implemented, despite the revised educational base and expansion of infrastructure [22].

Traditional education models typically advance students based on the number of credit hours earned and instructional hours completed. Consequently, the traditional teaching methods may limit how quickly a student can progress through a program and may not accurately assess whether students retain the knowledge and skills that have been taught [50]. In addition, improving students' higher order thinking skills is an important task for universities in the modern digital world [5]. For example, problem-solving skills, critical thinking, the use of technologies, and the ability to retrieve and analyze information are critical skills for the current workforce [101] and should be emphasized in computing courses. Nevertheless, despite the development of technology and applications in recent years, the traditional lecture-based teaching method continues to prevail [5, 10, 16, 61]. This may hinder higher education institutions' ability to facilitate effective learning that prepares students to meet the requirements of the twenty-first century workforce [5].

Computer science has been perceived by some as an intellectually scientific discipline that teaches problem solving; a fundamental understanding of computer science has been considered to enable learners to be both innovative creators with design skills and educated consumers of technology [35]. In addition, Guzdial [39] states that educators and instructors should better understand how to teach computing so that students have the knowledge to successfully apply computing in their fields of interest. Computing course teachers should design their computing activities to help students realize which potential analyses and visualizations could be used in the problem-solving process [101].

To develop students' design and problem-solving skills and provide effective and practical teaching in computing courses, the researcher in this study applied design-based learning (DBL) in the involved computing course. DBL is an educational approach in which learners gather and apply knowledge and skills to solve design problems [37]. Thus, DBL was integrated into an online computing course, and its effects on enhancing students' skills in using PowerPoint and Word, SDLR, and experience of online learning were explored.

Educational technologies have become popular tools in class, and they introduce certain didactic aspects without tremendously increasing teachers' workload [40, 41]. However, few studies have discussed effective online teaching methods and integration with educational technologies for both students and teachers [83]. It is important for educators to develop effective online teaching methods [65]. Thus, the author in this research designed a course titled "Applied Information Technology: Office Software" by refining web-based teaching methods of a computing course according to specific student characteristics and course orientations, and empirically measured students' skills in using PowerPoint and Word, SDLR, and their experience of online learning in a computing course. Specifically, the research questions addressed in this study are as follows:

1. In an online learning environment, do students who receive *CBL* intervention have better development of skills in using PowerPoint and Word, SDLR, and their experience of online learning in a computing course, than those without *CBL*?
2. In an online learning environment, do students who receive *DBL* intervention have better development of skills in using PowerPoint and Word, SDLR, and their experience of online learning in a computing course, than those without *DBL*?

2 Literature review

2.1 Competency-based learning

Competency can be formally interpreted as multidimensional, comprised of skills, abilities, knowledge and psychological factors that are brought together in complex behavioral responses to environmental cues [25, 71]. Employers may worry about the disconnect between school education and work competencies; people may not possess the basic skills needed when they enter the workplace [80]. Thus, competency-based education is well known to advance the match between educational performance and employment opportunities [7, 32].

The purpose of CBL is to reduce the gap between education and workplace [7]; thus it has been increasingly used in higher education over the past 10 years [67, 70]. It is an approach that establishes a specific learning outcome, utilizes pedagogy that is consistent with students' current performance, then measures students' outcomes using structured methodology, and adjusts the curricula based on the evaluation [70, 76]. The history of CBL can be traced back to Greenhill, Metz, and Stander [38], who propose that learners should develop their own major competencies. CBL is generally used to learn specific skills rather than for abstract learning as it attaches great importance to students' performance and learning outcomes as defined by objectives and course goals [66].

In a CBL environment, the competency requirements can help learners to identify their expertise and facilitate competency-oriented social learning and networking [20]. The advantage of CBL is that competencies are transparent and open, learners in the learning process and environment can understand the learning goals and outcomes [8]. The CBL model has the benefit of conspicuous connection to ambitious students' performance, because the teaching processes shift the focus from instructional delivery to their learning outcomes [92]. In addition, it is indicated that students' core competencies, metacognitive abilities and academic performance in a CBL course were significantly higher than those who did not learn in that environment [32]. Moreover, researchers and instructors have started to integrate CBL models into e-learning programs to help students achieve better learning effects [20, 75]. Thus, the researcher in this research integrated CBL into a blended course to develop students' practical skills in using PowerPoint and Word, and improve their SDLR and experience of online learning.

2.2 Design-based learning

The educational approach of DBL is intended to bridge the gap between formal and informal learning [91]. In this environment, students are encouraged to solve problems through the design that they create collaboratively [98]. The characteristic benefit of DBL is to promote students solving real-life design problems [62], and it now has been widely used in technology-enhanced learning environments [100]. DBL projects include hands-on, open-ended, authentic and multidisciplinary design tasks [36]. Taking a comprehensive view of courseware development to conduct design-based research is necessary, as this can promote progressive and iterative review and revision of the instructional design plan and output [79, 100]. Furthermore, the process of DBL not only supports students' reflections and visualizes their active thinking [57], but also connects both inquiry and reasoning towards generating innovative artifacts, systems and solutions [36].

DBL has been introduced and successfully experienced in education, as evidence shows that it promotes students' self-direction ability and team work skills, and also supports the enhancement of reasoning in teaching the sciences [6, 28, 36]. In this regard, to integrate learning technologies into DBL activities has the benefit of further promoting students to connect formal and informal learning experiences [98]. Ke [44] conducted a computer-assisted, math game-making activity in facilitating DBL for students, wherein it was found that students' design thinking is usually experience driven, which stimulates them to reflect on their observations and experiences of math-related phenomena and problem solving in previous daily life or gaming activities.

Moreover, in their study Duran et al. [29] investigate the effect of collaborative DBL on 77 high school students' science, technology, engineering, and mathematics (STEM) learning; the findings indicate that the DBL program had a significant impact on students' STEM skills and understanding of the instructional topics. After participating in DBL activities, students learned how to build designs, solve the problems they encounter, discover relationships among many elements, and develop attitudes to continuously tackle emerging challenges [45]. It is worthwhile and valuable to adopt design-based and collaborative approaches to build community in online courses [78]. Therefore, DBL was applied in a blended computing course to help students achieve better learning effects, including their skills in using PowerPoint and Word, SDLR, and online learning experience.

2.3 Self-directed learning readiness

The current rapid changes in educational, political, social, and economical realms create an urgent need for self-directed learning (SDL), which is equally important to both younger students and adult learners [4]. SDL is a process in which learners can take the initiative, with or without others' help, to diagnose the needs of their learning, develop their learning objectives, determine learning materials, choose and adopt appropriate learning strategies and to evaluate their learning outcomes [47, 51]. SDL has been widely adopted in educational settings and research about learning online suggests that web activities can be used to foster students to be self-directed, and become autonomous learners [1].

The extent to which students possess the abilities, tendencies, and personality traits necessary for SDL is represented by their self-directed learning readiness (SDLR) [4, 33]. SDLR refers to the degree that learners have the attitudes, capability and personality characteristics necessary for SDL [33, 94, 99]. It was originally emphasized in nursing education, and now is also studied and used in other domains [96]. SDLR is currently treated as one of the key learning outcomes in online education [51, 89]. Thus, the researcher explored whether students' SDLR in this online computing course is improved after they received the interventions of CBL and DBL.

2.4 Experience of online learning

The Internet can be regarded as one of the most important technologies affecting daily life, and has now been widely adopted in education [42]. It is important for teachers to know their students' experience of online learning in a web-based learning environment. Students' experience of online learning is one of the critical factors in their learning performance, so it should be evaluated to grasp students' perspective and attitude toward the online courses they have participated in and the online pedagogy they have received [73]. In a well-designed online learning environment with appropriate teaching methods for students' specific needs, students have a better chance to perform effectively and have a satisfactory experience in online learning [83].

To provide a positive experience of online learning, the researcher re-designed an online computing course, and integrated online teaching methods of CBL and DBL. Then, students' experience of online learning was collected via questionnaires, and further analyzed to identify if students have better experience in online learning after they received interventions of online CBL and/or DBL.

3 Empirical study

3.1 Subjects

In this study, the subjects were 153 undergraduates from four classes taking a compulsory course titled "Applied Information Technology: Office Software". Students in the CBL and DBL class (C1, $n=32$), the CBL and non-DBL class (C2, $n=36$), the non-CBL and DBL class (C3, $n=43$), and the non-CBL and non-DBL class (C4, control group, $n=42$) were all from the department of Finance. Students from non-computer field departments in Taiwan generally lack the skills to appropriately use application software [84]. In addition, the subjects used the same course website built based on Moodle—which is an open-source learning management system—though with different pedagogies and learning materials. The experimental design for the four groups (conditions) is illustrated in Fig. 1.

Before the experiment began, the teacher declared that this class would be provided through both Internet and the classroom, and students would receive teacher's interventions in an experiment. It was also announced that students had the right to drop and select another teacher's course, if they did not want to stay in this experiment.

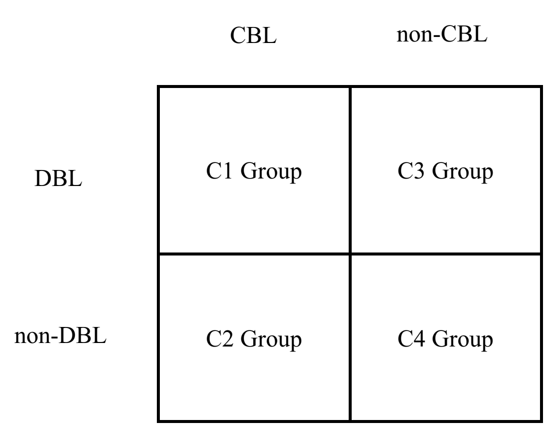

Fig. 1 Experimental design for this research

3.2 Course setting

The course involved was a semester-long, 2-credit-hour course for first-year students from non-computer field departments. This course focused on developing students' skills for using Microsoft Word and PowerPoint. In the initial stage, the teacher first introduced the basic functions of Word and PowerPoint. Then, the teaching focused on solving real-life or simulated problems that employees may face in workplaces. In addition, this course aimed to help students pass examinations for certificates in Word and PowerPoint. Thus, these students had to take an examination for a certificate in PowerPoint and Word in the 11th and 17th week of the semester, respectively.

3.3 Experimental design and procedure

The researcher investigated the effects of CBL and DBL on improving students' skills in using PowerPoint and Word, SDLR, and experience of online learning. The experimental design was a 2 (CBL vs. non-CBL) × 2 (DBL vs. non-DBL) factorial pretest/posttest design, and four classes were involved in this experiment. The first class (C1) simultaneously received the treatment of online CBL and DBL, the second class (C2) received the treatment of online CBL only, and the third class (C3) received the treatment of online DBL only. These were the experimental groups, while the final group (C4), which received traditional instruction, served as the control group. The teaching in the four classes was delivered in a blended online/in-person format. The overall schedule of the course is illustrated in Fig. 2.

3.3.1 Intervention concerning CBL

The CBL approach involves redefining program, classroom, course, and experiential education objectives as competencies or skills and designing coursework that promotes students' competency development [8, 14]. It uses competencies as the pedagogical structure for curriculum design and learning resource management as well as for supporting a competency-oriented learning process [20]. CBL requires complete alignment between the program's task, curriculum, and competencies, and the prevention of the possibility of mission drift [70]. In addition, the learning contents in this CBL environment were delivered in a blended format, which allowed students to build on their previous knowledge of identifying and solving problems to focus on the application of knowledge and skills rather than on theoretical knowledge [32].

In the context of this study, the development of the CBL curriculum incorporated general computing skills, critical thinking, and reasoning [32]. In the implementation of CBL in C1 and C2, the researcher adopted Baughman et al. [8] suggestions of the top five course competencies:

1. Analysis and judgment: making sure and understanding issues and problems faced; using effective approaches for developing appropriate solutions; and taking actions that are consistent with available facts and possible consequences;
2. Communication: clearly delivering ideas and content through online course, and providing digital learning

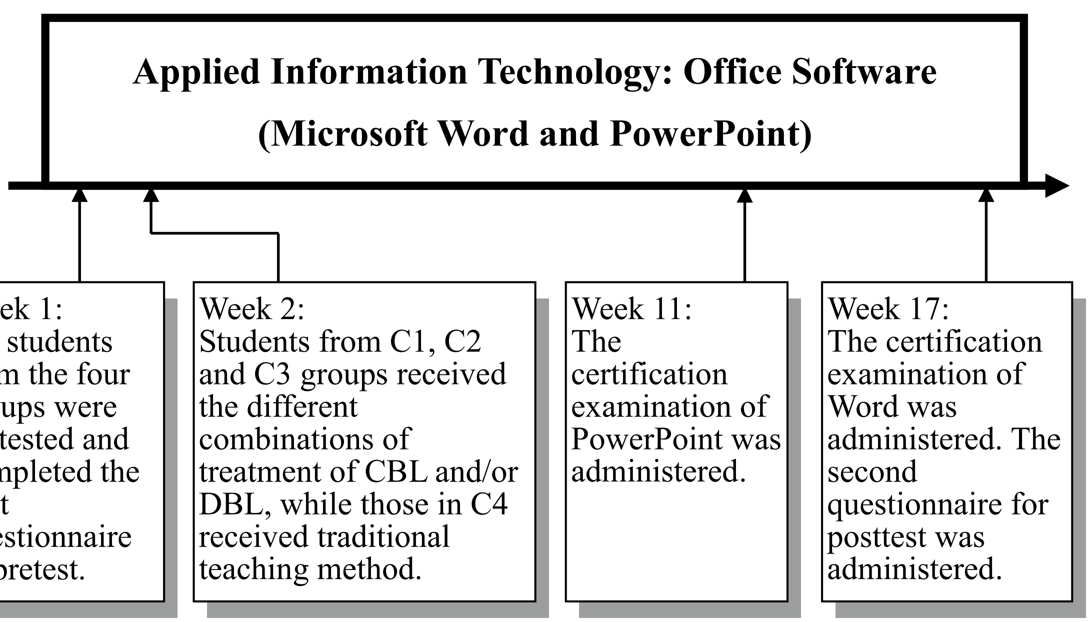

Fig. 2 Proposed schedule of the course and certification examinations during the semester

material to students that engages them and helps them understand;
3. Initiative: taking prompt action to solve problems and accomplish objectives;
4. Continuous learning: regularly creating and taking advantage of learning opportunities; providing new information related to this computing course; using newly gained skills on the job and for problem solving, and learning through applications;
5. Teamwork: effectively and positively participating as a member of a team to move the team toward completion of learning goals.

3.3.2 Intervention concerning DBL

In the implementation of DBL, the researcher adopted and followed the suggestions of previous educators introduced below. DBL mainly focuses on the planning and design of activities in which learners make design decisions in the cognitive thinking processes [28, 30]. In addition, DBL relies heavily on communication and interaction between group or team members, so that they might construct more efficient design by encouraging the provision of appropriate feedback and idea generation [98]. In a DBL environment, design and computing can merge, so that students can analyze and rethink the process of knowledge construction or learning during the learning process [44].

The DBL approach makes students' plan and reflect on their construction process [27, 36]. In a DBL environment, students are taught and assessed based on collaborative teamwork processes; thus, the instructor's formative feedback can be regarded as a meaningful instrument to assist the design learning process, and to construct domain knowledge [36]. Teachers play another important role in the DBL process by, for example, assisting students to construct their learning process by asking guiding questions, by providing scaffolding processes, and by stimulating discussion to use domain terminology [21, 56, 58, 59]. Thus, in the implementation of DBL in C1 and C3, the researcher adopted and followed the abovementioned approach. Hence, the DBL approach in this study was conducted in the following manner [45]:

1. (Re)Defining a problem: rethink about the problem students' face, and redefine it;
2. Planning action: plan the schedule and the necessary actions;
3. Implementing: Gather the resources, including the necessary texts, figures, and solutions, and put them into action;
4. Evaluating: present, observe, survey, record, and evaluate the performance;
5. Specifying findings: record the achievements and findings.

After students execute the design tasks, address the challenges, and assess the process, they may have enhanced opportunities to learn not only knowledge but also about their choices made in the planning, experimenting, and design processes [36].

3.4 Evaluation

3.4.1 Skills in using PowerPoint and Word

Assessment of students' learning is a critical part of life in universities for both staff and students [93]. Teaching application-oriented computing courses in Taiwan usually focus on facilitating students to pass certification examinations [81]. In the present course, all students were required to take an examination for a certificate in PowerPoint in the 11th week, and Word in the 17th week, of the semester. These certificate examinations were administered by a trustworthy and well-known organization in Taiwan named Computer Skills Foundation.

The Word and PowerPoint examinations had three and two problems, respectively, which each consisting of 5–8 sub-problems. Before testing, students were assigned random seats. They had 40 min to complete each examination. Finally, the researcher tested the differences in skills in using PowerPoint and Word among the four groups of students.

3.4.2 Self-directed learning readiness

Students in this study were asked to complete the 40-item Self-directed Learning Readiness Scale (SDLRS), developed by Fisher, King, and Tague [34], twice. The first administration was in the first week as the pretest and the second in the 16th week for the posttest. SDLRS was used for assessing students' readiness for self-directed learning. SDLRS comprises three subscales: self-management (13 items), Desire for learning (12 items), and self-control (15 items). These items were rated on a 5-point Likert-type scale (1 = strongly disagree and 5 = strongly agree) [95]. After students completed the questionnaire, the researcher examined the differences in the SDLR among the four groups of students.

3.4.3 Students' experience of online learning

Students from the four groups were also required to complete a sub-questionnaire to extract their experience of online learning. The researcher adopted the questionnaire of Boyle et al. [11] and Tsai and Shen [88] to measure students' thoughts regarding any blended course they had previously participated in and any interventions concerning online CBL and DBL they had previously received. This sub-questionnaire with five simple questions served as a tool to gather data about students' thoughts regarding online CBL and DBL. For instance, students were asked the question: "Is the teaching method of computational thinking helpful for developing skills in using PowerPoint and Word?" (1-Very helpful; 5-Useless). In addition, they were asked about their thoughts on any previous blended computing course with this question: "Please compare this blended course and the teacher's teaching methods with other traditional computing courses and rate it on a 5-point scale" (1-Much better; 5-Much worse). The researcher thus compared and explored whether online CBL and DBL improves students' online learning experience.

4 Results

4.1 Pretests

Before adopting the CBL and DBL teaching methods in the involved course, a pretest was conducted to prevent the potential of students' initial differences causing a bias in the evaluation. The researcher first checked students' skills in using Microsoft PowerPoint and Word, and their SDLR before the experiment began. In the first course of the semester, the researcher asked whether students from the four classes had learned Word and PowerPoint, or already earned related computer certifications before this course. At that time, nine students reported that they had already learned to use Word and/or PowerPoint before entering this course. These nine students were then removed from this experiment, although they still remained in their original classes. Finally, the 153 students who had not been taught PowerPoint and Word previously were regarded as participants in this study.

Moreover, a pretest applying one-way ANOVA was also conducted to check students' SDLR before they received different teaching methods in this research. The result of the analysis is shown in Table 1, which indicates that there was no significant difference in the students' SDLR among these four groups.

Table 1 One-way ANOVA: pretest of students' SDLRS

Dependent variable	Group (*I*)	Group (*J*)	Mean difference (*I* − *J*)	Std. error	Sig.
SDLRS	G1	G2	0.03583	0.10292	0.989
		G3	0.00200	0.10657	1.000
		G4	0.16535	0.10240	0.459
	G2	G1	−0.03583	0.10292	0.989
		G3	−0.03383	0.09962	0.990
		G4	0.12953	0.09516	0.605
	G3	G1	−0.00200	0.10657	1.000
		G2	0.03383	0.09962	0.990
		G4	0.16336	0.09909	0.440
	G4	G1	−0.16535	0.10240	0.459
		G2	−0.12953	0.09516	0.605
		G3	−0.16336	0.09909	0.440

4.2 Post-tests

4.2.1 Effects of competency-based learning (research question 1)

To explore the effects of CBL, the independent samples *t* test was used to compare students' skills in using PowerPoint and Word, SDLR, and their experience of online learning between the CBL group (C1 and C2) and non-CBL group (C3 and C4). As the data in Table 2 shows, the difference in students' scores for Word between the CBL group (77.35) and non-CBL group (70.87) is statistically insignificant. In addition, the difference in students' PowerPoint scores between the CBL group (92.15) and non-CBL group (88.88) is also insignificant.

Regarding the effects of CBL on students' SDLR and experience of online learning, Table 3 indicates that no significant difference was found between students' SDLR between CBL group (3.60) and non-CBL group (3.64). Moreover, the experience of students' online learning between the CBL group (3.13) and non-CBL group (3.21) did not show significant difference. That is, the expected effects of CBL on students' skills in using PowerPoint and Word, SDLR, and experience of online learning were not identified.

4.2.2 Effects of design-based learning (research question 2)

Regarding the effect of DBL in an online computing course, the author investigated the difference in the students' skills in using PowerPoint and Word, SDLR, and their online learning, between the DBL group (C1 and C3) and non-DBL group (C2 and C4) via the independent samples *t* test. The results in Table 4 show no significant difference in the students' Word score between DBL group (75.52) and non-DBL group (72.52). Nevertheless, a significant difference in students' PowerPoint score is found in the DBL group (92.65) compared with the non-DBL group (88.10) ($p = 0.035$). Thus, DBL may help students in to better develop their skills in using PowerPoint.

Furthermore, as shown in Table 5, there is no significant difference in students' SDLR between the DBL group (3.59) and non-DBL group (3.65). However, the *p* value in the

Table 2 Comparison of grades: CBL group and non-CBL group

	Group	n	Mean	SD	F	t value	df	p
Word	CBL group	68	77.35	24.265	0.997	1.456	151	0.147
	non-CBL group	85	70.87	29.602				
PowerPoint	CBL group	68	92.15	11.540	0.694	1.503	151	0.135
	non-CBL group	85	88.88	14.638				

Table 3 Comparison of self-directed learning readiness and experience of online learning: CBL group and non-CBL group

	Group	n	Mean	SD	F	t value	df	p
SDLR	CBL group	68	3.60	0.589131	0.642	−0.452	151	0.652
	non-CBL group	85	3.64	0.508732				
Experience of online learning	CBL group	68	3.13	0.538394	0.521	−0.907	151	0.366
	non-CBL group	85	3.21	0.545026				

Table 4 Comparison of grades: DBL group and non-DBL group

	Group	n	Mean	SD	F	t value	df	p
Word	DBL group	75	75.52	24.136	3.533	0.780	151	0.437
	non-DBL group	78	72.05	30.382				
PowerPoint	DBL group	75	92.65	9.756	3.557	2.123*	151	0.035
	non-DBL group	78	88.10	15.909				

*$p < 0.05$

Table 5 Comparison of self-directed learning readiness and experience of online learning: DBL group and non-DBL group

	Group	n	Mean	SD	F	t value	df	p
SDLR	DBL group	75	3.59	0.521869	1.802	−0.644	151	0.520
	Non-DBL group	78	3.65	0.567263				
Experience of online learning	DBL group	75	3.08	0.588172	0.000	−2.125*	151	0.035
	Non-DBL group	78	3.26	0.479712				

*$p < 0.05$

DBL group and non-DBL group is 0.035 (< 0.05), implying that significant difference in students' experience of online learning exists between the DBL group (3.08) and non-DBL group (3.26). The reason why the non-DBL group had better experience of online learning is discussed in Sect. 5.2.

5 Discussion and implications

Information and communication technologies and related applications have become pervasive over the past decade [18]. Teaching with educational technology in a smart way could improve students' achievement [9, 15, 41]. To develop students' competency, SDLR, and experience of online learning, the researcher applied online CBL and DBL to improve students' learning in this study. Thus, this present study may contribute to the online education field in the following ways.

First, the online course and treatments of CBL and DBL were designed based on the specific needs of students' learning characteristics and course orientations of a computing course, and can serve as a reference for other teachers of computing courses. Second, this paper emphasizes and highlights the importance of students' SDLR and experience of online learning. The study also evaluated and tested whether the two factors improved after students received the treatments of online CBL and DBL. Finally, the presented study may be one of the early attempts to simultaneously adopt and integrate CBL and DBL in an online course to enhance students' learning effectiveness and competency, and provide empirical evaluation of their effects on improving students' skills in using PowerPoint and Word, SDLR, and online learning experience. These contributions could provide insights for online teachers who wish to provide effective design and teaching methods to other learners.

5.1 Effects of competency-based learning

In higher education, e-learning has been regarded as a tool to support teaching [46]. Online learning in higher education has increased rapidly because of its potential to achieve the educational goals of life-long learning by increasing access to professional development opportunities [3, 64]. In this study, the author integrated CBL in an online computing course to improve students' learning. As shown in Table 2, the skills for using PowerPoint and Word of students in the CBL group is higher than those of the non-CBL group, although not significantly (Word, $p=0.147$; PowerPoint, $p=0.135$). Levy and Ramim [55] expected significant increases in technology skills through CBL, though they did not find the effects of CBL on enhancing students' technology skills, which is consistent with our findings.

In addition, Table 3 shows that there are no significant differences in the CBL group students' SDLR ($p=0.652$) or experience of online learning ($p=0.366$) compared with the non-CBL group. In other words, the expected effects of CBL were not. Potential reasons for the nonsignificant differences may be that the participants were from the department of Finance, and did not regard this computing course as one of their major courses. They may have paid more attention to other major courses and may have not immersed themselves well in the CBL environment. Furthermore, the length of the experiment might not be sufficient for assessing the effects on the students' learning outcomes [52]. Moreover, the use of CBL in the e-learning field is still in a state of academic validation and not widely practiced; further validation through empirical studies is recommended [20].

5.2 Effects of design-based learning

Recent research in the e-learning field has emphasized the need for facilitating the learning process in DBL practices [19]. In this empirical research, Table 4 shows that there is significantly better development by the end of the course in DBL students' skills in using PowerPoint ($p=0.035$*). The finding of the present study is similar to that by Ellefson et al. [31] that DBL can promote students' learning. Their study indicated that students learn about course content and knowhow in the involved course through a series of interactions, investigations, and design modifications.

Table 5 reveals that there is no difference in the students' SDLR ($p=0.520$). A significant difference was present in the students' experience of online learning ($p=0.035$*) between the non-DBL group (3.26) and DBL group (3.08). The potential reasons for the unexpected results in the students' experience of online learning and the nonsignificant effects on their SDLR may be the attributes of the course itself. In other words, the adoption and implementation of DBL in the involved course titled "Applied Information Technology: Office Software" may not be an appropriate selection for this experiment. The software (Word and PowerPoint) involved in this course are procedural-oriented ones [81, 87], and may not be appropriate for the implementation of DBL. The adoption of DBL in a procedural-oriented course may not be helpful for students' learning; instead, students may be confused when adopting DBL in an inappropriate course, and even have a worse experience of online learning.

Furthermore, course selection is critical for the implementation and evaluation of innovative teaching methods; thus a design-oriented course may be more suitable and provide a broader stage for students to apply what they have learned [54]. Thus, future researchers are encouraged to adopt and evaluate the effects of DBL in a more design-oriented course or a course comprising ill-structured or complex tasks.

5.3 Potential problems and limitations of this study

In this study, the researcher re-designed a blended computing course, integrated CBL and DBL into the curriculum, and explored the effects on improving students' computing skill in using PowerPoint and Word, SDLR, and online learning experience. Owing to the nature of the quasi-experimental design, there may be a few potential limitations in drawing firm conclusions from the results. Although the researcher first conducted a pretest, and made sure that students had similar level of skills in using PowerPoint and Word and SDLR before receiving the treatments of online CBL and DBL, problems with the quasi-experimental design may still exist.

First, students' information literacy competence for e-learning in the four groups may not necessarily have been the same when the experiment began, thus causing potential bias of evaluation of their learning outcomes. In addition, some results of this research are based on students' self-reported data collected via a questionnaire survey. The reliability and validity of the data also relied on psychometric techniques, the results of which are subjective [20]. Thus, these factors may potentially affect the validity of the results. Researchers and teachers interested in adopting CBL and DBL should be aware of these potential factors of quasi-experimental design that may influence the effects claimed in this study.

6 Conclusion

The rapid development of technology has led to the creation and integration of new learning spaces in contemporary higher education [60]. Online learning is thought to have advantages over traditional teaching methods, including flexibility and accessibility to study anytime and everywhere [13, 90]. In these innovative and creative pedagogical approaches to teaching and learning [74], pedagogical and technical deficiencies still exist within the learning environments. In response, educational institutions have to select appropriate pedagogies to meet the needs of students who are comfortable with the use of new technologies in their personal and professional lives [2].

Based on reflections on previous teaching and research in computing courses, the researcher adopted and re-designed innovative teaching methods of CBL and DBL in an online computing course to develop students' skills in using PowerPoint and Word, and also improve their SDLR, and experience of online learning. The findings reveal that students with intervention of DBL in an online course had significantly better development of skill in using PowerPoint than those without DBL. However, students who received the online CBL approach did not develop significantly better skills in using PowerPoint and Word, nor a higher level of SDRL or experience of online learning in this involved computing course. Still, the researcher expects that these results regarding the implementation of CBL and DBL could provide insights for online teachers who wish to provide effective design and teaching methods for their students' learning.

Acknowledgements The author would like to express appreciation for the financial support of MOST research Grant 105-2511-S-130-001 from the Ministry of Science and Technology, Taiwan, ROC.

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