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LONG PAPER

Applying online externally-facilitated regulated learning and computational thinking to improve students' learning

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Abstract This study aims to explore, via quasi-experiments, the effects of online externally-facilitated regulated learning (ERL) and computational thinking (CT) on improving students' computing skills in a blended learning environment. Four classes in a one-semester course entitled 'Applied Information Technology: Data Processing' were the samples for this research. The first class (C1, ERL&CT group) simultaneously received the interventions regarding online ERL and CT, the second class (C2, CT group) received the intervention regarding online CT, and the third class (C3, ERL group) received the intervention regarding online CT, while the last group (C4, control group) received a traditional teaching method, although teaching was also conducted in a blended computing class. Students in ERL&CT group and CT group came from the Department of Finance, while the ERL group and control group came from the Department of Law at a comprehensive university. According to the posttest analysis, the results indicate that students who received the intervention of online ERL had statistically better development of computing skills for using Excel by semester-end than those without. In addition, this study also reveals that the application of online CT alone could be helpful in students' development of computing skills. Furthermore, the results indicate that students' computing skills could be improved under the condition of simultaneously applying ERL and CT. Based on the findings of this study, the authors present implications for online teachers and educators, particularly for those teaching computing courses.

Keywords Online externally-facilitated regulated learning · Online computational thinking · Computing skills · E-learning · Online education

1 Introduction

In a rapidly changing world, technology holds an important place in human life in a large variety of contexts from science to education, agriculture to commerce, transportation to communication; it facilitates life and continues to develop [13]. The adoption of technologies in education also promotes students' learning. For example, synchronous and asynchronous communication tools such as online chat rooms and forums enable students to communicate and complete their tasks [57]. In online education, one of the distinguishing characteristics is the autonomy students experience in the learning environment. Most online environments provide considerable autonomy for learners, which can enhance learners' self-directed actions [16, 30, 46, 47]. The researchers in this study designed an appropriate online teaching method based on the considerations of the learning environment and the need for effective online pedagogy in computing education described below.

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1.1 The need for externally-facilitated regulated learning

As the Internet serves as a resource-based learning tool, it brings new trends and applications for teaching and learning [45]. However, in online courses, students learn independently without the instructor's on-the-spot monitoring [69]. Students now spend their lives surrounded by video games and cell phones filled with entertainment [31]. In such an environment, full of shopping websites, online games, and social networking websites (e.g., Facebook, Twitter, and Plurk), teachers are challenged to concentrate students' attention in an online course [65]. In this regard, it is suggested by educators that students have to manage learning activities by themselves and adopt self-regulated learning in online learning environments [18]. Many researchers have adopted self-regulated learning (SRL), which refers to a learner's intentional efforts to manage and direct complex learning activities [34], and argue that it is critical for successful online learning [18, 42, 44, 63, 68].

In Taiwan, many students are accustomed to accept and follow their teachers' and school's arrangements for learning. They usually lack the ability to manage their time effectively and regulate their learning independently [65]. In order to examine learners' actual achievements, it is imperative to monitor students' learning processes such that teachers may follow learners' progress and determine their development and competencies [32]. Regarding feedback from instructors to online learners, conventional wisdom says the more feedback the better [61]. In addition, immediate feedback is most important for learners and can promote sustained motivation [7]. Thus, some online educators indicate the importance of externally-facilitated regulated learning (ERL), where students have access to a human tutor who facilitates their self-regulated learning. The human tutor should explicitly prompt students to deploy specific self-regulated processes in the implementation of SRL [6]. Therefore, the researchers in this study extended SRL to ERL to develop students' regular learning habits, and explore its effects on improving students' learning.

1.2 The need for computational thinking

In response to the increasing demand to compete in a global economy, countries need to prepare students with the appropriate technical knowledge and communication skills to be competitive in the twenty-first century [74, 75], and Taiwan is no exception to this trend. A variety of approaches to teaching introductory computing courses have been introduced [19, 20]. In Taiwan's computing education, many teachers tend to use inappropriate and lack-of-context examples in teaching of different sections [43]. Students who learn in this context may not know how to integrate what they learn in a course, thus experience limited competence in their future workplaces [66]. To develop and enhance students' problem-solving and computing skills, computational thinking (CT), which comprises the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be carried out by an information-processing agent effectively [77], is considered to be one of the potential solutions.

Internationally, there is a growing awareness of the necessity of providing appropriate computing education in universities and schools. Computing education is considered increasingly important, as expressed by Wing [76] and Caspersen and Nowack [12]. The Next Generation Science Wing's [76] call to action for CT served as the starting point for two National Academy of Sciences workshops assembling leading researchers from education, learning science and computer science (CS) fields, and leaders from the computing industry, to explore the nature of CT, its educational and cognitive implications [50] and the pedagogical aspects of CT [25, 51]. Finally, the National Science Foundation's attention to this proves that CT is a critical component for education and society and deserves the attention of researchers and educators [52]. In this regard, the researchers in this study applied CT in a computing course and investigate its effects on improving students' computing skills.

Educational technology plays a critical role in many teaching reform efforts at the postsecondary level, yet research suggests that faculty tend to adopt these technology-based innovations in a slow and inconsistent fashion. As online education and educational technologies develop, it is necessary to design appropriate online teaching methods and interventions, and to investigate their effects on improving students' learning. Therefore, the researchers in this study redesigned a course titled 'Applied Information Technology: Data Processing,' by refining online teaching methods and strategies based on reflections from previous experiences and iterations of this course [64, 65, 68, 73], and adopted ERL and CT, then empirically measured changes in students' computing skills in a blended computing course.

2 Literature review

2.1 Externally-facilitated regulated learning

Given the openness, flexibility and freedom in online learning environments, students have more autonomy to determine their learning actions in comparison with classroom settings [15, 16, 46]. However, not all learners are

able to work and learn effectively in a computer-mediated communication environment where a limited amount of external structure and regulation is provided, thereby requiring a lot of self-determination from learners [36, 46, 54, 55]. Thus, many researchers and educators have mentioned the importance of SRL and indicated its effects on improving students' learning in the online learning environments [18, 43, 44, 63, 68, 70].

With the development and adoption of SRL in online or hypermedia learning environments, it is indicated that students could benefit from scaffolds that foster SRL processing because they rarely effectively self-regulate by themselves [4, 6, 65]. These scaffolds can be humans externally regulating the students' learning, or computer-based tutors modeling student learning and providing adaptive feedback and scaffolding [5, 10, 29, 71]. Thus, some online teachers extended SRL to ERL, in which learners attempted the same learning task, with access to a human tutor who facilitated their learning by administering prompts for students to engage in several adaptive SRL processes [79]. This approach extends and combines contemporary notions of adaptive learning with computer-based learning environments [11, 60] and human tutors as adaptive regulating agents to develop students' regular learning [82, 83].

The implementation and facilitation of SRL is a balancing act between external support and internal regulation [26]. It is reported that the ERL participants engaged in more activation of prior knowledge, use of the feeling of knowing and judgment of learning, drawing upon, hypothesizing, coordination of information sources, monitoring progress toward goals, and expressing task difficulty [78]. Learners in the ERL condition could gain statistically more declarative knowledge and a greater number of participants in this condition displayed a more advanced mental model [6]. Those self-regulated learners guided by human tutors engaged in more monitoring activities than traditional self-regulated learners [22]. Therefore, according to the literature reviewed in this subsection, the following hypothesis can be proposed:

H1 In an online learning environment deploying an ERL instructional method, development of students' computing skills is positive, and performance higher compared to those taught without an ERL instructional method.

2.2 Computational thinking

Modern educators indicate that CT is a broader term which includes a problem-solving framework that combines problem representation, prediction, and abstraction [28, 33, 49, 58]. CT draws on concepts and practices that are fundamental to computing and CS [58]. CT's essence is thinking like a computer scientist when facing problems [25]. Moreover, Sengupta et al. [58] also highlight the pedagogical benefits of integrating CT with science learning, including their synergies.

Computing education is emphasized at more basic levels around the world; for example, countries such as Russia, New Zealand, Australia, and South Africa have already made room for CS in the K–12 curriculum [25]. In addition, the UK has piloted programs to teach computing to schoolchildren following a bold 2012 policy charter from the Royal Society [56]. The researchers in this study adopted CT in a blended computing course to develop students' practical computing skills. Therefore, based on the literature reviewed in this subsection, the following hypothesis (H2) is proposed:

H2 In an online learning environment deploying a CT instructional method, development of students' computing skills is positive, and performance higher compared to those taught without a CT instructional method.

Although there are new studies indicating the necessity of CT [37, 53] and the importance and effects of ERL in online education [23], there are very few studies that simultaneously discuss and investigate the effects of ERL and CT, particularly in an online learning environment. Nevertheless, based on the literature reviewed in this study, it is argued that the development of students' computing skills will be better when the teacher adopts ERL and CT intervention. Thus, the following hypothesis (H3) is proposed:

H3 In an online learning environment deploying an ERL AND CT intervention, development of computing skills is positive, and performance higher compared to those without ERL and CT intervention.

3 The empirical study

3.1 Participants

The study participants were undergraduates from four classes taking a compulsory course entitled 'Applied Information Technology: Data Processing.' Students in the first (ERL&CT group) and the second (CT group) classes came from the department of Finance, while the third (ERL group) and the last (control group) classes came from the Department of Law, at the same university. The four classes involved were taught by the same lecturer. All the students participating came from a non-information or non-computer science department and generally lacked the skills to use application software well. In addition, participants used the same course Web site built based on

Moodle, which is an open-source Learning Management System.

3.2 Course setting

In this study, the involved course was a semester-long, 2 credit-hour course targeting first-year undergraduates from non-information or non-computer science departments. The course focused on developing students' computing skills for using Microsoft Excel, and, more importantly, passing the respective certification examination. In this course, the teacher first introduced the basic functions of Excel. Then, the teacher applied the strategies of CT as described in Sect. 3.3.2 and asked students to design and complete designated sheets and documents in their experimental groups.

As more and more universities and vocational schools in Taiwan link the goals of computing courses with related computing certificates [70], this course targeted helping students to earn certification in Microsoft Excel. In this regard, most of the teaching focused on solving simulated problems. Then, the students had to take an examination for a certificate in Microsoft Excel in the last week of the semester.

	CT	non-CT
ERL	Most significant effect (C1 Group)	Medium effect (C3 Group)
non-ERL	Medium effect (C2 Group)	No difference (C4 Group)

Fig. 1 The variation and expected effects of instructional methods

3.3 Experimental design and procedure

The experiment followed a 2 (ERL vs. non-ERL) × 2 (CT vs. non-CT) factorial pretest–posttest design (see Fig. 1). There were a total of 187 students in the four class sections. Students in the four groups solved the same tasks but in different learning conditions. The ERL&CT group (C1, $n = 50$), CT group (C2, $n = 49$), ERL group (C3, $n = 47$) were experimental, while C4 (C4, $n = 41$) was the control group.

The effects of ERL and CT on improving students' computing skills were investigated in a blended computing course. The schedule of the course is illustrated in Fig. 2.

3.3.1 Intervention concerning ERL

In the ERL&CT (C1) and ERL (C3) groups, students received extra requirements for regular learning. They had to implement self-regulation strategies to develop regular learning habits. At the beginning of the course, students from the ERL&CT group received additional instruction in SRL strategies [81]. A lecture on how to manage study time and self-regulate learning was delivered to students in the second week of the semester. In addition to receiving this instruction, students in the ERL&CT group had access to a human tutor who scaffolded students' SRL by prompting participants to: (1) activate their prior knowledge, (2) create plans and goals for their learning and to monitor the progress they were making toward the goals, and (3) deploy several key SRL strategies, including summarizing, coordination of informational sources, and drawing [78].

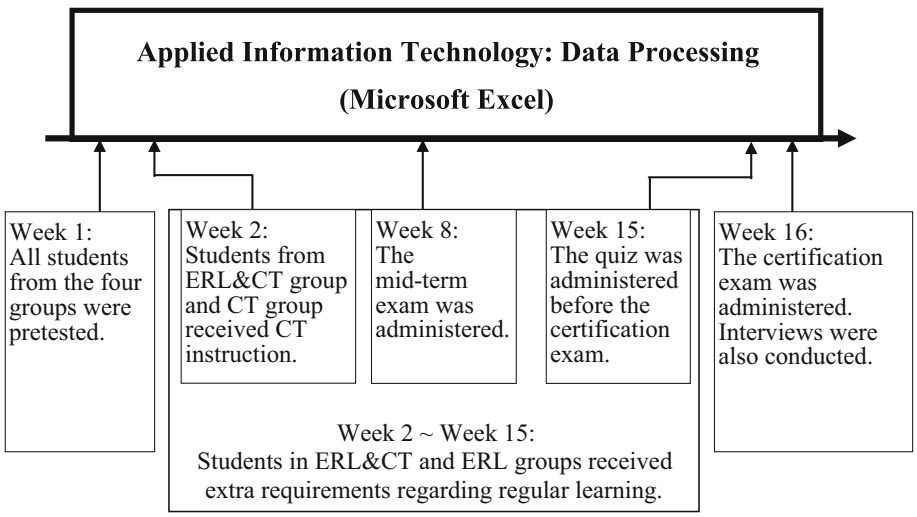

Fig. 2 The schedule of the course and certification examinations during the semester

A tutoring script for the human tutor was designed and followed, based on the human tutoring literature [6, 17, 24] and recent empirical findings on online SRL [3, 65, 68, 69]. That is, the tutor used the following script proposed by Azevedo et al. [6] to help students in regulating their learning:

1. Ask the student what he or she already knows about Microsoft Excel to set some goals for the student and to determine how much time to spend on each goal;
2. Suggest that the student reads the introduction section and learns basic skills of Microsoft Excel; ask questions to make sure of student's understanding of the skills; determine that the student understands the purpose of functions;
3. Revisit and reconsider the whole learning goal, give time reminder from the course website, indicate which goals have been met and which still need to be satisfied;
4. Suggest that the student reads text and online materials for Microsoft Excel; prompt student to summarize content and practice the skills. Measure student's understanding. If the student did not understand, then have the student re-read the introduction and practice major functions of Excel, and then measure understanding again [repeat (4)];
5. Revisit and reconsider the whole learning goal, give time reminder from the course Web site, indicate which goals have been met and which still need to be satisfied;
6. Activate student's prior knowledge about using the sub-functions of Microsoft Excel. Prompt the student to learn advanced computing skills and formulas in Excel; prompt the student to summarize, and take notes. Measure student's understanding. If the student did not understand, then have him/her re-read the related chapters and online materials, and then measure understanding again [repeat (6)]. If the student demonstrates understanding, then proceed to (7);
7. Assess progress toward whole learning goal, give time reminder from the course Web site, and ask the student to spend the remaining time reviewing notes and practicing for the certification examination.

3.3.2 Intervention concerning CT

Integrating CT with science in a manner that supports the development of students' scientific expertise requires the design of coherent curricula in which CT, programming, and modeling are interwoven with learning in the specific domains [58]. Computing education requires more thinking about, not only the using of, application software [14]. As CT draws upon concepts that are fundamental to computing and CS, it also includes practices such as problem representation, abstraction, decomposition, simulation, verification, and prediction [58].

The instructor in this study created interesting and challenging simulated problem situations for students in the ERL&CT (C1) and CT (C2) groups. At the beginning of each class period, the instructor first led students in a 10-min warm-up activity to review the computing skills they had worked on the previous week, then introduced new material and illustrated the procedures and functions of Microsoft Excel. The instructor carefully illustrated and explained the functions and formulas used for problem solving in Excel. After that, students were told about the situations and related problems that they had to deal with.

The researchers in this study adopted the processes of CT suggested by Yeh et al. [80]. That is, 1 week after the spreadsheet section of the class was completed, students were required to use Microsoft Excel to solve simulated problems of the three categories in an hour session. Questions of different categories were on separate spreadsheets, and the students were instructed not to switch to the next spreadsheet until they solved all the problems on one sheet. The CT categories and processes are described below:

1. *Recall* Students from the ERL&CT (C1) and CT (C2) groups were required to illustrate the purpose of a function or formula. They entered an open-ended description in a cell on the spreadsheet;
2. *Application* Students from the ERL&CT (C1) and CT (C2) groups had to use data and functions to find or analyze for a correct answer. They were cued by what data were available and which function they could use to analyze the data;
3. *Problem solving* Students from the ERL&CT (C1) and CT (C2) groups were required to choose formulas or functions to solve problems. In this category, there was no cue with regard to which formula or function should be used for students.

3.4 Evaluation

To avoid the potential threat from students' initial differences that might cause bias in the evaluation of students' development of computing skills using Microsoft Excel, the researchers first checked this before the start of the experiment. That is, in the first week of the semester, students from the four groups were asked if they had been taught or used Excel before taking this course. It was found that 21 students had been taught Excel. As their previous learning experience of Microsoft Excel might affect the measurement in this study, they were excluded from the

experimental sample in this study, though they still remained in this course.

Teaching in this computing course usually focuses on helping students to pass certification examinations [59]. All students were required to take an examination for a certificate in Microsoft Excel. The examination was conducted in the final week of the semester by a trustworthy, well-known organization in Taiwan, namely 'Computer Skills Foundation.' The examination comprises three main problems, each consisting of 7–9 sub-problems. A student's score comes from her/his correctness and completeness of problem solving. Students have 40 min to complete the exam. A student can earn the certification for Microsoft Excel if his/her score is higher than 70. The examination scores to test the potential effects of online ERL and CT on improving students' computing skills in using Microsoft Excel.

4 Results

4.1 The effects of ERL

In this study, the independent samples *t* test was applied to compare students' computing skills between different groups. The independent samples *t* test is used for analyzing quantitative continuous data (e.g., grades) [48, 67]. In the tests, a *p* value of <0.05 was considered significant. To explore the effect of ERL, the independent samples *t* test was applied to compare students' computing skills using Excel between different groups who adopted ERL (students in C1 and C3) and those did not adopt ERL (students in C2 and C4).

The results in Table 1 show a significant difference in the scores of students' computing skills in the ERL (88.5670) compared with those in the non-ERL group (81.9000). Thus, H1 was supported, and it is believed that the intervention of online ERL can effectively develop students' computing skills for using Excel.

4.2 The effects of CT

With regard to the effects of online CT, the authors tested the difference of students' computing skills for using Excel between different groups who used CT (students in C1 and C2) and those who did not use CT (students in C3 and C4) via the independent samples *t* test. According to the data presented in Table 2, students' computing skills in the CT group (88.7273) were significantly higher than those in the non-CT group (81.5682). Therefore, H2 was also supported, and it can be argued that the online CT could lead to students' development of computing skills for using Excel.

4.3 The combined effects of ERL and CT

The authors further investigated the effects of online ERL and CT on improving students' computing skills. The results in Table 3 show that computing skills in the ERL&CT group (92.3200) were significantly higher in contrast to that of the control group (78.1220). Accordingly, H3 was supported, and it can be argued that the combined effects of online ERL and CT on students' computing skills are positive as their performance is higher than those without.

Table 1 Comparison of scores: ERL group (C1 and C3) and non-ERL group (C2 and C4)

Group	*n*	Mean score	SD	*F*	*t* value	*df*	*p*
ERL group	97	88.5670	20.08156	4.901	2.041	185	0.043*
Non-ERL group	90	81.9000	24.49721				

* $p < 0.05$

Table 2 Comparison of scores: CT group (C1 and C2) and non-CT group (C3 and C4)

Group	*n*	Mean score	SD	*F*	*t* value	*df*	*p*
CT group	99	88.7273	16.84008	12.296	2.193	185	0.030*
Non-CT group	88	81.5682	27.12669				

* $p < 0.05$

Table 3 Comparison of scores: ERL&CT group (C1) and control group (C4)

Group	*n*	Mean score	SD	*F*	*t* value	*df*	*p*
ERL&CT group	50	92.3200	14.34621	17.239	2.964	89	0.004**
Control group	41	78.1220	29.97182				

** $p < 0.01$

5 Discussion and implications

As the technology advances, there are many advantages of applying Internet-based materials for professional development because of the rapid update, richness of information, interactivity and easy transfer of information characterizing this technology [1, 2]. In this study, the researchers applied online ERL and CT to improve students' computing skills in a blended computing course. Based on the design of online teaching methods and the research results, it is argued that this study may contribute to the field of online learning in the following three ways. Firstly, this study specified how online instructors can develop students' regular learning habits via the adoption of ERL and further improve learning performance in an online or blended course. Secondly, this study and design of online CT may provide a reference for computing courses instructors to improve their students' computing skills by using CT instructional strategies in a blended course. Finally, this is one of the first attempts to investigate the effects of the various combinations of ERL, CT and online learning in computing courses.

5.1 The effect of online ERL

With the development of Internet and educational technologies, teachers expect that students can have better learning performance in online learning environments. However, it is indicated that online learning environments may not meet the original purpose of providing students with a tool to support their learning process, and achieve better learning effects [62, 72]. In order to help students learn in the online environment teaming with free entertainment, online ERL was adopted to help students regulate themselves and further improve their computing skills. The data in Table 1 indicate the statistically significant difference of students' computing skills between the ERL group (C1 and C3, mean = 88.5670) and the non-ERL group (C2 and C4, mean = 81.9000) ($p = 0.043$). Therefore, it is believed that the intervention of online ERL may result in better development of computing skills.

Indicated by social constructivist theories of education, modern environments include capabilities for teacher–student and student–student, synchronous and asynchronous communication and interaction [39]. The authors in this study integrated online ERL with educational and communicational technologies to improve teachers' interaction with students, help students develop regular learning habits and achieve the set learning goals. The adoption and intervention of online ERL was found effective in developing students' computing skills. The findings regarding online ERL were similar to those in Azevedo et al.'s [6], Gašević et al.'s [23], and Kauffman et al.'s [35] research. In this regard, it is suggested that teachers could extend SRL to ERL when implementing online education for their students.

5.2 The effect of online CT

CT consists of a broad and somewhat debated range of analytic and problem-solving skills, dispositions, habits, and approaches used in computing courses [8, 9]; International Society for Technology Education and The Computer Science Teachers Association, [27, 41]. In this study, CT was adopted in a blended computing course, and its significant positive effect on improving students' computing skills in using Excel was illustrated. According to the data presented in Table 2, a significant difference of students' computing skills exists between the CT group (C1 and C2, mean = 88.7273) and the non-CT group (C3 and C4, mean = 81.5682) ($p = 0.030$). That is, the intervention of online CT may lead to comparatively better development of students' computing skills.

These findings are aligned with those in the studies of Curzon et al. [21] and Sengupta et al. [58], and suggest that students should adopt CT to develop understanding or solve problems. Moreover, it is further suggested that teachers should consider both integrated and discrete methods of pedagogy and how these fit within their core curriculum and computing education goals [28].

5.3 Related studies

As mentioned in Introduction, the course presented in this work was redesigned based on reflections from four previous teaching iterations [64, 65, 68, 73]. The first of these works reveals that students who received online collaborative learning with initiation attain higher grades than those without [64]. The second indicates that students in the group of SRL and blended learning with five online classes have the highest grades for using database management systems, and have positive thoughts regarding the interventions of SRL and blended learning [73]. In the third work, it is reported that students who receive web-enabled problem-based learning (PBL) and SRL have significantly better long-term computing skills than those who receive traditional didactic lectures [68]. The fourth work describes that students who receive online collaborative learning with initiation and SRL with feedback have the best grades for their computing skills [65].

When each iteration of the courses was completed, the researchers discussed, reflected on, and refined the interventions of online teaching methods for the next experiment. Based on reflections from the four previous studies, the authors of the study presented in this paper designed an appropriate online computing course, extended SRL to ERL to develop students' regular learning habits, and adopted CT to help students learn in the problem-solving processes. In the present study, positive effects from interventions of ERL and CT were found in developing students' computing skills using Microsoft Excel.

5.4 Potential problems and limitations of this study

In this research, there may be a few potential limitations in drawing firm conclusions due to threats to validity arising from the nature of quasi-experimental design. Though the researchers checked students' computing skills and removed those who had learned Excel from the experiment, there may still exist a problem with the quasi-experimental design. For instance, students' personal characteristics and readiness for e-learning in the four groups may not necessarily have been the same when they entered the computing course, thus causing bias of measurement. The domain knowledge of the study participants may also affect the reliability of the results. Therefore, the potential individual differences and factors of quasi-experimental design mentioned above may threaten the validity of this study. Online educators and researchers who apply ERL and CT should be aware of these contextual factors and factors of quasi-experimental design that may threaten the effects of online ERL and CT claimed in this research.

6 Conclusion

Though many innovations and applications of Internet technologies have been suggested in online higher education, very little original research investigating the impact of online learning environments on students' learning processes and performance can be found [38]. Universities offering online courses are putting many efforts into ensuring that online students are as satisfied as those attending traditional courses in classrooms [40]. Thus, ERL and CT were adopted and integrated and their effects on improving students' learning in a blended computing course were explored.

The results of this study illustrate that students who receive and adopt online ERL have statistically better development of computing skills than those without. In addition, it can be argued that students who receive the intervention of online CT can develop significantly better computing skills in using Excel than those without. Moreover, the authors also investigated the combined effects of ERL and CT and found that students who simultaneously receive interventions of ERL and CT have significantly better computing skills that those receiving traditional teaching method in the blended learning environment. Therefore, it is suggested that computing teachers could adopt ERL to develop students' regular learning behavior, and use CT to improve students' practical problem-solving skills. Finally, the authors expect that the design of an online course with ERL and CT could provide references and insights for schools and teachers when conducting online or blended courses for their students, particularly for computing courses.

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