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LONG PAPER

# Applying Online Content-Based Knowledge Awareness and Team Learning to Develop Students' Programming Skills, Reduce their Anxiety, and Regulate Cognitive Load in a Cloud Classroom

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## Abstract

As Information and Communication Technology (ICT) infrastructure has rapidly become commonplace in most countries worldwide, the development of ICT-related competence is now considered to be a key goal in Taiwan's curriculum. Nowadays, society expects undergraduates to develop essential computer abilities before entering the workplace. In addition to possessing computing skills, students are also required to have problem-solving ability and teamwork competency. To equip students to meet these expectations, the researchers integrated two teaching approaches, using content-based knowledge awareness (CoKA) and team learning (TL) to enhance students' programming skills in an online computing course, and to reduce students' anxiety and regulate cognitive load in the cloud classroom involved in this study. In this research, the authors conducted a quasi-experiment to examine the influences of CoKA and TL. Therefore, the design for the experiment was a 2 (CoKA vs. non-CoKA) × 2 (TL vs. non-TL) factorial pretest/posttest design. There were 184 participants, who were neither information nor computer majors, from four classes, enrolled in a required course titled 'Programming Design'. The first class (G1) simultaneously received the online CoKA and TL intervention, the second class (G2) received only the online CoKA intervention, and the third class (G3) received only the online TL intervention; these served as the experimental groups, while the last class (G4), which received a traditional teaching approach, served as the control group. According to the results, students who received online TL had significant increase in their computing skills, and significant decrease in their level of anxiety and cognitive load. However, the expected effects of CoKA on developing students' skills in designing mobile applications, reducing anxiety level and regulating cognitive load were not found. The design of integrating CoKA and TL in an online course could be a reference for educators when conducting online, flipped, or blended courses, particularly for those focusing on developing skills in computer programming.


**Keywords** Online content-based knowledge awareness · Online team learning · Cloud classroom · Programming course · Programming skills

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## 1 Introduction

Recently, research reports that college enrollments in the USA have been declining, while the enrollments in online programs and courses have been increasing [46, 70]. Online learning revolutionizes how people learn due to its attributes of availability regardless of time and place, easy access through the Internet, and freedom for learners to choose contents and pace in learning [15]. The use of technologies has changed students' expectations, stimulated their thinking and re-engineered approaches to teaching and learning [26]. However, as each student has their own individual characteristics, they behave differently in learning [33, 97]. In order to use technology successfully and effectively in one's teaching approach, teachers need to be able to 'fit' pedagogy, content and technology together [40].

With the recent advancements in computer applications and Internet technologies, students have to learn different kinds of programming languages so that they can deal with problems encountered [10, 16]. However, many undergraduate students are unsuccessful in these important programming courses [66], feeling anxious and struggling with cognitive load while learning programming [75]. Feeling such high anxiety may hinder students' learning performance [11]. Thus, the researchers attempted to adopt and integrate innovative learning strategies to facilitate students in building their programming skills, while aiding them to counteract their anxiety and regulate cognitive load.

In this study, the researchers designed an online computing course according to students' needs for programming skills and to help them develop essential computer competence before entering the workforce. Moreover, the researchers also considered and reflected on their previous studies in order to apply appropriate teaching approaches for students.

### 1.1 Adoption of content-based knowledge awareness

Computer science is a distinctive subject in the school curriculum, with its own curriculum documents defining the skills students will learn and the knowledge they will acquire by studying this subject [35]. Different from some other courses, a computer course requires a more comprehensive approach to design and develop the course modules, and each course module is comprised of multiple learning components [2, 92, 107]. However, computing education in Taiwan may not be as practical as educators might expect [102]. It is also revealed that just because students understand how to operate software does not necessarily mean that they can apply it in correspondence with practical situations [42]. Educators have also indicated that if a computer course merely repeats operations without nurturing students' ability in deciphering problems, this may result in poor problem-solving capability after joining the workforce [120]. Hence, gaining knowledge and obtaining available information, plus developing the competence to utilize software in solving problems are all important for students [9], so teachers have to provide learners with higher-order thinking learning activities [42].

To provide effective teaching in a computing course and improve students' computing skills in programming, content-based knowledge awareness (CoKA) may be one of the potential approaches. CoKA is a paradigm that leads to the team members themselves generating the to-be-exchanged representations of learners' task-relevant knowledge content and information structures [31, 51, 52]. It is found that students' collaboration through structuring and improving interaction within CoKA teams leads to better results than for those who did not participate in CoKA teams [31],this interaction also directly promotes collaborative learning outcomes [28, 52]. Moreover, it is revealed that online learning technologies and environments are becoming of great interest as a result of improvements in learning management systems and are often applied for developing students' programming skills [14]. Thus, the researchers adopted CoKA in an online computing course to develop students' programming skills, relieve their anxiety and regulate cognitive load in a cloud classroom.

### 1.2 The need for team learning

Over the years, it is increasingly expected that students should not just reproduce the learned discipline-specific skills and knowledge that form the core of college courses [3, 76]. Concurrently, employers have expressed issues such as the absence of fundamental employability skills and teamwork abilities in undergraduates [39]. As we know, interaction, such as in teamwork, is an important factor for learning. Some research results indicate that successful learning is determined by learners' participation, engagement, and social interaction [59].

Nevertheless, the deployment of information technology in schools has faced many barriers [18]. Students in an online learning environment, especially in a computing course, may feel isolated [99]. In addition, it is mentioned that teamwork competency is one of the critical factors to success for career programmers [73], as well as the norm for the development of many information systems projects [112]. For example, in McLoughlin's (2002) study, both programming skills and teamwork competency are regarded as learning outcomes. In order to enhance students' interactions and develop their teamwork abilities, team learning (TL) was adopted and its effects on students' learning were explored in this research. TL plays an important role as an essential component of students' learning [77]. One learning team can persistently enhance other learning teams through instilling knowledge, information and skills [82]. TL has now become one of the important topics in extant literature, which highlights its significance in enhancing learning performance, gaining knowledge, and sustaining students' competitive advantage [5, 27, 41, 57]. When learners participate in a team, they can assess and reflect on previous participation experiences and explain the outcomes through discussion with team members [77]. However, there is little documented about adopting TL in the education domain [5], particularly for computing education. Thus, the researchers in this study adopted TL to develop students' programming skills, reduce anxiety and regulate cognitive load in a cloud classroom.

Learning programming is a task with a high level of cognitive load, as students have to practice repeatedly, and study hard to acquire great programming skills [62, 110]. When designing programming education, it is necessary to take cognitive load into account [61]. Providing support to students is one way to promote their participation rate and relieve cognitive load [119]. Students' cognitive load can be considered as a key factor affecting their programming performance [110]. Modifying the learning material may alleviate both pressure and anxiety [75]. In this regard, the authors integrated CoKA and TL with educational technologies to ease students' anxiety and regulate cognitive load as they develop their programming skills.

## 2 Literature review

### 2.1 Content-based knowledge awareness

The use of CoKA in modern online education is highly emphasized [50]. CoKA is derived from the literature based on common mental models, shared ground, and transactive memory systems [19]. It is also called Knowledge and Information Awareness paradigm [29], and focuses on the presentation of content that is easily extractable and helpful for efficient group performance [28]. CoKA has been established as a positive teaching approach that can be adopted to improve knowledge exchange for learning tasks to be accomplished and as the underlying construct of new knowledge [51]. Collaborators can grasp the knowledge held by each teammate and easily explore possible links between learners' respective pieces of knowledge [52].

In the computer science domain, knowledge awareness is regarded as applied information about activities related to learning resources, and can serve as individually-held background information which facilitates team members to coordinate a collaborative task [28]. The presence of CoKA in a learning environment may moderate the effects of different knowledge distributions, especially in online learning teams, because there are few other ways to estimate teammates' knowledge [52]. When in the CoKA paradigm, each team member in transient online collaboration teams submits a (visual) depiction of the entirety of the task-relevant knowledge content that they had at the time of initial collaboration [51]. Moreover, CoKA also deals with the issues inherent in direct group interactions and computer-mediated tasks [31]. Students who receive CoKA can immediately observe the distribution of knowledge within the team and sense its symmetry or asymmetry [52]. That is, from the outset of the collaboration each individual teammate can perceive the knowledge awareness that is provided by each of the other teammates [51].

According to past studies, the advantages of CoKA are that it could improve students' learning performance in the designated learning tasks [29], as well as promote them to share, and interact cognitively over the particular information [30]. As for the effects of CoKA on students' learning performance, it is revealed that participants in CoKA teams outperform those who have access to the whole of the team's knowledge [51]. When collaborating through CoKA, students are more effective at solving their learning tasks, understanding the teaching materials, and are able to remind one another which teammate holds which piece of knowledge [29, 51, 80]. Therefore, CoKA was implemented in our re-designed computing course in a cloud classroom, and this research examined its effects on enhancing students' learning.

### 2.2 Team learning

In higher education, unlike under other contexts, teams work in a different fashion; for instance, academic teams are formed internally in, or external to, the specific context [5]. The definition of TL is a process of aligning and developing the capacity of a team to achieve the goals that members share [82], and TL can improve their operating efficiency, or alter their decisions and performances [5]. It is revealed that TL is a complex social phenomenon which develops over time [56]. It is an active behavioral process of dialoging, sharing, discussion and exchange among team members [53].

Many studies indicate that TL has a beneficial influence on team adaptation and team performance by leading learners to ask questions, discuss, and seek feedback, which means team members can evaluate their assumptions about the way in which they do something, discuss divergent opinions, and then obtain better performance [25, 77, 78]. When implementing TL, the benefits of knowledge sharing provide an association of the level of the individual, where the knowledge resides, with different levels of the team, so competitive value is generated and sustained. This has been widely studied, especially in how knowledge sharing can be aided by technology [5].

Integrating online technologies with the TL approach can assist students in progressing on extensive tasks and learning together [114]. It is indicated that a context of TL can activate learners with a high individual learning orientation to exhibit more individual learning behavior [41]. In addition, Decuyper [22] categorize TL outcomes by indicating how they adapt to learning environments, create and collect new knowledge, or apply new ideas to focus on team activities, procedures and goals [106]. Students learning together in a team can perform at a level of collective intelligence that is better than any individual's. [5]. Furthermore, it is also reported that TL could be effective in reducing students' anxiety [32]. Therefore, in the present study, the researchers adopted TL to develop students' programming skills, reduce their anxiety and regulate cognitive load in the online computing course and cloud classroom used.

### 2.3 Students' programming skills

Society is becoming increasingly aware of the importance of providing computing courses through appropriate teaching methods in universities [103]. At almost each level of education in Taiwan, computing education is particularly highlighted. It is observed that even undergraduates in departments of Applied English or Law have to take several compulsory computing courses before graduation [17, 98].

Computer programming is regarded as a critical competence for the development of problem-solving skills [45]. As a professional subject, computer programming integrates problem-solving strategies with programming logic activities, and poses challenges for students [110]. Programming skills are regarded as an integral part of computational thinking [23, 58], and can find their way into the frameworks of digital literacy [79, 83]. Some programming languages may require users or learners to write code correctly and grammatically according to exact rules [10]. Thus, the researchers regarded students' programming skills as their ability to develop a complete mobile application with purposive functions, in which the programming is written correctly and grammatically. Based on this, the outcomes of online CoKA and TL on developing students' programming skills were examined.

### 2.4 Anxiety

Anxiety is defined as a feeling of worry, fear, and tension or uncomfortable awareness that something undesirable is about to occur [36, 60, 89]. Anxiety is a part of educational settings, especially when learner's performance or competence is evaluated [72]. When students perceive that their cognitive or learning motivation is overwhelmed by the demanding academic situation, anxiety symptoms appear [37, 71, 84].

Previous studies have revealed that a proper level of anxiety can facilitate student learning; however, an anxiety overload can lead to negative effects [90, 91, 108]. Many previous studies and education theories have been devoted to exploring the negative relationship between learner anxiety and learning performance [7, 65, 81, 116]. Furthermore, it is reported that the higher anxiety students feel, the more their learning performance in computer programming design courses may be hindered [11]. In this regard, the researchers adopted CoKA and TL to help reduce students' anxiety while they develop their programming skills in a cloud classroom.

### 2.5 Cognitive load

Cognitive Load Theory (CLT) was initially developed during the 1980s [93], and it comprises diverse constructs that stand for the load on the specific learner's cognitive system that performing a specific task elicits [68]. From the perspective of cognitive theories, cognitive load has been recognized as an important factor in successful and efficient learning [49]. Cognitive load affects the understanding of expertise development and education, so many researchers are dedicated to exploring this issue [95].

Nevertheless, high cognitive load commonly results in adverse effect on learning [69]. Furthermore, extraneous cognitive load can negatively affect cognitive processes that lead to learning in e-learning environments [55]. It is also pointed out that an increase in cognitive load results in a negative effect on perceived efficiency [20]. When novice learners participate in a computer programming course, they may experience cognitive load at varying levels of magnitude that, at some point, may negatively affect the online learner's performance and ability to learn programming concepts and theories [87]. Therefore, the researchers integrated CoKA and TL in a computing course to help students counteract heavy cognitive load in a cloud classroom.

## 3 Empirical study

### 3.1 Course setting

Curriculum design is interwoven with pedagogy [35]. The course involved in this study was a semester-long, two-credit-hour course titled 'Programming Design', addressed to first-year undergraduates at a comprehensive university in Taiwan. This course focused on developing students' skills of designing mobile applications with App Inventor. At the introductory stage, the teacher acquainted students with the syntaxes and basic functions of App Inventor. Then, the teacher applied the approach of CoKA described in subsection '3.3.1. Intervention of content-based knowledge awareness', as well as the strategies of TL introduced in subsection '3.3.2. Intervention of team learning' for the experimental groups. Beginning in the 16th week of the semester, students started to present their mobile applications.

## 3.2 Participants

The participants were 184 undergraduates from non-information, non-computer departments taking a required course titled 'Programming Design' for two hours a week. The mean age of participants was 18.63 years old. The gender breakdown was 77 males and 107 females. All contents of the four classes involved were administered by the same teacher. The experimental design of the four groups, the CoKA and TL class (G1, $n=53$), the CoKA and non-TL class (G2, $n=40$), the non-CoKA and TL class (G3, $n=41$), and the non-CoKA and non-TL class (G4, control group, $n=50$) is shown in Fig. 1.

Before the online computing course began, the teacher declared that this course would be provided through both the Internet and the classroom, and all students in the four class cohorts (groups) would receive teacher's interventions of a different combination of teaching methods in an experiment. Moreover, it was also announced by the teacher that participants in the four classes had the freedom and right to drop and select another teacher's course if they did not want to be part of this experiment.

## 3.3 Experimental design and procedure

The experimental design was a 2 (CoKA vs. non-CoKA) × 2 (TL vs. non-TL) factorial pretest/posttest quasi-experiment. As the involved course in this research is a compulsory one, participants studied with their original class cohorts. The teacher could not randomly assign students to groups. Although the teacher conducted pretests of students' programming skills, anxiety, and cognitive load before the experiment began, the pretest performances were not considered in grouping students. The researchers selected three of the classes as the experimental groups, while the fourth class served as the control group. The first class (G1) that simultaneously received the intervention of online CoKA and TL, the second class (G2) that received the intervention of online CoKA only, and the third class (G3) that received the intervention of online TL only, were the experimental groups, while the non-CoKA and non-TL group (G4), that

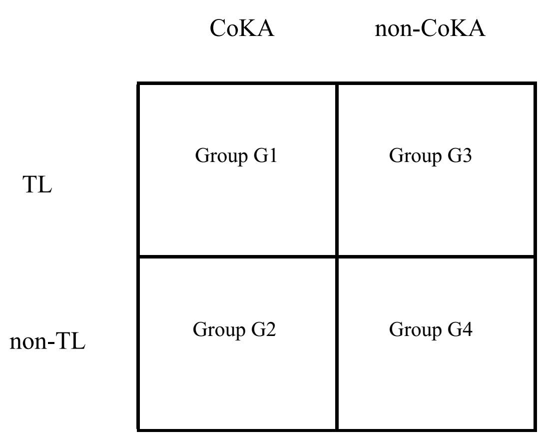


**Fig. 1** Experimental design of the study

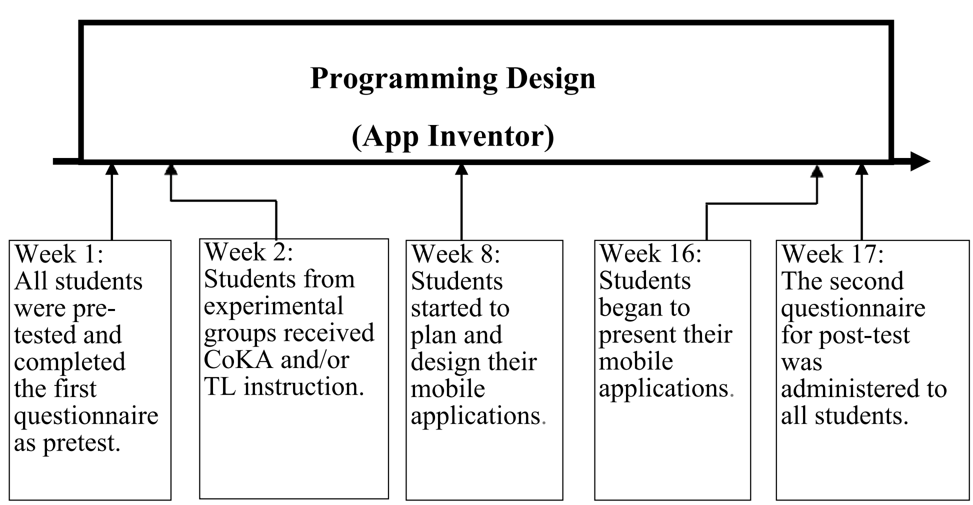


**Fig. 2** Schedule of the course and measurements during the semester

served as the control group, received traditional teaching. The course schedule is illustrated in Fig. 2.

#### 3.3.1 Intervention of content-based knowledge awareness

A growing amount of research shows that CoKA is a significant determinant of learning [51]. Digital concept maps have been frequently used to foster CoKA [29, 52, 64]. After learners get familiar with the assigned concept map, each member becomes an expert on their respective part of the team's knowledge; then members are instructed to contribute their knowledge so that a problem can be solved collaboratively [31]. Therefore, students should be given a concept map standing for their fractional knowledge on the specified topic, which means they have to combine their own concept maps with those of their partners, and then solve the designated learning tasks [51].

To conduct CoKA in G1 and G2, the researchers divided students into teams, where each team had four to six members. Computer-supported students were asked to solve problems using an online system so that they could use the system or an online chat app (e.g., LINE, WeChat, or Skype) for fostering knowledge and information awareness [29, 80]. The researchers and teacher in this study adopted and followed the suggestions by Engelmann et al. [31] in developing a CoKA environment. More specifically, the CoKA environment in this study was carried out in the following ways:

1. At the beginning of the course, the teacher presented the syntaxes and basic functions of App Inventor, and informed students about the types of tasks they were about to learn;
2. Students were divided into teams, and were given insight into the entirety of other members' task-related knowledge content at the outset of their collaboration;
3. The teacher followed the syllabus to teach, and a concept map depicting a part of their team's knowledge was shown to each student;
4. After recognizing the assigned concept map, students became experts on their respective parts of the team's knowledge; team members were asked to combine their knowledge with that of others to solve the learning problems;
5. During this course, all students were required to discuss the task types and share how to solve these learning tasks with their team members by using Moodle discussion forum or by teams in an online chat app (e.g., LINE).

#### 3.3.2 Intervention of team learning

When adopting the TL approach, teachers can monitor, provide guidance, and evaluate teams while members work jointly with each other to finish the learning tasks via online tools in an extramural setting [105]. For the implementation of TL in this study, students from G1 and G3 were encouraged to share and exchange information, explore different perspectives, and then integrate the new findings with previous information and proactively form new strategies to eliminate the obstacles [77]. Moreover, as mutual understanding about the temporal aspects of work is an essential element to facilitate the TL process [77], students were expected to meet certain deadlines.

In this study, the researchers randomly divided students from G1 and G3 into teams. As it is suggested that setting deadlines is crucial for team members to plan and make sure that teams are capable of accomplishing the tasks assigned [77], the researchers asked each team to set up a timeline to finish each assignment. In addition, the following six processes were incorporated when implementing TL (Decuyper, Dochy & Van den Bossche, 2010; [106]:

1. Sharing: Students from different backgrounds have varied knowledge and skill domains. That is, students were encouraged to share their ideas and thoughts, so that team members could deliver their opinions to each other;
2. Co-construction: Students were asked to interact with team member, and then engage in recurring cycles of acknowledging, repeating, illustrating, questioning, converging, and achieving shared knowledge, abilities, strategies or creative thoughts;
3. Constructive conflict: This could be regarded as a negotiation or dialogue because students may have different perspectives or debate that can facilitate them to communicate and discuss;
4. Team reflexivity: During the TL approach, the instructor needed to develop a planning table to understand members' learning processes;
5. Storage: The ideas and plans members proposed were saved in the software and/or the hardware, or shared forum of the Web site and cloud classroom of the team;
6. Retrieval: Members could retrieve information and save for future use or later inspection.

#### 3.3.3 Intervention for control group (G4)

In this research, students in the control group also received the same learning materials, class hours, practice time, and assignments as those in G1, G2, and G3, however, without the interventions of CoKA or TL. The teaching in control group featured traditional lectures on basic syntaxes of App Inventor, and required students to complete the applications with expected functions. Students in the control group had neither to implement CoKA nor adopt the six processes of TL.

## 3.4 Measurement

### 3.4.1 Pretests of students' computing skills, anxiety, and cognitive load

**3.4.1.1 Programming skills** In this programming course, the researchers took students' learned programming skills as their learning performance. To test whether the intervention was effective or not, the researchers checked whether students had ever learned how to write computer program code or had the experience of programming before they entered this course. This aimed to reduce the potential threat of students' initial differences that may undermine measurement. Hence, in the first week of the semester, students from all four groups were asked to complete two simple mobile applications as a pretest. The pretest questions of programming skills were chosen from an examination that is administered by the Computer Skills Foundation, and mainly tested if students in the four groups had similar levels of programming skills before they received the intervention of CoKA or TL.

**3.4.1.2 Anxiety** All students were asked to complete a questionnaire as a pretest in the first week of the semester to comprehend their anxiety. The State Trait Anxiety Inventory (STAI), developed by Spielberger [86], contains 20 items for assessing state anxiety (STAI-S) and 20 for trait anxiety (STAI-T). STAI-S measures how the person feels at that moment, and STAI-T measures how the person generally feels. The researchers used STAI scale to explore how students' felt prior to the learning process. The participants were asked to score items using a 4-point response scale (1 = strongly disagree, 4 = strongly agree). A total score was calculated by summing up the value for each statement and calculating the arithmetic mean. On this scale, a higher score means a higher state of anxiety.

**3.4.1.3 Cognitive load** The measurement of students' cognitive load in the pretest could confirm if students have similar levels of cognitive load in this computing course before the experiment began. In the context of this study, the cognitive load questionnaire developed by Hwang, Yang and Wang [43] was adopted, which was based on the measures of Paas [67] and Sweller, van Merriënboer, and Paas [94]. The questionnaire consists of eight items with a six-point Likert rating scheme, which can be divided into two parts, with five items for "mental load" (ML) and three items for "mental effort" (ME). All participants in this study were required to complete this pretest of cognitive load.

After the pretests were completed, the authors tested if differences exist of students' anxiety (STAI-S & STAI-T), and cognitive load (ML + ME) among G1, G2, G3 and G4. Based on a one-way ANOVA of pretest results, the differences of students' anxiety and cognitive load among G1, G2, G3 and G4 are not statistically significant. Furthermore, based on checking which students had previous learning experience in designing mobile applications, students who were already acquainted with mobile application design software were excluded from the experimental sample, although they still remained in this course. Based on the pretest analysis and teacher's confirmation, the authors in confirmed that the participants had similar levels of regarding anxiety, cognitive load, and computing skills in designing mobile applications when the study was initiated. Therefore, the hidden concerns of initial variance among students are minimized.

### 3.4.2 Posttests of students' programming skills, anxiety, and cognitive load

**3.4.2.1 Programming skills** In the 16th week of the semester, students began to present the mobile applications they designed. The teacher mainly graded according to Mobile App Rating Scale (MARS), which is an unbiased and dependable rubric for evaluating the quality of mobile applications, developed by Stoyanov et al. [88]. The criteria include the functionality, aesthetics, information quality, engagement, and subjective quality. The more functional and complete mobile applications were, the higher the scores students got. That is, students could receive high scores if their designed mobile application fit the definition of quality mobile applications well. The teacher reviewed and commented on both students' presentations and the mobile applications they designed. The teacher graded students' performances on oral presentations and system demonstration according to the rubric mentioned above. Students on the same team received the same grade from the rubric. However, their individual grades may have varied according to the quality of her/his presentation and the ability to improvise when asked questions or challenged.

**3.4.2.2 Anxiety** All students were required to complete the STAI questionnaire twice for evaluating their anxiety. As mentioned, the first administration was in the first week as the pretest, and the second was in the seventeenth week for the posttest. After the posttest, the difference of students' anxiety among the four groups was analyzed. Moreover, the change in students' anxiety from start to finish of the semester was also analyzed.

Cronbach $\alpha$ test was used to check if the items are correlated with each other. The results displayed good internal consistency with Cronbach's $\alpha = 0.944$ in STAI-S and $\alpha = 0.914$ in STAI-T; therefore, the researchers could be sure that items have shared covariance and probably measure the same underlying concept.

**3.4.2.3 Cognitive load** The students completed the cognitive load questionnaire developed by Hwang, Yang and Wang [43] in the seventeenth week for the posttest. The difference of students' cognitive load in this programming course and cloud classroom among the four groups was analyzed. Furthermore, the change in students' cognitive load from the beginning to the end of the semester was also investigated and reported.

For the overall reliability, Cronbach α test was also adopted in this section. The results reveal that Cronbach's $\alpha = 0.970$ in cognitive load, meaning the items have shared covariance ($\alpha > 0.8$); therefore, measurement can be considered reliable.

### 3.5 Cloud classroom used

In this study, the researchers and teacher provided a cloud classroom for students' learning. In addition to the course Web site (Moodle), students could also log on to the cloud classroom developed by the university to use the learning material or software they need. Personal computer, tablet PC, or WebPad can be used to access this feature and students could practice the learned programming skills after class. They could also use the necessary software and materials in this cloud classroom if they did not own their own copies (see Fig. 3).

## 4 Results

### 4.1 Effects of online content-based knowledge awareness

The independent samples $t$-test was used in this study to analyze and compare students' computing skills (grades), anxiety (STAI-S & STAI-T), and cognitive load (ML + ME) between CoKA group (G1 and G2) and non-CoKA group (G3 and G4) in a mobile application designing course. The results in Table 1 indicate no significant difference ($p = 0.061 > 0.05$) in grades of CoKA students' computing skills for designing mobile application (81.58) compared with those in non-CoKA group (78.95). That is, the intervention of online CoKA did not contribute to students' development of computing skills for designing a mobile application. As the posttest results of anxiety and cognitive load were also not significant ($p > 0.05$), the expected effects of CoKA on improving students' programming skills, reducing their anxiety, and regulating cognitive load were not found in this study.

### 4.2 Effects of online team learning

As for the TL group (G1 and G3) and non-TL group (G2 and G4), the results of independent $t$-test are shown in Table 2. These indicate significant difference in grades of


Fig. 3 System interface of the cloud classroom

**Table 1** Comparison of computing skills (grades), anxiety (STAI-S & STAI-T), and cognitive load (ML + ME) in CoKA group (G1 & G2) and non- CoKA group (G3 & G4)

| Group | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dependent variable | CoKA | | | | non-CoKA | | | | t | df | Sig. (two-tailed) |
| | N | M | SD | SE | n | M | SD | SE | | | |
| Computing skills | 93 | 81.58 | 9.125 | 0.946 | 91 | 78.95 | 9.818 | 1.029 | 1.887 | 182 | 0.061 |
| Anxiety (STAI-S) | 93 | 1.9892 | 0.5325 | 0.0552 | 91 | 2.0538 | 0.5114 | 0.0536 | -0.839 | 182 | 0.403 |
| Anxiety (STAI-T) | 93 | 2.1328 | 0.5084 | 0.0527 | 91 | 2.2060 | 0.5007 | 0.0525 | -0.984 | 182 | 0.326 |
| Cognitive load | 93 | 3.1519 | 1.1723 | 0.1216 | 91 | 3.3324 | 1.0615 | 0.1113 | -1.094 | 182 | 0.275 |

**Table 2** Comparison of computing skills (Grades), Anxiety (STAI-S & STAI-T), and Cognitive Load (ML + ME) in TL group (G1 & G3) and non-TL group (G2 & G4)

| Group | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Dependent variable | TL | | | | non-TL | | | | t | df | Sig. (two-tailed) |
| | n | M | SD | SE | n | M | SD | SE | | | |
| Computing skills | 94 | 83.18 | 10.199 | 1.052 | 90 | 77.24 | 7.761 | 0.818 | 4.429 | 182 | 0.000 |
| Anxiety (STAI-S) | 94 | 1.9298 | 0.5602 | 0.0578 | 90 | 2.1167 | 0.4625 | 0.0487 | -0.839 | 178 | 0.014 |
| Anxiety (STAI-T) | 94 | 2.0878 | 0.5741 | 0.0592 | 90 | 2.2539 | 0.4060 | 0.0428 | -0.984 | 168 | 0.024 |
| Cognitive load | 94 | 2.9734 | 1.1598 | 0.1196 | 90 | 3.5208 | 1.0083 | 0.1063 | -1.094 | 180 | 0.001 |

TL students' computing skills for designing a mobile application (83.18) compared with those in non-TL group (77.24) ($p < 0.05$). This suggests that the implementation of online TL had positive effects on improving students' development of computing skills for designing a mobile application. The difference of anxiety and cognitive load between the TL group and non-TL group were also significant ($p < 0.05$). That is, students' adoption of online TL could be helpful to improve students' programming skills, reduce their anxiety, and regulate cognitive load in the learning process.

### 4.3 Combined effects of online content-based knowledge awareness and team learning

In order to investigate the effects of online CoKA and TL on students' learning effects, a one-way ANOVA was applied to analyze students' computing skills for designing mobile applications (grades), anxiety, and cognitive load under the four conditions (groups). The data in Table 3 reveals that learners in G1, who received the intervention of online CoKA and TL, exhibited significantly better computing skills than those of G2 (receiving CoKA & non-TL teaching methods) and G4 (receiving traditional teaching methods), with a significance of $p = 0.00032 < 0.05$ and $p = 0.00055 < 0.05$, respectively. In addition, when comparing G1 with G4, the combined effects of CoKA and TL could also be found in the cognitive load, with a significance of $p = 0.03066 < 0.05$, meaning these methods may help regulate learners' cognitive load. Thus, it is believed that the combined effects of online CoKA and TL on students' skills for designing a mobile application and cognitive load are positive, and higher than for those who received the traditional teaching method.

## 5 Discussion and implications

As the way universities prepare graduates for their future professional lives is changing, it is important to fully utilize the affordances of technology, and focus on innovative teaching methods at college level [48]. Despite the benefits of Web technologies already being confirmed [12, 13, 117], students still report being dissatisfied with their learning conditions [12, 13, 85]. Succeeding in online learning environments is dependent upon many elements [1]. Therefore, new teaching approaches, strategies in learning and innovative tools are necessary to improve the development of practical knowledge, skills and specific competencies in students [8]. This research is expected to provide insights and references for educators and designers of computing education and online pedagogy. In this regard, the researchers reflected on their previous teaching in computing courses, designed appropriate teaching methods of CoKA and TL for this course, and explored the effects of these on enhancing students' programming skills, reducing anxiety, and regulating cognitive load in this online course and cloud classroom.

**Table 3** One-way ANOVA: Posttest of students' Computing Skills, Anxiety (STAI-S & STAI-T), and Cognitive Load (ML + ME)

| Dependent variable | Group(I) | Group(J) | Mean difference (I-J)f | Std. error | Sig | F | *p* |
|---|---|---|---|---|---|---|---|
| Computing Skills | G1 | G2 | 8.34481 | 1.88251 | 0.00032 | 8.721 | 0.000 |
| | | G3 | 4.56006 | 1.86938 | 0.11809 | | |
| | | G4 | 7.58981 | 1.77198 | 0.00055 | | |
| | G2 | G1 | -8.34481 | 1.88251 | 0.00032 | | |
| | | G3 | -3.78476 | 1.99749 | 0.31248 | | |
| | | G4 | -0.75500 | 1.90665 | 0.98419 | | |
| | G3 | G1 | -4.56006 | 1.86938 | 0.11809 | | |
| | | G2 | 3.78476 | 1.99749 | 0.31248 | | |
| | | G4 | 3.02976 | 1.89368 | 0.46654 | | |
| | G4 | G1 | -7.58981 | 1.77198 | 0.00055 | | |
| | | G2 | 0.75500 | 1.90665 | 0.98419 | | |
| | | G3 | -3.02976 | 1.89368 | 0.46654 | | |
| Anxiety (STAI-S) | G1 | G2 | -0.14389 | 0.10823 | 0.62287 | 2.191 | 0.091 |
| | | G3 | -0.00557 | 0.10748 | 0.99996 | | |
| | | G4 | -0.22564 | 0.10188 | 0.18288 | | |
| | G2 | G1 | 0.14389 | 0.10823 | 0.62287 | | |
| | | G3 | 0.13832 | 0.11484 | 0.69412 | | |
| | | G4 | -0.08175 | 0.10962 | 0.90624 | | |
| | G3 | G1 | 0.00557 | 0.10748 | 0.99996 | | |
| | | G2 | -0.13832 | 0.11484 | 0.69412 | | |
| | | G4 | -0.22007 | 0.10888 | 0.25599 | | |
| | G4 | G1 | 0.22564 | 0.10188 | 0.18288 | | |
| | | G2 | 0.08175 | 0.10962 | 0.90624 | | |
| | | G3 | 0.22007 | 0.10888 | 0.25599 | | |
| Anxiety (STAI-T) | G1 | G2 | -0.08064 | 0.10461 | 0.89762 | 2.256 | 0.083 |
| | | G3 | 0.02372 | 0.10388 | 0.99687 | | |
| | | G4 | -0.21589 | 0.09847 | 0.19051 | | |
| | G2 | G1 | 0.08064 | 0.10461 | 0.89762 | | |
| | | G3 | 0.10436 | 0.11100 | 0.82924 | | |
| | | G4 | -0.13525 | 0.10595 | 0.65337 | | |
| | G3 | G1 | -0.02372 | 0.10388 | 0.99687 | | |
| | | G2 | -0.10436 | 0.11100 | 0.82924 | | |
| | | G4 | -0.23961 | 0.10523 | 0.16285 | | |
| | G4 | G1 | 0.21589 | 0.09847 | 0.19051 | | |
| | | G2 | 0.13525 | 0.10595 | 0.65337 | | |
| | | G3 | 0.23961 | 0.10523 | 0.16285 | | |
| Cognitive load (ML + ME) | G1 | G2 | -0.55601 | 0.22887 | 0.12052 | 4.026 | 0.008 |
| | | G3 | -0.13909 | 0.22727 | 0.94531 | | |
| | | G4 | -0.64976 | 0.21543 | 0.03066 | | |
| | G2 | G1 | 0.55601 | 0.22887 | 0.12052 | | |
| | | G3 | 0.41692 | 0.24284 | 0.40227 | | |
| | | G4 | -0.09375 | 0.23180 | 0.98319 | | |
| | G3 | G1 | 0.13909 | 0.22727 | 0.94531 | | |
| | | G2 | -0.41692 | 0.24284 | 0.40227 | | |
| | | G4 | -0.51067 | 0.23022 | 0.18175 | | |
| | G4 | G1 | 0.64976 | 0.21543 | 0.03066 | | |
| | | G2 | 0.09375 | 0.23180 | 0.98319 | | |
| | | G3 | 0.51067 | 0.23022 | 0.18175 | | |

### 5.1 Effects of online content-based knowledge awareness

With the rapid growth in educational technologies, pedagogical applications have gradually changed from the conventional teaching model to those executed in Web-based learning environments [96]. According to previous research [29, 52], CoKA could be more effective in online education and be more competitive than traditional learning methods. Thus, the authors were encouraged to integrate CoKA in an online computing course to boost students' learning outcome and to see if this method could ease students' anxiety and regulate cognitive load as they develop their programming skills.

However, the data in Table 1 indicates that there is no significant difference in grades, anxiety, and cognitive load between the CoKA and non-CoKA groups. Although the anticipated effects of the online CoKA method on developing students' computing skills, easing anxiety, and reducing cognitive load were not exhibited in this research, the non-significant differences and results may be due to the following potential factors. First, based on the researchers' previous teaching experiences in computing courses, other factors may include that first-year students were not fully familiar with the concept map or how to generate and share task-relevant knowledge with group members, or they lack persistence in executing those designated processes while exploring their college life outside of class. Many students who grew up with traditional didactic education in Taiwan may not accommodate themselves well to innovative teaching methods. Students who are used to didactic education could be unwilling or unable to take responsibility for their own learning [100]. The participants in this study may have faced difficulty in sharing and combining their knowledge with that of others to solve the learning problems. In the teaching in this course, it was found that some students did not adapt to CoKA and apply it well. Some of the students may have relied on their teammate(s) who have greater capacity for programming, and thus missed the opportunity to learn programming through designing mobile applications and teamwork. Second, a previous study also indicated that it is very hard to modify students' learning habits or styles with a one-semester intervention [104]. Nevertheless, if teachers could adapt CoKA for first-year students from non-computer departments for a longer period, those students could still have the chance to benefit from the treatment of CoKA and educational technologies.

### 5.2 Effects of online team learning

Several studies indicate that the benefits of TL employed in classrooms include not only improvement of team performances and the advantage of knowledge sharing, but also positive social-emotional reactions, such as a sense of security and the overall experience of interacting with team members [111, 113, 115]. In this study, the researchers adopted online TL and explored its effects on improving students' learning. At the end of the semester, a significant improvement in students' computing skills in designing mobile applications could be observed in TL group ($p < 0.05$), as well as a significant decrease in level of anxiety and cognitive load, when compared with non-TL group (see Table 2).

Some existing studies show support regarding TL as a factor for improving students' performances in the classroom [6, 44]. As for TL in regulating anxiety and cognitive load, similar positive effects can be found in other research, such as the study by Myers, Sateia, and Desai [63], which investigates the use of TL method and its association with reduced burnout among medical residents. A study by Eren-Sisman, Cigdemoglu, and Geban [32] also shows that TL could help palliate students' anxiety in a STEM class setting. The application of TL can facilitate students' interaction and sharing among the teams, and regulate their anxiety and cognitive load when learning programming in an online environment, and further lead to better learning performance. Therefore, the researchers suggest that teachers could consider employing TL in their online or blended courses to assist their students in achieving better learning performance.

### 5.3 Combined effects of online content-based knowledge awareness and team learning

The authors also investigated the combined effects of CoKA and TL on students' learning effects in an online computing course. The results obtained from this research indicate that students who received both online CoKA and TL (G1) had significantly better development of their computing skills and a relatively more regulated cognitive load than those who received traditional teaching method (G4). It is revealed that knowledge awareness is critical for the success of collaboration [24, 118]. CoKA could be a reliable way of enhancing knowledge exchange within collaborating online groups in the technology-supported collaborative learning domain [51]. Thus, it is believed that the application of CoKA may facilitate students' collaboration and teamwork, help students accommodate themselves to the situation of TL, and further lead to better development of computing skills and regulated cognitive load.

Although the sole treatment of online CoKA did not contribute to better performance in students' computing skills, or reduced anxiety and cognitive load, as the outcomes suggest, it may remain partly effective. Additionally, this study serves as an indication that without CoKA and TL, the traditional way of teaching programming (e.g., G4) may result in poor student performance, higher anxiety and cognitive load. With some tailored adjustments, the study results could be useful to teachers who want to employ CoKA or TL in curriculum design, and shed some light to educators who are in search of innovative approaches to assist their students toward practical and productive learning processes.

### 5.4 Potential contributions from this study

In recent years, the use of technologies in students' learning and their academic domain has received increased scholarly attention [47]. With the constant development of computer technologies, educators use a variety of tools to assist course design [4, 12, 13], and make learning more accessible to people. It is also indicated that computing skills and information literacy are important issues for modern society [74, 99, 101]. The younger generation is expected to be innovative, productive, and possess fundamental skills, such as critical thinking, ability to decode and process information, embrace teamwork and collaboration, and acquire further skills in technology, information management and media literacy [121].

Given the increasing demand for college students' competence, improving the quality of computing education and outcomes is a priority. Thus, the researchers believe that this study contributes to e-learning theory in two ways. First, the design of online TL instructional method in this study may provide a reference for educators to improve students' programming skills and co-working skills. Secondly, this study may be one of the first attempts to investigate and explore the effects of the various combinations of CoKA, TL, and cloud classroom in programming courses. Based on these contributions, this research could provide insights for teachers and researchers who want to design appropriate teaching methods for online courses in this domain.

### 5.5 Potential problems and limitations

The application of technology to support teaching and learning has been highly valued since technology can transform existing learning activities into more active, attractive and engaging processes [21, 109], which has been given precedence in many countries when it comes to curriculum [54]. Thus, the researchers re-designed a blended computing course, integrated CoKA and TL with educational technologies, and investigated their effects on improving students' programming skills, reducing anxiety and regulating cognitive load in a cloud classroom. Certain limitations and problems with drawing firm conclusions may still exist, due to the threats to the validity of conclusions drawn through the quasi-experimental design.

When conducting this experiment, all of the participants first completed pretests to measure their computing skills, evaluate their anxiety and assess their cognitive load; even so, each student's computer competence may not be necessarily the same, and this may result in bias in the evaluation. It is worth noting that some potential problems of experimental validity, such as the Hawthorne effect, may influence students' performance. Moreover, as the experiment was conducted in a required course, the teacher and researchers in this study could not select students for each group. These factors may affect and threaten the validity of the results. Teachers who may adopt CoKA and TL in their online courses should be aware of the individual differences and potential problems of quasi-experimental design that may influence the results and the claimed effects.

## 6 Conclusions

There is little doubt that the past 20 years have brought an evolution in pedagogy for higher education [38]. The importance of collaborative learning is being emphasized in recent years, and approaches based on different theories all contribute to this phenomenon. Students can be guided by educators or supported by computer programs, to work with teammates and share knowledge to complete learning tasks, as such methods have proven to be effective in many studies [34, 52]. In the quest of exploring the effects of CoKA and TL, the results obtained in this investigation show that the CoKA group did not particularly excel in computer programming grades, nor did they feel more relived from anxiety or that their cognitive load was eased compared to non-CoKA group. As for TL, the analysis suggests that online TL performed significantly better in developing students' computing skills, reducing their level of anxiety and regulating cognitive load. The authors propose that CoKA and TL method could still be partly effective with further adjustments, therefore could serve as useful pedagogies for teachers who want to employ CoKA or TL in curriculum, particularly in computing courses.

## References

1. Aldosemani, T.I., Shepherd, C.E., Gashim, I., Dousay, T.: Developing third places to foster sense of community in online instruction. Br. J. Edu. Technol. **47**(6), 1020–1031 (2016)
2. Barajas, M., Owen, M.: Implementing virtual learning environments: looking for holistic approach. Edu. Tech. Soc. **3**(3), 39–53 (2000)
3. Barrie, S.C.: A conceptual framework for the teaching and learning of generic graduate attributes. Stud. High. Edu. **32**(4), 439–458 (2007)
4. Bell, B.S., Federman, J.E.: E-learning in postsecondary education. Future Child. **23**(1), 165–185 (2013)

5. Bui, H.T.M., Baruch, Y., Chau, V.S., He, H.: Team learning: the missing construct from a cross-cultural examination of higher education. Asia Pac. J. Manag. **33**(1), 29–51 (2016)
6. Carmichael, J.: Team-based learning enhances performance in introductory biology. J. Coll. Sci. Teach. **38**(4), 54–61 (2009)
7. Carver, C.S., Scheier, M.F.: A control-process perspective of anxiety. Anxiety Res. **1**, 17–22 (1988)
8. Castillo-Manzano, J.I., Castro-Nuño, M., Díaz, M.T.S., Yñiguez, R.: Does pressing a button make it easier to pass an exam? Evaluating the effectiveness of interactive technologies in higher education. Br. J. Edu. Technol. **47**(4), 710–720 (2016)
9. Chang, C.C., Tseng, K.H., Lou, S.J.: A comparative analysis of the consistency and difference among teacher assessment, student self-assessment and peer-assessment in a Web-based portfolio assessment environment for high school students. Comput. Educ. **58**(1), 303–320 (2012)
10. Chang, C.K.: Effects of using Alice and Scratch in an introductory programming course for corrective instruction. J. Edu. Comput. Res. **51**(2), 185–204 (2014)
11. Chang, S.E.: Computer anxiety and perception of task complexity in learning programming-related skills. Comput. Hum. Behav. **21**(5), 713–728 (2005)
12. Cheng, E.W.L., Chu, S.K.W., Ma, C.S.M.: Tertiary students' intention to e-collaborate for group projects: exploring the missing link from an extended theory of planned behaviour model. Br. J. Edu. Technol. **47**(5), 958–969 (2016)
13. Cheng, X., Li, Y., Sun, J., Huang, J.: Application of a novel collaboration engineering method for learning design: a case study. Br. J. Edu. Technol. **47**(4), 803–818 (2016)
14. Cherepovskaya, E. N., Gorshkova, E. V., & Lyamin, A. V. (2017). Assessment of students' programming skills by using multi-style code editor. In International Conference on Smart Education and Smart E-Learning (pp. 225–234). Springer, Cham.
15. Cinquin, P.A., Guitton, P., Sauzéon, H.: Online e-learning and cognitive disabilities: a systematic review. Comput. Educ. **130**, 152–167 (2019)
16. Chiou, G.F., Wu, C.C.: A computer curriculum guideline for junior high schools in Taiwan: Its impacts, and issues. ACM SIGCUE Outlook **25**(1–2), 21–29 (1997)
17. Chyr, W.L., Shen, P.D., Chiang, Y.C., Lin, J.B., Tsai, C.W.: Exploring the effects of online academic help-seeking and flipped learning on improving students' learning. Edu. Tech. Soc. **20**(3), 11–23 (2017)
18. Clarke, L., Abbott, L.: Young pupils', their teacher's and classroom assistants' experiences of iPads in a Northern Ireland school: "Four and five years old, who would have thought they could do that?" Br. J. Edu. Technol. **47**(6), 1051–1064 (2016)
19. Clariana, R. B., Engelmann, T., & Kozlov, M. (2016). The influence of graphical or textual representations on team concept map form: further validation of a measure of knowledge structure. Retrieved from: http://cmc.ihmc.us/cmc2016papers/cmc2016-p82.pdf
20. Costley, J., Lange, C.: The mediating effects of germane cognitive load on the relationship between instructional design and students' future behavioral intention. Electron. J e-Learn. **15**(2), 174–187 (2017)
21. Cuban, L.: High access and low use of technologies in high school classrooms: explaining an apparent paradox. Am. Educ. Res. J. **38**(4), 813–834 (2001)
22. Decuyper, S., Dochy, F., Van den Bossche, P.: Grasping the dynamic complexity of team learning: an integrative model for effective team learning in organisations. Edu. Res. Rev. **5**(2), 111–133 (2010)
23. Denning, P.J.: The great principles of computing. Am. Sci. **98**, 369–372 (2010)
24. Dillenbourg, P., Bétrancourt, M.: Collaboration Load. In: Elen, J., Clark, R.E. (eds.) Handling complexity in learning environments: research and theory, pp. 142–163. Advances in Learning and Instruction Series, Pergamon (2006)
25. Edmondson, A.C.: Psychological safety and learning behavior in work teams. Adm. Sci. Q. **44**(2), 350–383 (1999)
26. Ellis, R.A., Pardo, A., Han, F.: Quality in blended learning environments - Significant differences in how students approach learning collaborations. Comput. Educ. **102**, 90–102 (2016)
27. Ely, R.J., Padavic, I., Thomas, D.A.: Racial diversity, racial asymmetries, and team learning environment: effects on performance. Org.Stud. **33**, 341–362 (2012)
28. Engelmann, T., Dehler, J., Bodemer, D., Buder, J.: Knowledge awareness in CSCL: a psychological perspective. Comput. Hum. Behav. **25**, 949–960 (2009)
29. Engelmann, T., Hesse, F.W.: How digital concept maps about the collaborators' knowledge and information influence computer-supported collaborative problem solving. Int. J. Comp.Support. Collab. Learn. **5**, 299–320 (2010)
30. Engelmann, T., Hesse, F.W.: Fostering sharing of unshared knowledge by having access to the collaborators' meta-knowledge structures. Comput. Hum. Behav. **27**, 2078–2087 (2011)
31. Engelmann, T., Kozlov, M.D., Kolodziej, R., Clariana, R.B.: Fostering group norm development and orientation while creating awareness contents for improving Net-based collaborative problem solving. Comput. Hum. Behav. **37**, 298–306 (2014)
32. Eren-Sisman, E.N., Cigdemoglu, C., Geban, O.: The effect of peer-led team learning on undergraduate engineering students' conceptual understanding, state anxiety, and social anxiety. Chem. Edu. Res. Prac. **19**(3), 694–710 (2018)
33. Essalmi, F., Ayed, L.J.B., Jemni, M., Graf, S., Kinshuk. : Generalized metrics for the analysis of E-learning personalization strategies. Comput. Hum. Behav. **48**, 310–322 (2015)
34. Fischer, F., Kollar, I., Stegmann, K., Wecker, C.: Toward a script theory of guidance in computer-supported collaborative learning. Edu. Psychol. **48**, 56–66 (2013)
35. Fluck, A., Webb, M., Cox, M., Angeli, C., Malyn-Smith, J., Voogt, J., Zagami, J.: Arguing for computer science in the school curriculum. Edu. Tech. Soc. **19**(3), 38–46 (2016)
36. Frederickson, L.: Anxiety transmission in the patient with myocardial infarction. Heart Lung **18**, 17–22 (1989)
37. González, A., Fernández, M.V.C., Paoloni, P.V.: Hope and anxiety in physics class: Exploring their motivational antecedents and influence on metacognition and performance. J. Res. Sci Teach. **54**(5), 558–585 (2017)
38. Gratz, E., Looney, L.: Faculty resistance to change: An examination of motivators and barriers to teaching online in higher education. Int. J. Online Pedag. Course Des. **10**(1), 1–14 (2020)
39. Hare, J. (2011). *Business takes dim view of academe*. The Australian. Retrieved from www.theaustralian.com.au/higher-education/business-takes-dim-view-of-academe/story-e6frgcjx-1226030289897
40. Heitink, M., Voogt, J., Verplanken, L., van Braak, J., Fisser, P.: Teachers' professional reasoning about their pedagogical use of technology. Comput. Educ. **101**, 70–83 (2016)
41. Hirst, G., van Knippenberg, D., Zhou, J.: A cross-level perspective on employee creativity: Goal orientation, team learning behavior, and individual creativity. Acad. Manag. J. **52**(2), 280–293 (2009)
42. Hsu, T.C.: Effects of a peer assessment system based on a grid-based knowledge classification approach on computer skills training. Edu. Technol. Soc. **19**(4), 100–111 (2016)
43. Hwang, G.J., Yang, L.H., Wang, S.Y.: A concept map-embedded educational computer game for improving students'

learning performance in natural science courses. Comput. Educ. **69**, 121–130 (2013)
44. Jakobsen, K.V., Knetemann, M.: Putting structure to flipped classrooms using team-based learning. Int. J. Teach. Learn. Higher Edu. **29**(1), 177–185 (2017)
45. Kalelioglu, F., Gülbahar, Y.: The effects of teaching programming via Scratch on problem solving skills: a discussion from learners' perspective. Inform. Edu. **13**(1), 33–50 (2014)
46. Keebler, D.W., Huffman, J.: Effective eLearning and transformative pedagogical strategies: STEM programs. Int. J. Online Pedag. Course Des. **10**(2), 61–70 (2020)
47. Kimmons, R., Veletsianos, G.: Education scholars' evolving uses of twitter as a conference backchannel and social commentary platform. Br. J. Edu. Technol. **47**(3), 445–464 (2016)
48. Kopcha, T.J., Rieber, L.P., Walker, B.B.: Understanding university faculty perceptions about innovation in teaching and technology. Br. J. Edu. Technol. **47**(5), 945–957 (2016)
49. Korbach, A., Brünken, R., Park, B.: Measurement of cognitive load in multimedia learning: a comparison of different objective measures. Instr. Sci. **45**(4), 515–536 (2017)
50. Kozlov, M.D., Buder, J., Thiemann, D.: Can knowledge awareness tools help find learning partners with complementary knowledge? IEEE Trans. Learn. Technol. **11**(3), 334–341 (2017)
51. Kozlov, M.D., Engelmann, T., Buder, J., Hesse, F.W.: Is knowledge best shared or given to individuals? Expanding the Content-Based Knowledge Awareness paradigm. Comput. Hum. Behav. **51**, 15–23 (2015)
52. Kozlov, M.D., Große, C.S.: Online collaborative learning in dyads: effects of knowledge distribution and awareness. Comput. Hum. Behav. **59**, 389–401 (2016)
53. Kozlowski, S.W.J., Ilgen, D.R.: Enhancing the effectiveness of work groups and teams. Psychol. Sci.Public Interest **7**(3), 77–124 (2006)
54. Lang, C., Craig, A., Casey, G.: A pedagogy for outreach activities in ICT: promoting peer to peer learning, creativity and experimentation. Br. J. Edu. Technol. **48**(6), 1491–1501 (2017)
55. Lange, C., Costley, J., Han, S.L.: The effects of extraneous load on the relationship between self-regulated effort and germane load within an e-learning environment. Int. Rev. Res. Open Distribut. Learn. **18**(5), 64–83 (2017)
56. Lehmann-Willenbrock, N.: Team learning: New insights through a temporal lens. Small Group Res. **48**(2), 123–130 (2017)
57. Li, Y., Chun, H., Ashkanasy, N., Ahlstrom, D.: A multi-level study of emergent group leadership: effects of emotional stability and group conflict. Asia Pacif. J. Manag. **29**(2), 351–366 (2012)
58. Lye, S.Y., Koh, J.H.L.: Review on teaching and learning of computational thinking through programming: what is next for K-12? Comput. Hum. Behav. **41**, 51–61 (2014)
59. Ma, W.W., Yuen, A.H.: Understanding online knowledge sharing: an interpersonal relationship perspective. Comput. Educ. **56**(1), 210–219 (2011)
60. Medalie, J.H., Goldbourt, U.: Angina pectoris among 10,000 men: II. Psychosocial and other risk factors as evidenced by a multivariate analysis of a five year incidence study. Am. J. Med. **60**(6), 910–921 (1976)
61. Moons, J., De Backer, C.: The design and pilot evaluation of an interactive learning environment for introductory programming influenced by cognitive load theory and constructivism. Comput. Educ. **60**(1), 368–384 (2013)
62. Mow, I.C.: Issues and difficulties in teaching novice computer programming. In: Innovative techniques in instruction technology, e-learning, e-assessment, and education, pp. 199–204. Springer, Berlin (2008)
63. Myers, C.G., Sateia, H.F., Desai, S.V.: Association between team learning behavior and reduced burnout among medicine residents. J. Gen. Intern. Med. **33**(12), 2037–2039 (2018)
64. Novak, J.D., Canas, A.J.: The origins of the concept mapping tool and the continuing evolution of the tool. Inf. Vis. **5**(3), 175–184 (2006)
65. Owens, M., Stevenson, J., Hadwin, J.A., Norgate, R.: Anxiety and depression in academic performance: an exploration of the mediating factors of worry and working memory. School Psychol. Int. **33**(4), 433–449 (2012)
66. Özmen, B., Altun, A.: Undergraduate students' experiences in programming: difficulties and obstacles. Turkish Online J. Qualitative Inquiry **5**(3), 1–27 (2014)
67. Paas, F.: Training strategies for attaining transfer of problem-solving skill in statistics: a cognitive load approach. J. Educ. Psychol. **84**(4), 429–434 (1992)
68. Paas, F.G., van Merriënboer, J.J.G.: The efficiency of instructional conditions: an approach to combine mental effort and performance measures. Hum. Factors **35**(4), 737–743 (1993)
69. Paas, F.G., van Merriënboer, J.J.G.: Variability of worked examples and transfer of geometrical problem-solving skills: a cognitive load approach. J. Educ. Psychol. **86**(1), 122–133 (1994)
70. Palvia, S., Aeron, P., Gupta, P., Mahapatra, D., Parida, R., Rosner, R., Sindhi, S.: Online education: worldwide status, challenges, trends, and implications. J. Global Information Technol. Manag. **21**(4), 233–241 (2018)
71. Pekrun, R., Perry, R.P. Control-value theory of achievement emotions. In: International Handbook of Emotions in Education, pp. 120–141. Taylor & Francis (2014)
72. Pugh, C.M., Obadina, E.T., Aidoo, K.A.: Fear of causing harm: use of mannequin-based simulation to decrease student anxiety prior to interacting with female teaching associates. Teach. Learn. Med. **21**(2), 116–120 (2009)
73. Rehling, L., Hollaar, L., Bailis, S.: Co-teaching engineering and writing: learning about programming, teamwork, and communication. Issues Interdiscip. Stud. **15**, 125–147 (1997)
74. Rockman, I.F.: Introduction: The importance of information literacy. In: Rockman, I.F. (ed.) Integrating information literacy into the higher education curriculum: Practical models for transformation, pp. 1–28. Jossey-Bass, San Francisco, CA (2004)
75. Rogerson, C., Scott, E.: The fear factor: how it affects students learning to program in a tertiary environment. J. Information Tech. Educ. **9**, 147–171 (2010)
76. Rowe, M.: Developing graduate attributes in an open online course. Br. J. Educ. Technol. **47**(5), 873–882 (2016)
77. Santos, C.M., Passos, A.M., Uitdewilligen, S.: When shared cognition leads to closed minds: temporal mental models, team learning, adaptation and performance. Eur. Manag. J. **34**, 258–268 (2016)
78. Savelsbergh, C.M.J.H., van der Heijden, B.I.J.M., Poel, R.F.: The development and empirical validation of a multidimensional measurement instrument for team learning behaviors. Small Group Res. **40**, 578–607 (2009)
79. Scherer, R. (2016). Learning from the past-The need for empirical evidence on the transfer effects of computer programming skills. *Frontiers in Psychology, 7*. Retrieved from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5021694/
80. Schreiber, M., Engelmann, T.: KIA for initiating Transactive Memory System processes of computer-supported collaborating ad hoc groups. Comput. Hum. Behav. **26**, 1701–1709 (2010)
81. Seipp, B.: Anxiety and academic performance: a meta-analysis of findings. Anxiety Res. **4**(1), 27–41 (1991)
82. Senge, P.M.: The fifth discipline: The art and practice of the learning organization. Broadway Business. Doubleday (2006)

83. Siddiq, F., Hatlevik, O.E., Olsen, R.V., Throndsen, I., Scherer, R.: Taking a future perspective by learning from the past-a systematic review of assessment instruments that aim to measure primary and secondary school students' ICT literacy. Educ. Res. Rev. **19**, 58–84 (2016)
84. Sinatra, G.M., Broughton, S.H., Lombardi, D.: Emotions in science education. In: International Handbook of Emotions in Education, pp. 415–436. Routlege (2014)
85. Smith, G.G., Sorensen, C., Gump, A., Heindel, A.J., Caris, M., Martinez, C.D.: Overcoming student resistance to group work: online versus face-to-face. Internet Higher Educ. **14**(2), 121–128 (2011)
86. Spielberger, C.D.: Manual for the State-Trait Anxiety Inventory STAI (Form Y). Consulting Psychologists Press, Palo Alto, CA (1983)
87. Stachel, J., Marghitu, D., Brahim, T.B., Sims, R., Reynolds, L., Czelusniak, V.: Managing cognitive load in introductory programming courses: a cognitive aware scaffolding tool. J. Integrat. Des. Process Sci. **17**(1), 37–54 (2013)
88. Stoyanov, S. R., Hides, L., Kavanagh, D. J., Zelenko, O., Tjondronegoro, D., & Mani, M. (2015). Mobile app rating scale: A new tool for assessing the quality of health mobile apps. *JMIR mHealth and uHealth, 3*(1), e27. Retrieve from http://mhealth.jmir.org/article/viewFile/mhealth_v3i1e27/2
89. Su, C.H.: The effects of students' learning anxiety and motivation on the learning achievement in the activity theory based gamified learning environment. EURASIA J. Math. Sci. Technol. Educ. **13**(5), 1229–1258 (2017)
90. Su, Y.N., Kao, C.C., Hsu, C.C., Pan, L.C., Cheng, S.C., Huang, Y.M.: How does Mozart's music affect children's reading? The evidence from learning anxiety and reading rates with e-books. Educ. Tech. Soc. **20**(2), 101–112 (2017)
91. Suarez, M.J., Quimbo, M.A.T.: Test anxiety and selected personal factors as determinants of academic performance of undergraduate online learners. Malays. J. Distance Educ. **18**(1), 29–51 (2016)
92. Sun, J.: Multi-dimensional alignment between online instruction and course technology: a learner-centered perspective. Comput. Educ. **101**, 102–114 (2016)
93. Sweller, J.: Cognitive load during problem solving: Effects on learning. Cognit. Sci. **12**, 257–285 (1988)
94. Sweller, J., van Merriënboer, J.J.G., Paas, F.G.: Cognitive architecture and instructional design. Educ. Psychol. Rev. **10**(3), 251–296 (1998)
95. Szulewski, A., Gegenfurtner, A., Howes, D.W., Sivilotti, M.L., van Merriënboer, J.J.G.: Measuring physician cognitive load: Validity evidence for a physiologic and a psychometric tool. Adv. Health Sci. Educ. **22**(4), 951–968 (2017)
96. Tan, K.E.: Using online discussion forums to support learning of paraphrasing. Br. J. Educ. Technol. **48**(6), 1239–1249 (2017)
97. Tlili, A., Essalmi, F., Jemni, M., Kinshuk, & Chen, N. S. : Role of personality in computer based learning. Comput. Hum. Behav. **64**, 805–813 (2016)
98. Tsai, C.W.: The role of teacher's initiation in online pedagogy. Educ. + Train. **54**(6), 456–471 (2012)
99. Tsai, C.W.: An effective online teaching method: the combination of collaborative learning with initiation and self-regulation learning with feedback. Behav. Inform. Tech. **32**(7), 712–723 (2013)
100. Tsai, C.W.: A quasi-experimental study of a blended course integrated with refined web-mediated pedagogy of collaborative learning and self-regulated learning. Interact. Learn. Environ. **22**(6), 737–751 (2014)
101. Tsai, C.W.: Exploring the effects of online team-based learning and co-regulated learning on students' development of computing skills. Interact. Learn. Environ. **24**(4), 665–680 (2016)
102. Tsai, C.W., Shen, P.D., Chiang, I.C., Chen, W.Y., Chen, Y.F.: Exploring the effects of web-mediated socially-shared regulation of learning and experience-based learning on improving students' learning. Interact. Learn. Environ. **26**(6), 815–826 (2018)
103. Tsai, M.C., Tsai, C.W.: Applying online externally-facilitated regulated learning and computational thinking to improve students' learning. Univ. Access Inf. Soc. **17**(4), 811–820 (2018)
104. Tsai, M.C., Shen, P.D., Chen, W.Y., Hsu, L.C., Tsai, C.W.: Exploring the effects of web-mediated activity-based learning and meaningful learning on improving students' learning effects, learning engagement, and academic motivation. Univ. Access Inf. Soc. **19**(4), 783–798 (2020)
105. Türel, Y.K.: Relationships between students' perceived team learning experiences, team performances, and social abilities in a blended course setting. Internet Higher Educ. **31**, 79–86 (2016)
106. Van der Haar, S., Segers, M.S.R., Jehn, K.A.: Towards a contextualized model of team learning processes and outcomes. Educ. Res. Rev. **10**, 1–12 (2013)
107. van Merriënboer, J.J.G., Kirschner, P.A.: Ten steps to complex learning: A systematic approach to four-component instructional design, 2nd edn. Routledge, New York, NY (2013)
108. Vickers, J.N., Williams, A.M.: Performing under pressure: The Effects of physiological arousal, cognitive anxiety, and gaze control in biathlon. J. Mot. Behav. **39**, 381–394 (2007)
109. Voet, M., De Wever, B.: Towards a differentiated and domain-specific view of educational technology: an exploratory study of history teachers' technology use. Br. J. Educ. Technol. **48**(6), 1402–1413 (2017)
110. Wang, X.M., Hwang, G.J.: A problem posing-based practicing strategy for facilitating students' computer programming skills in the team-based learning mode. Educ. Tech. Res. Dev. **65**(6), 1655–1671 (2017)
111. Watzek, V., Anselmann, V., Mulder, R.H.: Team learning and emotions during teamwork: a qualitative study. Res. Papers Educ. **34**(6), 769–789 (2019)
112. Wells, C.E.: Teaching teamwork in information systems. In: Challenges of information technology education in the 21st century, pp. 1–24. IGI Global (2002)
113. Wiese, C.W., Burke, C.S.: Understanding team learning dynamics over time. Front. Psychol. (2019). https://doi.org/10.3389/fpsyg.2019.01417
114. Williams, E.A., Duray, R., Reddy, V.: Teamwork orientation, group cohesiveness, and student learning: a study of the use of teams in online distance education. J. Manag. Educ. **30**(4), 592–616 (2006)
115. Williams, L., Wiebe, E., Yang, K., Ferzli, M., Miller, C.: In support of pair programming in the introductory computer science course. Comput. Sci. Educ. **12**(3), 197–212 (2002)
116. Wine, J.D.: Cognitive attentional theory of test anxiety. In: Sarason, I.G. (ed.) Test anxiety, pp. 349–385. Erlbaum, Hillsdale, N.J. (1980)
117. Woo, M., Chu, S., Ho, A., Li, X.: Using a Wiki to scaffold primary-school students' collaborative writing. Educ. Tech. Soc. **14**(1), 43–54 (2011)
118. Xiao, L. (2011). A shared rationale space for supporting knowledge awareness in collaborative learning activities: an empirical study. In *2011 IEEE 11th international conference on advanced learning technologies* (pp. 71–75). IEEE
119. Yang, T.C., Hwang, G.J., Yang, S.J., Hwang, G.H.: A two-tier test-based approach to improving students' computer-programming skills in a web-based learning environment. Educ. Tech. Soc. **18**(1), 198–210 (2015)
120. Yang, Y.T.C.: Virtual CEOs: A blended approach to digital gaming for enhancing higher order thinking and academic

achievement among vocational high school students. Comput. Educ. **81**, 281–295 (2015)
121. Yukselturk, E., Altiok, S.: An investigation of the effects of programming with Scratch on the preservice IT teachers' self-efficacy perceptions and attitudes towards computer programming. Br. J. Educ. Technol. **48**(3), 789–801 (2017)

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