Universal Access in the Information Society
https://doi.org/10.1007/s10209-024-01127-w

LONG PAPER

# Integrating online partial pair programming and socially shared metacognitive regulation for the improvement of students' learning

Chia-Wen Tsai[1] · Michael Yu-Ching Lin[2] · Yih-Ping Cheng[3] · Lynne Lee[4] · Chih-Hsien Lin[5] · Jian-Wei Lin[6] · Min-Ling Hung[7] · Wen-Yu Chen[8]

Accepted: 29 May 2024


## Abstract

Many universities around the world were forced to lock down and students had to continue their learning in online environments in response to the COVID-19 pandemic. Teachers thus had to adopt effective and appropriate online teaching pedagogy integrated with related educational technologies to help their students achieve satisfactory learning outcomes in these courses. In addition, the world-wide problems of high failure level and dropout rates in programming courses challenge both teachers and students. Aiming to develop students' practical programming skills, commitment to learning, and reduce learning disengagement, the researchers behind this study adopted two teaching approaches, integrating online partial pair programming (PPP) and socially shared metacognitive regulation (SSMR), to explore their effects on students' learning performance in an online programming course. A quasi-experiment was implemented to explore the effects of online PPP and SSMR. The participants comprised three classes of students, all from non-information or non-computer departments taking a compulsory course titled 'Programming Design'. The experimental groups included the first class (G1) simultaneously receiving the online PPP and SSMR intervention and the second class (G2) receiving only the online SSMR intervention. The third class (G3) received a traditional teaching method (non-PPP and non-SSMR) delivered online and served as the control group. Both quantitative and qualitative data were collected and analyzed. Experimental results show that the SSMR group (G2) demonstrated significantly better development of programming skills and commitment to learning than the control group (G3). However, the expected effects of online PPP on improving students' learning were not found. The implications of designing pedagogies with PPP and SSMR in an online programming course for decision-makers in governments and universities, researchers, and teachers implementing online courses, particularly programming courses, are provided and discussed.

**Keywords** Online partial pair programming · Online socially shared metacognitive regulation · Programming course · Programming skills · Commitment to learning · Learning disengagement · Cloud classroom

## 1 Introduction

Computing and programming has been (re)integrated into basic education curricula in many nations, as understanding the concepts of programming code, computing, and programming is critical for agentic citizenship in modern education and society [78]. Although there are many educators indicating the importance of computing and programming education, students' dropout rate from programming courses is very high as many find it quite difficult to learn and understand programming [88]. In addition, many universities were forced to lock down and students had to learn in online environments because of the COVID-19 pandemic restrictions [38]. This may increase the difficulty of teaching programming, as learning in online environments may result in students having a sense of isolation [19, 107] and distraction [109]. Thus, adopting and integrating effective teaching methods with educational technologies is necessary to facilitate students attaining better learning outcomes in online or blended programming courses.

### 1.1 The need for means of overcoming learning challenges

In recent years, the keenness to learn programming has been increasing as modern society and workplaces have greatly

Extended author information available on the last page of the article

Published online: 09 June 2024

increased needs for more employees with programming skills [72]. However, learning programming is a difficult task for students [96], as illustrated by many students struggling and dropping out of programming courses [113]. The high failure level and dropout rates in programming courses are serious problems worldwide [76]. In addition, it is also indicated that programming courses are complex and regarded as a major challenge in computer science [64]. Moreover, the teachers and students of programming courses may face even more challenges in online courses [75]. In this regard, the importance of and necessity for re-designing programming courses are emphasized by educators [19, 28].

Recent literature reveals that non-information students may face various difficulties and barriers when learning programming [91]. In order to develop and improve programming skills in an online course for non-information majors, the designers of this study sought a practical and appropriate teaching method. Partial pair programming (PPP), which is an innovative and effective teaching method for programming courses [120], in which there are different groups and every group consists of coder and reviewer [4], was selected for enhancing the learning of non-computer students in this study. It is reported that collaborative programming, such as PPP or pair programming (PP), can be reasonably used and implemented in programming course design as an approach worth learning from [102]. Thus, this study adopted PPP in an online programming course so that this research could demonstrate its effects on the development of students' programming skills and commitment to learning, and to reduce their learning disengagement in the cloud classroom environment.

### 1.2 The need for socially shared metacognitive regulation

Due to COVID -19 diffusing throughout the whole world, many educational institutions have experienced being locked down. In the face of this, colleges suddenly turned en masse to online learning environments that neither students nor teachers expected [70, 124, 127]. However, earlier studies point out that when students learn in entirely online environments, it may result in adverse outcomes, such as inattention and procrastination [18, 51, 70], particularly for university students, whose digital distraction and use of social media is common and rampant [3]. Moreover, it is reported that students' digital distraction (such as using smartphones in the course) may hinder their academic performance [47, 106, 111] and further affect their academic success and well-being. Therefore, teachers should adopt teaching strategies to minimize and regulate students' digital distraction [3].

Hence, this study adopted socially shared metacognitive regulation (SSMR), which refers to learners' collaborative regulatory activities wherein different learners are concurrently engaged as they monitor and control the group's cognition [32, 54]. In the implementation of SSMR, each team had to carry out four processes of metacognitive regulation skills (orientation, planning, monitoring, and evaluation) that are verbalised by teammates, who engage with and build upon their verbalised metacognitive regulation (MR) during their cooperation [31]. The socially shared aspect of MR has been shown to be critical as a collaborative regulation of the progress of the learners' cognitive activity and facilitation of their knowledge co-construction [53]. Recent studies further indicate the importance of learners' regular learning competence in fully online learning environments to overcome digital distraction and regulate their emotions [51, 70]. Additionally, SSMR is reported to potentially facilitate students' interaction in online learning [112]. Therefore, SSMR was employed to improve student's programming skills and commitment to learning, while reducing their learning disengagement in an online programming course.

Since emergency online learning in a crisis (e.g. COVID-19) presents challenges for teachers, students and parents, students' regular learning and motivation may be critical factors that can cultivate their learning success and well-being [86]. The role of students' regulation should therefore be emphasized when it comes to examining online education against the backdrop of COVID-19 [50]. How to organize programming course design to facilitate students' engagement, active learning, and also remain agile, is one of the priorities in both teaching practice and research [26]. So that students may learn and develop practical programming skills, improve their commitment to learning, and reduce their learning disengagement, this study investigated the effect on students' learning of PPP and SSMR integrated with educational technologies. The study thus addresses the following research questions:

1. Could online PPP result in better development of students' *programming skills* and *commitment to learning*, and reduce their *learning disengagement* in a cloud classroom?
2. Could online SSMR result in better development of students' *programming skills* and *commitment to learning*, and reduce their *learning disengagement* in a cloud classroom?
3. Could a combined intervention of online PPP and SSMR result in better development of students' *programming skills* and *commitment to learning*, and reduce their *learning disengagement* compared to those following traditional teaching method in a cloud classroom?

## 2 Literature review

### 2.1 Partial pair programming

Partial pair programming (PPP) is a new emerging and effective teaching method for programming courses, in which students discuss their project ideas, propose their ideas, and complete their task together as a pair [120]. The concept of PPP was mentioned by Ahmad et al. [4]. PPP is modified based on pair programming (PP) [120], a collaborative programming approach where two learners or programmers collaborate together to achieve their common learning goals or complete a project [67]. In the implementation of PPP, work of the pair (the driver and navigator) is a collinear approach [4]. In existing literature, it is reported that PP is effective in enhancing students' grades on assignments and their satisfaction [98], and is a more effective pedagogy for coding than solo programming [36]. In addition, it is also revealed that programming in pairs results in better learning effects, particularly for beginners [55].

Although the effects of PP are indicated in previous literature, problems in applying PP among younger students and programming novices are also revealed [120]. Less experienced learners in a PP environment are reported to be disengaged and learning less [23]. Moreover, an earlier study also illustrated that some non-information students may tend to rely on their teammate(s) with a greater programming ability and miss the chance to actually learn programming themselves through teamwork [19]. Following Wei et al.'s [120] suggestion that teachers should design PP to maximize young students' learning outcomes, particularly in large-size classes with over 40 students, the authors adopted PPP based on a modification of PP.

Instead of PP's emphasizing students' clear role divisions (a driver who writes code and a navigator who monitors the processes and corrects the errors) [100] and asking students to regularly switch roles, PPP focuses more on students' collaboration in pair programming by asking the student pairs to program collaboratively while requiring them to submit their individual programming projects [120]. As the involved introductory programming courses in this study were large-size classes for beginners, PPP could compensate for the limitations on the teacher's availability and facilitate students' collaboration by providing them with opportunities to each contribute their capabilities and learn from one another [120]. While there are some studies investigating the effects of PP in online learning environments and the effects of PPP in traditional learning environment (e.g. face-to-face classrooms), there are not many studies exploring the effects of PPP in online education. In various programming and computational thinking courses, teachers must apply different pedagogies and educational technologies to promote students' learning [17]. Thus, this study adopted PPP in online large-size classes to develop the programming skills and commitment to learning of non-information majors, while also reducing their learning disengagement.

### 2.2 Socially shared metacognitive regulation

Socially shared metacognitive regulation (SSMR) is defined as multiple students' reciprocal and joint engagement that impacts each one's metacognitive contributions [32]. SSMR also comprises the metacognitive regulation (MR) activities in which learners collaboratively engage in each other's regulative processes as they monitor and control their cognition [31, 54]. It is reported that students who have MR skills may choose appropriate strategies when facing hard learning tasks [101], and also promote their academic self-efficacy [22]. Beyond MR, it is indicated that SSMR corresponds with the social constructivist theory, emphasizing the key role of social knowledge construction and application in collaborative learning approaches, so it can be used for students in all learning environments, both onsite and online [13, 69].

Literature references indicate that learners' adoption of regulation strategies and extensive practice with them could facilitate their involvement in SSMR as they progress towards collaborative regulation with peers [29, 31, 74]. It is also revealed that SSMR positively affects students' collaborative processes [62]. Moreover, SSMR could enhance the depth of learners' discussions, while elevating both group learning outcome quality and individual learners' content comprehension [32, 57, 85, 116, 117].

In online learning environments, students' adoption of MR may facilitate their high engagement in the learning process [13]. For example, in order to become more effective learners, students with higher regulatory skills could reflect on their efforts and the strategies that they applied to attain their objectives [114]. Many educators have indicated that implementing self-regulation in online courses may be effective in improving learning performance through a process of training self-regulation skills, and that this also can inspire students' positive motivation [51, 58]. A recent study also indicates and supports that metacognition and self-regulation is important for students' success in online environments [94]. However, few studies have investigated the impacts or effects of SSMR on students' learning performances in online learning environments, particularly for programming courses. As it has been suggested that teachers and researchers consider adopting SSMR to achieve effective and productive collaborative learning in computer-supported or online learning environments [126], this study adopted SSMR for developing students' programming skills and commitment to learning, while reducing their learning disengagement in the cloud classroom of the online programming course used in this study.

### 2.3 Students' programming skills

Programming skills include problem-solving strategies and involve complex logic activities [6, 118]. Programming skills can be described as comprising two aspects for students. First, students need to acquire basic concepts of how to code the programs (coding). Second, programming skills also focus on problem-solving skills when fixing bugs after testing the programs (debugging) [7, 25, 42, 66, 82, 125]. In addition, there are studies evaluating students' programming skills according to their design quality, testing performance, and programming performance [103]. For this study, researchers defined learners' programming skills as their ability to create and develop a programming system with purposive functions. The effects of online PPP and SSMR to enhance students' programming skills were investigated.

### 2.4 Commitment to learning

Defined as a student's desire to be involved in her/his academic activities [11, 16], commitment to learning is one of the key factors supporting or hindering learning interactions [104]. Learner's commitment has also been described as the extent to which a learner is willing to engage in learning and is engaged in learning [93]. Existing literature reports that a student committed to learning regards learning as a critical investment in personal survival [83, 87].

This commitment is key for students' quality learning and academic success [5, 68]. It is also revealed that lack of commitment may result in learners having a lower level of interest in learning [63]. Without learners' commitment, meaningful learning interactions cannot emerge [104]. Recently, there have been studies that demonstrate commitment to learning as a critical factor when evaluating students' learning in online environments (e.g. [61, 93]). Thus, this study adopted PPP and SSMR as a means for developing students' commitment to learning in an online programming course.

### 2.5 Learning disengagement

Learning disengagement refers to the inactive state and withdrawal of effort during the learning process [122], which includes the concepts of non-participation, non-involvement and non-commitment that hinder students' learning, no matter in the physical, emotional, or cognition realms [92]. Recent studies indicate that learning disengagement is negatively connected to students' learning performance and achievement [9, 10, 21, 48]. Students who have learning disengagement may face educational obstacles, such as lack of learning interest, having low self-efficacy, dropping out, low retention, and achievement gaps [45, 81, 99].

Many studies indicate how important engagement in online learning environments is; for example, students with learning engagement would invest mental energy and effort to practice the subject and exert effort to solve problems in online courses [60, 95]. On the contrary, students with learning disengagement, often exhibited as disruptive behaviour, absence, and adverse school connectedness, are at risk of poor academic and social outcomes [48]. Students' disengagement may result in them dropping out from a course or achieving lower grades with reduced employment opportunities [10, 21]. Thus, this study integrated PPP and SSMR in an online programming course to assist students in reducing their learning disengagement.

## 3 Empirical study

### 3.1 Course setting

The involved online course was a semester-long, 2 credit-hour course named 'Programming Design' for first-year undergraduates at a comprehensive university in northern Taiwan. The focus of this online course was the development of students' programming skills in using Visual Basic for Applications (VBA). Previous research and educators indicate that students' pre-existent familiarity with the Microsoft Excel environment and how it is commonly used in the workplace could be positive reasons for teaching programming by VBA in a Microsoft Excel environment [39, 121].

During the initial stage of this programming course, the involved teacher first introduced the basic functions and syntaxes of VBA. Following, the teacher asked students in the respective experimental groups to implement PPP strategies as described in subsection '3.3.1. Intervention of partial pair programming', or to implement the approach of SSMR introduced in section '3.3.2. Intervention of socially shared metacognitive regulation'. In the 16th and 17th weeks of the semester in 2022–2023, students presented their created programs or systems during class sessions.

### 3.2 Participants

The study participants were students from departments unrelated to information technology or computer science, who were enrolled in a compulsory 'Programming Design' course. There were 95 undergraduates from three class sections. The gender breakdown was 39 males and 56 females. The mean age of students who participated in the study was 18.87 years old.

### 3.3 Experimental design and procedure

Before the experiment began, the authors sent our proposal for Ethical Review Approval to National Taiwan University. The study was approved by the Research Ethics Committee of National Taiwan University on September 15, 2022.

A quasi-experiment was executed to demonstrate the effects of online PPP and SSMR; the participants involved consisted of three classes. As shown in Table 1, the experimental groups were the first class (G1) that received the intervention of online PPP and SSMR simultaneously and the second class (G2) that received the intervention of online SSMR only, while the non-PPP and non-PPP group (G3) received traditional programming pedagogy and served as the control group. Figure 1 illustrates the course schedule for the study.

#### 3.3.1 Intervention of partial pair programming (for G1)

In the implementation of PPP, this study adopted Wei et al.'s [120] suggestion and first required students to form pairs for their discussion, sharing, and interaction. Alternately, one of them was the driver who writes the codes, while the other provided guidance and caught bugs in the role of navigator [37]. The classroom teacher introduced the PPP approach to students in G1 and familiarized them as to how to collaborate with their partners to complete the programming tasks for the course [120].

**Table 1** Experimental design of the study and anticipated effects of different instructional designs

| Group | Instructional designs | Expected effects |
|---|---|---|
| G1 | PPP and SSMR | Most significant effect |
| G2 | SSMR | Medium effect |
| G3 | Non-PPP and non-SSMR | No difference |

Throughout the PPP implementation, in each class, the responsible teacher started by introducing the basic functions and syntaxes of VBA. After that, student pairs were to discuss ideas for their projects together. They had to discuss, collect materials, and help each other to learn write code in VBA. Moreover, instead of emphasizing the distinct roles of driver and navigator and asking learners to regularly switch roles, the teacher emphasized the collaborative aspect of pair programming, reminding the paired students to collaborate for submitting their respective programming projects. Not only could the paired students discuss and solve problems together with their partner, they could also talk to the classmates in other teams or ask for the teacher's help if the pair failed to resolve the problems they encountered [120].

Furthermore, the paired students were asked to submit a short video of their discussions and problem-solving in Microsoft Teams or via an online course chat APP (e.g., LINE, WeChat, or Facebook Messenger) as group homework every week [19]. The teacher could check and know the students' learning status via these videos. If a student did not submit her/his group homework (the short video) to the course website before the deadline, no late submissions were accepted.

#### 3.3.2 Intervention of socially shared metacognitive regulation (for G1 and G2)

In the implementation of SSMR, the researchers adopted De Backer, Van Keer and Valcke's [30] and De Backer, Van Keer and Valcke's [31] suggestions and focused on the key metacognitive regulation skills (e.g. orientation, planning, monitoring, and evaluation) that are verbalised by learners, who interact with and build upon their verbalised

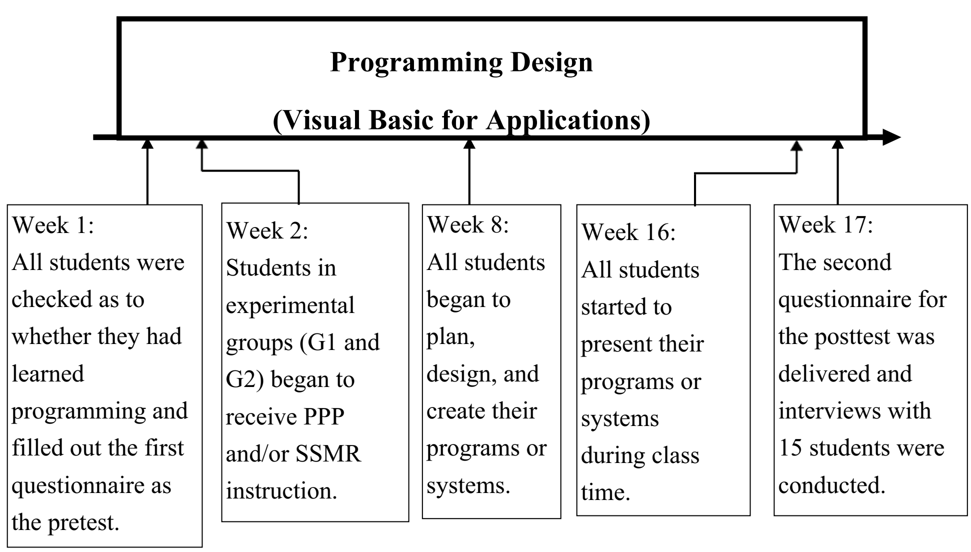


**Fig. 1** Course schedule and assessment during the semester

metacognitive regulation during their collaboration. Divided into six-member teams, each team was asked to implement SSMR in Microsoft Teams or via an online group chat APP (e.g., LINE or WeChat). In addition, students executed the following four processes.

1. Orientation: The collaborative students in G1 and G2 began task analysis, activating their prior knowledge, for the comprehension of learning objectives and to build initial mutual understanding [14, 30].
2. Planning: Students selected their problem-solving strategies and engaged in planning to undertake the group assignments [30, 77].
3. Monitoring: Students examined the quality of their collaborative problem-solving processes to identify inconsistencies and optimize task execution [30, 77, 119].
4. Evaluation: Students assessed their own process once they completed the collaborative learning, focusing on learning performance, group members' collaboration, and problem-solving processes [14, 30, 77].

Instead of approaching learning from the individual perspective, SSMR emphasizes a collective responsibility for MR among collaborating learners [30]. To ensure and check students' implementation of SSMR in this online programming course, students in G1 and G2 were asked to submit the screenshots of the aforementioned four processes from Microsoft Teams or via an online course chat APP as group homework weekly (see Fig. 2).

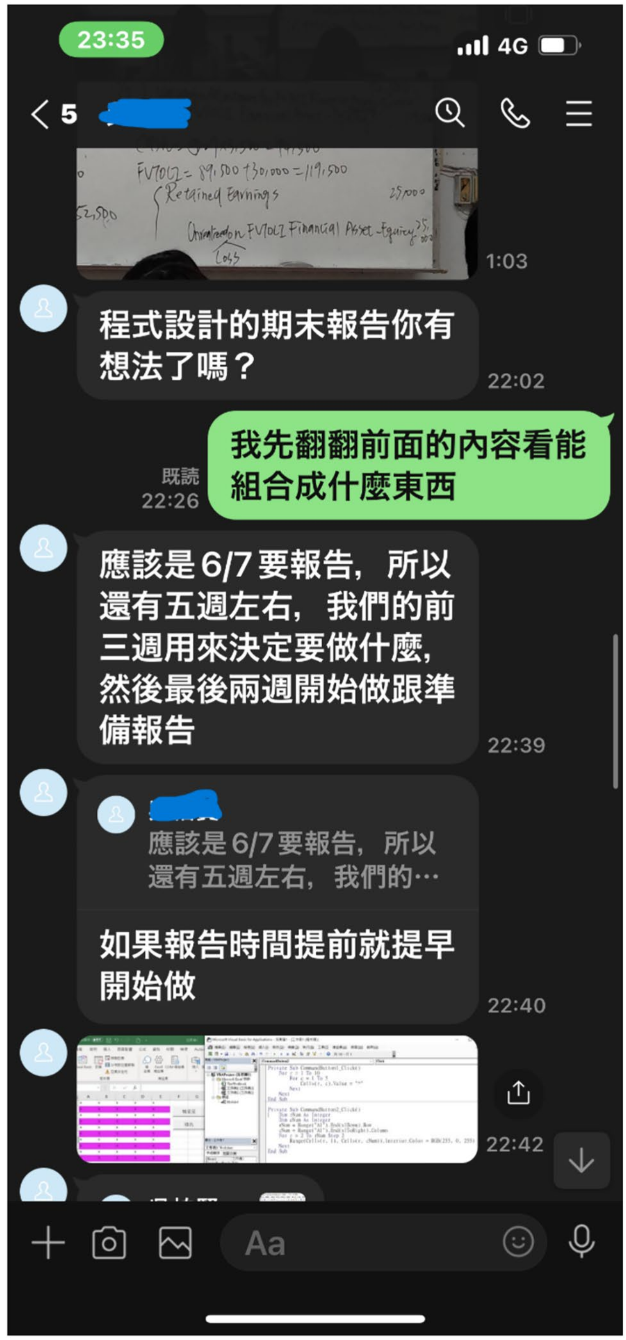


**Fig. 2** Screenshot from an SSMR group's discussion about their planning for the system they will design

### 3.3.3 Intervention for control group (G3)

Students in G3 (the control group) were provided with the same learning materials, class hours, practice opportunities, assignments, on the same website as those in G1 and G2. However, they did not have the interventions of PPP or SSMR. In the control group, conventional lectures covered fundamental syntax and functions of VBA. Participants were then required to create applications or systems with specified functions. Students in G3 neither had to adopt PPP nor implement SSMR.

## 3.4 Measurement

### 3.4.1 Pretest of students' programming skills, commitment to learning, and learning disengagement

**3.4.1.1 Programming skills** This study regarded students' programming design skills in VBA as one of the marks of learning performance. To investigate the effects of PPP and SSMR on students' learning, the researchers first checked students' pre-course experiences in learning how to design computer programming code or how to use Excel VBA for programming. None of the students in the three groups reported any such experiences. Thus, it is believed that all participants had similar low levels of programming skills or experience in programming or writing VBA code before engaging in the intervention of PPP and/or SSMR.

**3.4.1.2 Commitment to learning** All participants from three groups were asked to complete the Commitment to

Learning Scale [12, 16] as a pretest of their commitment to learning before the course started. Commitment to Learning Scale includes seven items investigated via a 4-point Likert scale [16]. Individual items were averaged to calculate the scale scores. The pretest investigated if there were any different levels of students' commitment to learning among the three groups before initiating the intervention of PPP and/or SSMR.

**3.4.1.3 Learning disengagement** Measuring students' learning disengagement on the pretest could validate if students' exhibited levels of learning disengagement were similar before the experiment began. The scale for measuring students' learning disengagement was adopted from Jang, Kim and Reeve's [56] questionnaire, which consists of 20 items using a 5-point Likert scale, ranging from 1 = "strongly disagree" to 5 = "strongly agree", measuring four dimensions: behavioral disengagement, cognitive disengagement, emotional disengagement, and social disengagement. This scale to measure student's learning disengagement was included as one of the pretests before students received the intervention of PPP and/or SSMR.

### 3.4.2 Posttests of students' programming skills, commitment to learning, and learning disengagement

**3.4.2.1 Programming skills** Beginning on the 16th week of the semester, students from the three groups began presenting the programs or systems they had created and developed. Students' systems or programs were graded blindly (not knowing which group students belong to) by the researchers, following the D&M IS Success Model, which encompasses six success dimensions: system quality, information quality, service quality, user satisfaction, usage, and net benefits [35] as an assessment process. The more complete students' systems or programs were, with appropriate functions included, the higher the scores they received.

While students were presenting, the responsible teacher asked questions and offered feedback on their systems or programs. Based on the aforementioned six success dimensions, the teacher and researchers scored students' system demonstrations and oral presentations. In general, students on the same team received the same grade according to the evaluation rules. However, individual grades may have varied because of a student's quality of presentation and responses to teacher's questions.

**3.4.2.2 Commitment to learning** The students were required to complete the commitment to learning scale twice, for measuring their commitment to learning. For the posttest, participants from all three groups completed the commitment to learning scale in week seventeen of the semester. The differences of students' commitment to learning programming among the three groups were analyzed immediately.

Cronbach α test was applied to check whether there was intercorrelation between items. The results exhibited good internal consistency with Cronbach's $\alpha = 0.851$; thus, the authors feel confident that items on the commitment to learning scale have shared covariance, and the same underlying concepts are most likely being evaluated.

**3.4.2.3 Learning disengagement** The students completed the learning disengagement scale adopted from Jang, Kim and Reeve's [56] questionnaire in week seventeen for the posttest. Then, the differences among the three groups of students regarding learning disengagement in this course were analyzed.

Cronbach α test was also used for the overall reliability in this subsection. The results indicate that Cronbach's $\alpha = 0.963$ for cognitive load, that means the items shared covariance ($\alpha > 0.8$). That is, the measurement in this study can be regarded as reliable.

**3.4.2.4 Interviews with students** To grasp students' learning process, performance and perspectives in this research, interviews were conducted with students at the end of the semester (the seventeenth week) to gather qualitative data. The researchers conducted a semi-structured interview with students lasting for 40 min after the last class of the semester. The interviewees were a total of fifteen students chosen randomly from the three classes (five students from each class) to investigate their perspectives and learning experiences in this online programming course, their experiences during the interventions of PPP and SSMR, and with the cloud classroom used in this study. The interview was recorded, transcribed, and analyzed.

## 3.5 Analytical methods

First, the researchers applied Cronbach's α and the rotation sums of squared loading of exploratory factor analysis to calculate the reliability and validity of the commitment to learning scale and learning disengagement scale. The results indicated that the rotation sums of squared loadings value for commitment to learning and learning disengagement are 69.786% and 72.168%, respectively, both greater than 60%. Moreover, the Cronbach's α values are 0.851 and 0.963, both greater than 0.7. Accordingly, the validity and reliability of the two scales in this study are acceptable, given that all the values met the standard levels. Second, the authors applied one-way ANOVA to confirm whether there are differences in the commitment to learning or learning disengagement among the three groups in the pretest. Finally, the independent sample *t*-test was applied to confirm the posttest pairwise differences between different groups.

# 4 Results

## 4.1 Pretests

To avoid measurement bias before adopting the PPP and SSMR learning strategies, the researchers implemented One-Way ANOVA. According to the One-Way ANOVA of the pretests in this study, there are no significant differences among G1, G2, and G3 for students' commitment to learning or learning disengagement (shown in Table 2). In addition, the teacher's investigation of whether students had prior related experience or learning before the experiment began revealed that none of the students prior programming experience. According to the pretest analyses and the teacher's precaution, it is believed that the students who participated in this study had equal levels of initial programming skills, commitment to learning, and learning disengagement before adopting the learning strategies. Therefore, this research could exclude the potential threat of initial variance among students.

## 4.2 Posttests

### 4.2.1 The effect of partial pair programming

To evaluate the effect of PPP, the researchers used the independent sample *t*-test to explore the differences of students' programming skills, commitment to learning and learning disengagement between PPP and SSMR group (G1) and SSMR group (G2). Table 3 reveals no significant difference in students' programming skills, commitment to learning and learning disengagement between G1 and G2 ($p > 0.05$). That is, the teaching strategy of PPP did not significantly affect students' programming skills, commitment to learning or learning disengagement in this study.

Table 3 indicates that the PPP and SSMR group students' performance did not demonstrate the expected benefits. To comprehend and analyze the effect of PPP, the teacher and researchers conducted interviews with students at the end of the semester. During the interview, one student (S1) pointed out a potential issue with the PPP intervention in practical implementation, which might be the reason why PPP did not result in improved performance in students' programming skills, commitment to learning and learning engagement.

**Table 2** One-way ANOVA: pretest of students' commitment to learning and learning disengagement

| Dependent variable | (I) Groups | (J) Groups | Mean difference (I–J) | SE | Sig | 95% CI | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Commitment | 1 | 2 | −0.223773 | 0.130611 | 0.236 | −0.54875 | 0.10121 |
| To learning | | 3 | −0.117051 | 0.1347 | 0.687 | −0.4522 | 0.2181 |
| | 2 | 1 | 0.223773 | 0.130611 | 0.236 | −0.10121 | 0.54875 |
| | | 3 | 0.106723 | 0.131745 | 0.721 | −0.22108 | 0.43452 |
| | 3 | 1 | 0.117051 | 0.1347 | 0.687 | −0.2181 | 0.4522 |
| | | 2 | −0.106723 | 0.131745 | 0.721 | −0.43452 | 0.22108 |
| Learning | 1 | 2 | 0.222818 | 0.162137 | 0.393 | −0.1806 | 0.62624 |
| Disengagement | | 3 | 0.196935 | 0.167212 | 0.502 | −0.21911 | 0.61298 |
| | 2 | 1 | −0.222818 | 0.162137 | 0.393 | −0.62624 | 0.1806 |
| | | 3 | −0.025882 | 0.163544 | 0.988 | −0.4328 | 0.38104 |
| | 3 | 1 | −0.196935 | 0.167212 | 0.502 | −0.61298 | 0.21911 |
| | | 2 | 0.025882 | 0.163544 | 0.988 | −0.38104 | 0.4328 |

**Table 3** Comparison of students' programming skills, commitment to learning and learning disengagement between PPP and SSMR group and SSMR group

| Dependent variable | Group | | | | | | | | t | df | Sig (two-tailed) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | PPP and SSMR group (G1) | | | | SSMR group (G2) | | | | | | |
| | n | M | SD | SE | n | M | SD | SE | | | |
| Programming skills | 31 | 73.94 | 10.878 | 1.954 | 34 | 77.150 | 8.749 | 1.501 | −1.317 | 63 | 0.193 |
| Commitment to learning | 31 | 2.608 | 0.511058 | 0.091789 | 34 | 2.887 | 0.711057 | 0.121945 | −1.823 | 59.852 | 0.073 |
| Learning disengagement | 31 | 2.511 | 0.613828 | 0.110247 | 34 | 2.503 | 0.92236 | 0.158183 | 0.043 | 63 | 0.966 |

> To be honest, it seems nothing special (PPPs' effect); I think more group members would be better. When there are only two members, if one student doesn't understand (the course content) or pays little attention to the course, the other one has to complete the assigned tasks by herself/himself.

Despite the data shown in Table 3 and the description in one interview stating the PPP strategy is unsuitable, some other students pointed out an advantage with PPP. For instance, one student (S2) expressed:

> It works (PPP strategies) because if my partner easily forgets to submit assignments, I can remind him/her.

Moreover, another student (S3) further mentioned the strengths of PPP, giving examples such as supervising another student within a pair:

> We asked each other questions (to complete the weekly programming tasks) and achieve the mutual effect of supervising each other.

Based on the interview data from the PPP and SSMR group's students, it is believed that the PPP intervention might benefit students' interaction and supervision with each other. According to the results and students' feedback, teachers and course designers who wish to apply the PPP strategy in online programming courses should carefully consider how to balance students' workload, facilitate students' adaptability and their interaction.

#### 4.2.2 The effect of socially shared metacognitive regulation

To investigate the effect of SSMR, the independent sample *t*-test was used to analyze the differences of students' programming skills, commitment to learning, and learning disengagement between the SSMR group (G2) and the control group (G3). Table 4 illustrates that the SSMR students' programming skills and commitment to learning exhibited significantly better development compared to the control group ($p < 0.05$). However, the difference of students' learning disengagement between G2 and G3 is not significant.

For further understanding of the SSMR group students' perspectives on the implementation of SSMR, students were interviewed by the teacher on how the SSMR strategy contributed to learning programming. One of the students (S4) affirmed the effectiveness of SSMR implementation on learning programming.

> In my opinion, it is effective. Usually, (in other courses) when you're doing a task alone, you can't discuss it with others. If you don't understand the course content, you can only ask the teacher. However, I think discussing with teammates is better, as it allows for a freer conversation.

According to the quantitative and qualitative data, students can collaborate with peers in the SSMR conditions. When students build more associations via interactive learning, this may contribute to developing optimal programming skills and foster the development of commitment to learning.

#### 4.2.3 The combined effect of partial pair programming and socially shared metacognitive regulation

In order to investigate the combined effects of PPP and SSMR on students' programming skills, commitment to learning and learning disengagement, the independent samples *t*-test was applied to compare the difference between PPP and SSMR group (G1) and control group (G3). Table 5 reveals that students in G1, who simultaneously received PPP and SSMR, developed significantly better programming skills ($p < 0.05$). However, the differences of students' commitment to learning and learning disengagement between G1 and G3 were not significant ($p > 0.05$). That is, the expected combined effects of the PPP and SSMR were found on developing students' programming skills, but not on their commitment to learning or learning disengagement.

**Table 4** Comparison of students' programming skills, commitment to learning, and learning disengagement between SSMR and the control group

| Dependent variable | Group | | | | | | | | t | df | Sig (two-tailed) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SSMR group (G2) | | | | Control group (G3) | | | | | | |
| | n | M | SD | SE | n | M | SD | SE | | | |
| Programming skills | 34 | 77.150 | 8.749 | 1.501 | 30 | 65.230 | 17.813 | 3.252 | 3.326 | 41.028 | 0.002* |
| Commitment to learning | 34 | 2.887 | 0.711057 | 0.121945 | 30 | 2.500 | 0.475657 | 0.086843 | 2.582 | 57.988 | 0.012* |
| Learning disengagement | 34 | 2.503 | 0.92236 | 0.158183 | 30 | 2.732 | 0.577671 | 0.105468 | −1.170 | 62 | 0.246 |

*$p < 0.05$

**Table 5** Comparison of students' programming skills, commitment to learning and learning disengagement between PPP and SSMR group and the control group

| Dependent variable | Group | | | | | | | | t | df | Sig (two-tailed) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | PPP and SSMR group (G1) | | | | Control group (G3) | | | | | | |
| | n | M | SD | SE | n | M | SD | SE | | | |
| Programming skills | 31 | 73.940 | 10.878 | 1.954 | 30 | 65.230 | 17.813 | 3.252 | 2.294 | 47.704 | 0.026* |
| Commitment to learning | 31 | 2.608 | 0.511058 | 0.091789 | 30 | 2.500 | 0.475657 | 0.086843 | 0.856 | 59 | 0.395 |
| Learning disengagement | 31 | 2.511 | 0.613828 | 0.110247 | 30 | 2.732 | 0.577671 | 0.105468 | −1.443 | 59 | 0.154 |

*$p < 0.05$

## 5 Discussion and implications

During the digitalization of the twenty-first century, programming skills have become an essential prerequisite skill for the education sector and workplace. Thus, many nations and educational institutions have recognized the significance of students' programming skills [49, 90]. However, it is indicated that learning programming skills in the online environment might come with some negative effects, such as high dropout rates and disengagement [33, 34, 40, 97]. Moreover, programming is a challenging subject with high failure levels [76]. Especially for non-information students, programming is an unfamiliar subject and it is hard to grasp the concepts, especially in an online environment without prompt support from peers or teachers [65]. Furthermore, existing literature mentions that inappropriate methods of instruction may develop unsuitable learning styles among students for computer programming subjects [65]. Hence, in order to enhance students' programming skills, educators, institutions and researchers should emphasize re-designing and planning programming pedagogy to align with students' learning needs more flexibly [19, 28, 52, 97].

In a world rife with widespread health emergencies and rapid displacement, education has undergone a rapid transition to online forms in many countries [46]. In face-to-face learning environments, teachers can more easily guide students' learning progress and assist them in comprehending complex and difficult concepts [123], notably those encountered in programming courses. While online learning amid the COVID-19 pandemic presented challenges, it has also been a catalyst for students to assume more responsibility for their own learning,thus, it is necessary to explore possible approaches during such health crises [43]. Hence, the authors argue that this study could contribute to the theory and practice of online learning and programming education in three different ways. Firstly, this research specifies how teachers can apply PPP instructional method to attain the benefits of improved interaction and regular learning habits in online programming curriculum, which is brimming with complex content and usually marked by little interaction. Secondly, the adoption and implementation of SSMR in online instruction could facilitate students to develop their metacognitive regulation and further enhance their learning outcomes (such as programming skills and commitment to learning) in a learning environment that may otherwise lead to students' digital distraction due to free online games, social networking websites, and shopping websites [24]. Finally, this study may be one of the early research endeavors to demonstrate the effects of the combination of PPP, SSMR, and educational technologies in a programming course conducted online. Drawing from these potential contributions, this study could provide references for appropriate teaching methods for online educators, teachers of programming courses, and researchers who design online courses.

### 5.1 Effect of partial pair programming

In the twenty-first century, programming skills are broadly essential in different fields and sectors, while many colleges, education reformers, researchers, and employers deem information literacy, programming skills, and creative thinking as advantageous competitive abilities in the workplace [73]. Learning programming is becoming more widespread in institutions of higher education to meet the increasing computing skills demand in the future [108]. Thus, for this study, the authors adopted the PPP treatment in online programming curriculum to enhance students' programming skills and commitment to learning, while reducing learning disengagement.

In the analysis shown in Table 3, it is indicated that the anticipated effects of PPP on students' programming skills, commitment to learning, and learning disengagement were not found in this investigation. In this subsection, the researchers attempt to explain and discuss the potential factors that led to the insignificant effects of PPP. First, it is suggested that an experienced learner (programmer) should serve the role as navigator in the implementation of PPP [4]. However, as this programming course targets first-year undergraduates from non-information departments, most students in this course are not experienced learners [108]. It was hard to find or select an experienced programmer for each pair. This may be one of the reasons for the finding of ineffectiveness of PPP in this study.

Second, the partial pair programming teaching method emphasizes peer collaboration rather than specifying role divisions clearly [100, 120]. However, based on qualitative data collected via an interview with students, it is indicated that the inequality of teamwork load often resulted in only one student in a pair assuming responsibility for tasks, which might have affected PPP's collaboration function. The existing literature also indicates that unequal task load, differing perspectives and divergent aims between members in the partial pair groups may result in insignificant effectiveness [27, 108].

Learning programming is challenging for novice and non-information major students, although some students in this study agreed with the benefit of PPP (such as interaction and mutual supervising between peers) for learning programming. However, students' different levels of attention to the course or unequal task load might have led to ineffective learning performance. Thus, the researchers suggest that course designers and teachers should pay attention to these potential factors and students' equitable workloads, to facilitate the use of PPP to enhance students' learning performance and interaction in online programming courses.

### 5.2 Effect of socially shared metacognitive regulation

Since the spread of the COVID-19 pandemic, higher education systems and institutions have been dramatically impacted [59]. Adopting online learning became an appropriate approach to avoid higher disease transmission conditions [71, 84]. Some negative effects, such as anxiety about academic performance [1, 41], stress about completing a degree [105], and even feeling loneliness or isolation during online learning activity [79], are emphasized in recent research. Assisting students to improve academic achievement, enhance engagement, and reduce their isolation are priority issues for educators [108]. Therefore, in this study the researchers applied SSMR to inspire students to learn programming along with increasing their commitment to learning and decreasing their learning disengagement.

According to Table 4, it is reported that students who received the SSMR method attained significantly better programming skills ($p = 0.002$), as well as significantly enhanced commitment to learning ($p = 0.012$) when compared to the non-SSMR students. These results are similar to the existing research that the SSMR strategy benefits students' cooperation in learning [62] and learning performance [2]. In addition, it is also claimed that the SSMR strategy is particularly applicable to highly demanding cognitive activity [112]. In this condition, SSMR is effective for learning complicated programming design, which verifies the expected effect in this study.

However, through the one-semester implementation of this study, SSMR did not achieve the expected effect of reducing students' learning disengagement ($p = 0.246$). Although SSMR could lead to positive emotional peer interactions [29, 89, 115], students in online learning conditions might decrease their emotional communication with peers as compared with face-to-face learning [8]. In addition, while programming is a difficult subject, once students do not keep up with the course progress along with their peers, they might become further disengaged, leading to inferior performance in the course. Nevertheless, based on the study findings, the authors still suggest that teachers of programming courses could apply SSMR in their online classes to improve students' development of programming skills and commitment to learning.

### 5.3 Combined Effect of partial pair programming and socially shared metacognitive regulation

The researchers adopted PPP and SSMR and investigated their combined effects on students' programming skills, commitment to learning, and learning disengagement in an online programming course. In Table 5, it is shown that students who implemented both online PPP and SSMR (G1) had statistically significant improvement of their programming skills, compared to the control group (G3) ($p = 0.026$). When students implement the interactive processes of SSMR, it might be a reliable way to enhance the interaction function of PPP. Thus, from the results of this study, the researchers argue that implementing SSMR may facilitate students' accommodation to the PPP situation, and further contribute to their programming skills.

However, the expected combined effects of the PPP and SSMR were not found on improving students' commitment to learning ($p = 0.395$) or learning disengagement ($p = 0.154$). The authors further discussed the data present in Table 5 and surveyed the existing literature to summarize possible factors leading to these results of ineffectiveness. First, programming is perceived as a difficult subject with a high failure rate [76]. For non-information majors (e.g. the students involved in this research), programming is regarded as complex and hard to understand, and not helpful for their career after they graduate [108]. Thus, the non-information majors might be hard to motivate to learn programming [28]. In addition, conflicts might occur during students' collaboration process of the teams or pairs, such as unbalanced task load, divergent learning goals, or differing opinions [27]. The abovementioned potential factors might have led to the ineffectiveness of combined effect of PPP and SSMR on students' commitment to learning and learning disengagement in this research.

### 5.4 Potential problems and limitations of this study

The researchers and teacher reflected on their prior teaching practices to revamp an online programming course through integration of PPP and SSMR with educational technologies, then examined the effects of these interventions on improving students' programming skills, commitment to learning and decreasing learning disengagement in this course. Although the researchers conducted a pretest before the study to mitigate any potential bias stemming from students' initial differences, there are some potential limitations and problems when attempting to draw firm research discoveries and conclusions. For example, it is hard to completely avoid students' interactions among the experimental and the control groups during the three real courses, which might result in a cross-contamination scenario [20]. In addition, the Hawthorne effect may be induced when students are aware that they are under study [20].

Moreover, it was hard for the teacher to select an experienced learner (programmer) as a navigator for each pair in the implementation of PPP, and that further led to its ineffectiveness in this study [108]. Future teachers who will adopt PPP should pay attention to this problem and help students select an experienced learner to serve as an appropriate navigator for each pair. Finally, during the period of the COVID-19 pandemic, the study environment and students' health were both disturbed. These factors may potentially influence the validity of results of adopting PPP and SSMR in online, flipped, or blended courses. Teachers and course designers should remain cognizant of the possible issues associated with the quasi-experimental design that could affect the reported findings and results.

## 6 Conclusion

The COVID-19 pandemic has led to a massive disruption of education and has also resulted in an extraordinary number of faculty and students engaging in online education [44, 110]. Although the Internet has become a key educational tool, research indicates that it is often applied without rigor of design and reflection [80]. In addition, it is currently challenging for novices to learn programming, with high dropout and failure rates [15], particularly for those who are from non-information majors. To promote students' programming performance, the teaching strategy in online courses should be re-designed and evaluated by teachers and researchers.

The empirical analysis of data for our first research question, concerning the effects of online PPP, demonstrate that its expected effects on developing students' programming skills, commitment to learning and learning disengagement were not found. Nonetheless, some students still affirmed this innovative teaching method (such as supervising each other) in the interview. Therefore, it is suggested that programming instructors could design PPP well and pay special attention to teamwork load equality, encouraging students to actively identify their own issues, and become proactive learners to achieve PPP's good effects. With regard to the second research question pertaining to the effects of online SSMR, it was found that students who adopted SSMR (G2) had better development of programming skills and commitment to learning. This high-quality cooperation might have led to the significant enhancement of students' learning performance.

As for the third research question concerning the combined effects of online PPP and SSMR, it was found that students who received both PPP and SSMR (G1) simultaneously had significantly better programming skills than those who did not (G3). However, combined effects of online PPP and SSMR on improving students' commitment to learning and learning disengagement were not found in this research. The potential reasons for the ineffectiveness of online PPP and SSMR (such as inexperienced learner serving as navigator in the implementation of PPP, online learning conditions may decrease students' peer emotional communication, and the non-information students might not be interested in learning programming) are reported in section '5. DISCUSSION AND IMPLICATIONS'. This research anticipated providing references and insights for educators of programming courses and for instructors interested in effective online teaching methods. Therefore, in this study the researchers integrated innovative teaching methods of PPP and SSMR for the online course and explored their combined effects on developing students' programming skills, commitment to learning, and reducing their learning disengagement in this online programming course.

**Acknowledgements** The authors would like to express appreciation for the financial support of NSTC research grant NSTC 111-2410-H-130-024 from National Science and Technology Council, Taiwan, R.O.C.

**Author contributions** 1. Chia-Wen Tsai: Conceptualization, Methodology.2. Michael Yu-Ching Lin: Online course design, Data curation.3. Yih-Ping Cheng: Writing- Reviewing and Editing.4. Lynne Lee: Writing- Reviewing and Editing.5. Chih-Hsien Lin: Data curation, Writing- Original draft preparation.6. Jian-Wei Lin: Writing- Reviewing and Editing.7. Min-Ling Hung: Writing- Original draft preparation.8. Wen-Yu Chen: Formal analysis, Data curation

**Funding** National Science and Technology Council, Taiwan, R.O.C., NSTC 111-2410-H-130-024.

**Data Availability** No datasets were generated or analysed during the current study.

## Declarations

**Conflict of interest** The authors declare that there are no conflicts of interest of financial or non-financial interest.

## References


1. Adedoyin, O.B., Soykan, E.: COVID-19 pandemic and online learning: the challenges and opportunities. Interact. Learn. Environ. **31**(2), 863–875 (2023)
2. Ader, M., van Bruggen, J. M., Vermeulen, M.: A scoping review on concepts and interventions of socially shared metacognitive regulation (SSMR). In: EARLI 2021 (pp. 130–130). Gothenburg: EARLI (2021)
3. Agarwal, M., Bishesh, B., Bansal, S., Kumari, D.: Role of social media on digital distraction: a study on university students. J. Content Commun. Commun. **13**(7), 125–136 (2021)
4. Ahmad, B., Saqib, S.M., Ahmad, S., Asghar, M.Z.: Partial pair programming: link between solo and pair programming. Innov. Syst. Des. Eng. **2**(3), 2222–1727 (2011)
5. Ahmad, C.N.C., Shaharim, S.A., Abdullah, M.F.N.L.: Teacher-student interactions, learning commitment, learning environment and their relationship with student learning comfort. J. Turkish Sci. Educ. **14**(1), 57–72 (2017)
6. Alshaye, I., Tasir, Z., & Jumaat, N.F.: The conceptual framework of online problem-based learning towards problem-solving ability and programming skills. In: 2019 IEEE Conference on e-Learning, e-Management & e-Services (IC3e) (pp. 1–4). IEEE (2019)
7. Alshaye, I.A., Jumaat, N.F., Tasir, Z.: Programming skills and the relation in fostering students' higher order thinking. Asian Soc. Sci. **14**(11), 76–82 (2018)
8. Amarneh, B.M., Alshurideh, M.T., Al Kurdi, B.H., Obeidat, Z. The impact of COVID-19 on E-learning: advantages and challenges. In: The International Conference on Artificial Intelligence and Computer Vision (Pp. 75–89). Springer, Cham (2021)
9. Bello, B.: Students' disengagement and e-learning: adaptivity as key challenge for post-COVID 19 e-learning systems in Nigeria. Sokoto Educ Rev **20**(1&2), 30–39 (2021)
10. Bennett, J.: Work-based learning and social support: Relative influences on high school seniors' occupational engagement orientations. Career Tech Educ. Res. **32**(3), 187–214 (2007)
11. Benson, P.L.: Developmental assets and asset-building community: conceptual and empirical foundations. In: Developmental Assets and Asset-Building Communities: Implications for Research, Policy, and Practice (pp. 19–43). Springer, Boston, MA (2003)
12. Benson, P.L., Leffert, N., Scales, P.C., Blyth, D.A.: Beyond the 'village' rhetoric: creating healthy communities for children and adolescents. Appl. Dev. Sci. **2**(3), 138–159 (1998)
13. Binali, T., Tsai, C.C., Chang, H.Y.: University students' profiles of online learning and their relation to online metacognitive regulation and internet-specific epistemic justification. Comput. Educ. **175**, 104315 (2021)
14. Butler, D.L.: Qualitative approaches to investigating self-regulated learning: contributions and challenges. Educ. Psychol. **37**, 59–63 (2002)
15. Cheah, C.S.: Factors contributing to the difficulties in teaching and learning of computer programming: a literature review. Contemp. Educ. Technol. **12**(2), ep272 (2020)
16. Chen, B.B., Han, W.: Ecological assets and academic procrastination among adolescents: the mediating role of commitment to learning. Front. Psychol. **8**, 1971 (2017)
17. Cheng, G.M., Chen, C.P.: Processing analysis of swift playgrounds in a children's computational thinking course to learn programming. Computers **10**(5), 68 (2021)
18. Cheng, S.L., Xie, K.: Why college students procrastinate in online courses: a self-regulated learning perspective. Internet Higher Educ. **50**, 100807 (2021)
19. Cheng, Y.P., Shen, P.D., Hung, M.L., Tsai, C.W., Lin, C.H., Hsu, L.C.: 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. Univ. Access Inf. Soc. **21**, 557–572 (2022)
20. Chiesa, M., Hobbs, S.: Making sense of social research: how useful is the Hawthorne effect? Eur. J. Soc. Psychol. **38**(1), 67–74 (2008)
21. Chipchase, L., Davidson, M., Blackstock, F., Bye, R., Clothier, P., Klupp, N., & Williams, M.: Conceptualising and measuring student disengagement in higher education: a synthesis of the literature. Int. J. Higher Educ. **6**(2), 31–42 (2017)
22. Cho, M.H., Shen, D.: Self-regulation in online learning. Distance Educ. **34**(3), 290–301 (2013)
23. Chong, J., & Hurlbutt, T.: The social dynamics of pair programming. In: 29th International Conference on Software Engineering (ICSE'07) (pp. 354–363). IEEE (2007)
24. 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. Educ. Technol. Soc. **20**(3), 11–23 (2017)
25. Çoklar, A.N., Akçay, A.: Evaluating programming self-efficacy in the context of inquiry skills and problem-solving skills: a perspective from teacher education. World J. Educ. Technol.: Curr. Issues **10**(3), 153–164 (2018)
26. Connolly, A.J., Mutchler, L.A.: A course plan for principles of IS programming to withstand COVID-19. Commun. Assoc. Inf. Syst. **48**(1), 5 (2021)
27. da Silva Estácio, B.J., Prikladnicki, R.: Distributed pair programming: a systematic literature review. Inf. Softw. Technol. **63**, 1–10 (2015)
28. Dawson, J.Q., Allen, M., Campbell, A., Valair, A.: Designing an introductory programming course to improve non-majors' experiences. In: Proceedings of the 49th ACM Technical Symposium on Computer Science Education (pp. 26–31). ACM (2018)
29. De Backer, L., Van Keer, H., Valcke, M.: Exploring evolutions in reciprocal peer tutoring groups' socially shared metacognitive regulation and identifying its metacognitive correlates. Learn. Instr. **38**, 63–78 (2015)
30. De Backer, L., Van Keer, H., Valcke, M.: Socially shared metacognitive regulation during reciprocal peer tutoring: identifying its relationship with students' content processing and transactive discussions. Instr. Sci. **43**(3), 323–344 (2015)
31. De Backer, L., Van Keer, H., Valcke, M.: Variations in socially shared metacognitive regulation and their relation with university students' performance. Metacogn. Learn. **15**, 233–259 (2020)
32. De Backer, L., Van Keer, H., Valcke, M.: The functions of shared metacognitive regulation and their differential relation with collaborative learners' understanding of the learning content. Learn. Instr. **77**, 101527 (2022)
33. De la Fuente, C., Guadagnin, E.C., Kunzler, M.R., Carpes, F.P.: Programming course for health science as a strategy to engage students during the coronavirus pandemic. Adv. Physiol. Educ. **45**(1), 53–58 (2021)
34. Delgado, F.: Teaching physics for computer science students in higher education during the COVID-19 pandemic: a fully internet-supported course. Future Internet **13**(2), 35 (2021)
35. Delone, W.H., McLean, E.R.: The DeLone and McLean model of information systems success: a ten-year update. J. Manag. Inf. Syst. **19**(4), 9–30 (2003)
36. Demir, Ö., Seferoglu, S.S.: A comparison of solo and pair programming in terms of flow experience, coding quality, and coding achievement. J. Educ. Comput. Res. **58**(8), 1448–1466 (2021)
37. Denner, J., Green, E., Campe, S.: Learning to program in middle school: How pair programming helps and hinders intrepid exploration. J. Learn. Sci. **30**(4–5), 611–645 (2021)

38. Deveci, A.D., Geçer, A.K., Budak, E.Ç.: An analysis of the utility of digital materials for high school students with intellectual disability and their effects on academic success. Universal Access Inf. Soc. **22**, 95–110 (2023)
39. dos Santos, M.T., Vianna, A.S., Jr., Le Roux, G.A.: Programming skills in the industry 4.0: are chemical engineering students able to face new problems? Educ. Chem. Eng. **22**, 69–76 (2018)
40. Dumford, A.D., Miller, A.L.: Online learning in higher education: exploring advantages and disadvantages for engagement. J. Comput. High. Educ. **30**(3), 452–465 (2018)
41. Feldman, J.: To grade or not to grade. Educ. Leadersh. **77**(10), 43–46 (2020)
42. Fessakis, G., Gouli, E., Mavroudi, E.: Problem solving by 5–6 years old kindergarten children in a computer programming environment: a case study. Comput. Educ. **63**, 87–97 (2013)
43. Gaeta, M.L., Gaeta, L., Rodriguez, M.D.S.: The impact of COVID-19 home confinement on Mexican university students: emotions, coping strategies, and self-regulated learning. Front. Psychol. **12**, 642823 (2021)
44. Gargano, T., Timke, E.E.: Reimagining engagement: adapting in-person simulations for synchronous classrooms. Int. J. Online Pedagog. Course Des. **12**(1), 1–18 (2022)
45. Gottfried, M.A.: Chronic absenteeism and its effects on students' academic and socioemotional outcomes. J. Educ. Stud. Placed Risk **19**(2), 53–75 (2014)
46. Greenhow, C., Lewin, C.: Online and blended learning: contexts and conditions for education in an emergency. Br. J. Edu. Technol. **52**(4), 1301–1305 (2021)
47. Gupta, N., Irwin, J.D.: In-class distractions: the role of Facebook and the primary learning task. Comput. Hum. Behav. **55**, 1165–1178 (2016)
48. Hancock, K.J., Zubrick, S.: Children and young people at risk of disengagement from school. Commissioner for Children and Young People, Western Australia, Subiaco, WA (2015)
49. Hobert, S.: Fostering skills with chatbot-based digital tutors–training programming skills in a field study. i-com, **22**(2), 143–159 (2023)
50. Holzer, J., Lüftenegger, M., Korlat, S., Pelikan, E., Salmela-Aro, K., Spiel, C., Schober, B.: Higher education in times of COVID-19: university students' basic need satisfaction, self-regulated learning, and well-being. Aera Open **7**, 1–13 (2021)
51. Hong, J.C., Lee, Y.F., Ye, J.H.: Procrastination predicts online self-regulated learning and online learning ineffectiveness during the coronavirus lockdown. Personality Individ. Differ. **174**, 110673 (2021)
52. Huang, R.H., Liu, D.J., Guo, J., Yang, J.F., Zhao, J.H., Wei, X.F., Knyazeva, S., Li, M., Zhuang, R.X., Looi, C.K., Chang, T.W.: Guidance on Flexible Learning During Campus Closures: Ensuring course quality of Higher Education in COVID-19 Outbreak. Smart Learning Institute of Beijing Normal University, Beijing (2020)
53. Iiskala, T., Volet, S., Jones, C., Koretsky, M., Vauras, M.: Significance of forms and foci of metacognitive regulation in collaborative science learning of less and more successful outcome groups in diverse contexts. Instr. Sci. **49**(5), 687–718 (2021)
54. Iiskala, T., Volet, S., Lehtinen, E., Vauras, M.: Socially shared metacognitive regulation in asynchronous CSCL in science: functions, evolution and participation. Frontline Learn. Res. **3**(1), 78–111 (2015)
55. Iskrenovic-Momcilovic, O.: Pair programming with scratch. Educ. Inf. Technol. **24**(5), 2943–2952 (2019)
56. Jang, H., Kim, E.-J., Reeve, J.: Why students become more engaged or more disengaged during the semester: a self-determination theory dual-process model. Learn. Instr. **43**, 27–38 (2016)
57. Janssen, J.J.H.M., Erkens, G., Kirschner, P.A., Kanselaar, G.: Task-related and social regulation during online collaborative learning. Metacogn. Learn. **7**, 25–43 (2012)
58. Jansen, R.S., van Leeuwen, A., Janssen, J., Conijn, R., Kester, L.: Supporting learners' self-regulated learning in Massive Open Online Courses. Comput. Educ. **146**, 103771 (2020)
59. Jiang, P., Namaziandost, E., Azizi, Z., Razmi, M.H.: Exploring the effects of online learning on EFL learners' motivation, anxiety, and attitudes during the COVID-19 pandemic: a focus on Iran. Curr. Psychol. **42**(3), 2310–2324 (2023)
60. Jung, Y., Lee, J.: Learning engagement and persistence in massive open online courses (MOOCS). Comput. Educ. **122**, 9–22 (2018)
61. Kim, D., Jung, E., Yoon, M., Chang, Y., Park, S., Kim, D., Demir, F.: Exploring the structural relationships between course design factors, learner commitment, self-directed learning, and intentions for further learning in a self-paced MOOC. Comput. Educ. **166**, 104171 (2021)
62. Kim, D., Lim, C.: Promoting socially shared metacognitive regulation in collaborative project-based learning: a framework for the design of structured guidance. Teach. High. Educ. **23**(2), 194–211 (2018)
63. Kohonen, V., Bedley, G.: Experiential language learning: second language learning as cooperative learner education. In: Collaborative Language Learning and Teaching, 45–64. Cambridge, Cambridge University Press (1992)
64. Koulouri, T., Lauria, S., Macredie, R.D.: Teaching introductory programming: a quantitative evaluation of different approaches. ACM Trans. Comput. Educ. **14**(4), 1–28 (2015)
65. Kumar, J.R., Mohamad, F.S.: Interventions for enhancing indigenous undergraduates' programming learning: a systematic review. J. Cognit. Sci. Hum. Dev. **9**(1), 83–112 (2023)
66. Lai, C.F., Jeng, Y.L., Huang, S.B.: Improving programming skills: the use of learning style theory and the instant response supplement tool. Library Hi Tech **41**(4), 1084–1098 (2023)
67. Lai, X., Wong, G.K.W.: Collaborative versus individual problem solving in computational thinking through programming: a meta-analysis. Br. J. Educ. Technol. **53**(1), 150–170 (2022)
68. Lawrence, K.C., Fakuade, O.V.: Parental involvement, learning participation and online learning commitment of adolescent learners during the COVID-19 lockdown. Res. Learn. Technol. **29**, 2544 (2021)
69. Lin, C.L., Hou, H.T., Tsai, C.C.: Analyzing the social knowledge construction and online searching behavior of high school learners during a collaborative problem solving learning activity: a multi-dimensional behavioral pattern analysis. Asia Pac. Educ. Res. **25**(5), 893–906 (2016)
70. Liu, X., He, W., Zhao, L., Hong, J.C.: Gender differences in self-regulated online learning during the COVID-19 lockdown. Front. Psychol. **12**, 1–8 (2021)
71. Lucey, C.R., Johnston, S.C.: The transformational effects of COVID-19 on medical education. JAMA **324**(11), 1033–1034 (2020)
72. Luik, P., Lepp, M.: Are highly motivated learners more likely to complete a computer programming MOOC? Int. Rev. Res. Open Distrib. Learn. **22**(1), 41–58 (2021)
73. Mahmud, M.M., Wong, S.F.: Digital age: the importance of 21st century skills among the undergraduates. Front. Educ. **7**, 950553 (2022)
74. Malmberg, J., Järvelä, S., Järvenoja, H., Panadero, E.: Promoting socially shared regulation of learning in CSCL: progress of socially shared regulation among low- and high-performing groups. Comput. Hum. Behav. **52**, 562–572 (2015)
75. Martin, F., Shanley, N. E., Hite, N., Pérez-Quiñones, M. A., Ahlgrim-Delzel, L., Pugalee, D., & Hart, E.: High school teachers teaching programming online: instructional strategies used

and challenges faced. In: RPP for CS '21: Annual Virtual CS4All Summit, 54–62 (2021)
76. Martins, S.: Analyzing human factor impacts of a programming pedagogy strategy at University of Coimbra: a long term assessment. ACM SIGCAS Comput. Soc. **50**(1), 20–26 (2021)
77. Meijer, J., Veenman, M.V.J., van Hout-Wolters, B.H.A.M.: Metacognitive activities in text-studying and problem-solving: development of a taxonomy. Educ. Res. Eval. **12**, 209–237 (2006)
78. Mertala, P.: The pedagogy of multiliteracies as a code breaker: a suggestion for a transversal approach to computing education in basic education. Br. J. Edu. Technol. **52**(6), 2227–2241 (2021)
79. Mizani, H., Cahyadi, A., Hendryadi, H., Salamah, S., Retno Sari, S.: Loneliness, student engagement, and academic achievement during emergency remote teaching during COVID-19: the role of the God locus of control. Human. Soc. Sci. Commun. **9**(1), 1–9 (2022)
80. Morbitzer, J.: On the rational use of the Internet in education. Interdiscip. Contexts Special Pedagogy **23**, 7–21 (2018)
81. Ng, C., Bartlett, B., Elliott, S.N.: Engaging in learning: the challenges and consequences for students from challenging backgrounds. In: Empowering Engagement. Springer, Cham. https://doi.org/10.1007/978-3-319-94652-8_1 (2018)
82. Oddie, A., Hazlewood, P., Blakeway, S., Whitfield, A.: Introductory problem solving and programming: robotics versus traditional approaches. Innov. Teach. Learn. Inf. Comput. Sci. **9**(2), 1–11 (2010)
83. Olokundun, M.A., Ibidunni, A.S., Peter, F., Amaihian, A.B., Ogbari, M.: Entrepreneurship educator's competence on university students' commitment to learning and business plan writing. Acad. Strateg. Manag. J. **16**(2), 1–10 (2017)
84. Orozco, L.E., Giraldo-García, R.J., Chang, B.: Best practices in online education during COVID-19: instructors' perspectives on teaching and learning in higher education. Psychology in the Schools, pp. 1–19 (2023)
85. Paans, C., Onan, E., Molenaar, I., Verhoeven, L., Segers, E.: How social challenges affect children's regulation and assignment quality in hypermedia: a process mining study. Metacogn. Learn. **14**, 189–213 (2019)
86. Pelikan, E.R., Lüftenegger, M., Holzer, J., Korlat, S., Spiel, C., Schober, B.: Learning during COVID-19: the role of self-regulated learning, motivation, and procrastination for perceived competence. Z. Erzieh. **24**(2), 393–418 (2021)
87. Perin, M.G., Sampaio, C.H., De Barcellos, M.D., Kugler, J.O.: The moderating effect of innovativeness on new product development ability. Produto Produção **11**(3), 19–28 (2010)
88. Prasad, A., & Chaudhary, K.:. interactive animation and affective teaching and learning in programming courses. In: Advances in Computer, Communication and Computational Sciences (pp. 613–623). Springer, Singapore (2021)
89. Rogat, T.K., Linnenbrink-Garcia, L.: Socially shared regulation in collaborative groups: an analysis of the interplay between quality of social regulation and group processes. Cognit. Instr. **29**(4), 375–415 (2011)
90. Prommun, P., Kantathanawat, T., Pimdee, P., Sukkamart, T.: An integrated design-based learning management model to promote Thai undergraduate computational thinking skills and programming proficiency. Int. J. Eng. Pedagogy **12**(1), 75–94 (2022)
91. Qian, Y., Lehman, J.: Using an automated assessment tool to explore difficulties of middle school students in introductory programming. J. Res. Technol. Educ. **54**(3), 375–391 (2022)
92. Rabahi, M.: Leading learning among Orang Asli students. [Unpublished doctoral thesis], Universiti Pendidikan Sultan Idris (2018)
93. Ranadewa, D.U.N., Gregory, T.Y., Boralugoda, D.N., Silva, J.A.H.T., Jayasuriya, N.A.: Learners' satisfaction and commitment towards online learning during COVID-19: a concept paper. Vis.: J. Bus. Perspect. Retrieved from: https://doi.org/10.1177/09722629211056705 (2021)
94. Roberts, J.S.: Integrating metacognitive regulation into the online classroom using student-developed learning plans. J. Microbiol. Biol. Educ. **22**(1), 1–5 (2021)
95. Robinson, C.C., Hullinger, H.: New benchmarks in higher education: student engagement in online learning. J. Educ. Bus. **84**, 101–108 (2008)
96. Rõõm, M., Lepp, M., Luik, P.: Dropout time and learners' performance in computer programming MOOCs. Educ. Sci. **11**(10), 643 (2021)
97. Salas-Pilco, S.Z., Yang, Y., Zhang, Z.: Student engagement in online learning in Latin American higher education during the COVID-19 pandemic: a systematic review. Br. J. Edu. Technol. **53**(3), 593–619 (2022)
98. Salleh, N., Mendes, E., Grundy, J.: Empirical studies of pair programming for CS/SE teaching in higher education: a systematic literature review. IEEE Trans. Softw. Eng. **37**(4), 509–525 (2011)
99. Smith, M.G.: Chronic Absenteeism and Its Effect on Students' Grade Point Average and Act Scores. [Unpublished doctoral thesis], Carson-Newman University (2019)
100. Sobral, S.R.: Is pair programing in higher education a good strategy? Int. J. Inf. Educ. Technol. **10**(12), 911–916 (2020)
101. Stanton, J.D., Neider, X.N., Gallegos, I.J., Clark, N.C.: Differences in metacognitive regulation in introductory biology students: when prompts are not enough. CBE—Life Sci. Educ. **14**(2), ar15 (2015)
102. Sun, L., Hu, L., Zhou, D.: Which way of design programming activities is more effective to promote K-12 students' computational thinking skills? A meta-analysis. J. Comput. Assist. Learn. **37**(4), 1048–1062 (2021)
103. Sun, Q., Wu, J., Liu, K.: How are students' programming skills developed: an empirical study in an object-oriented course? In: Proceedings of the ACM Turing Celebration Conference-China (pp. 1–6) (2019)
104. Teräs, H., Kartoğlu, Ü.: A grounded theory of professional learning in an authentic online professional development program. Int. Rev. Res. Open Distrib. Learn. **18**(7), 191–212 (2017)
105. Thompson, S.A., Johnson, M.W.: The Covid-19 dilemma: a roadmap to surmount future challenges in higher education. In: Innovation, Leadership and Governance in Higher Education: Perspectives on the Covid-19 Recovery Strategies (pp. 25–44). Springer Nature Singapore, Singapore (2023)
106. Throuvala, M.A., Pontes, H.M., Tsaousis, I., Griffiths, M.D., Rennoldson, M., Kuss, D.J.: Exploring the dimensions of smartphone distraction: development, validation, measurement invariance, and latent mean differences of the Smartphone Distraction Scale (SDS). Front. Psych. **12**, 199 (2021)
107. Tsai, C.W.: An effective online teaching method: the combination of collaborative learning with initiation and self-regulation learning with feedback. Behav. Inf. Technol. **32**(7), 712–723 (2013)
108. Tsai, C.W., Lin, M.Y.C., Cheng, Y.P., Lee, L.Y., Chyr, W.L., Lin, C.H., Lin, J.W., Tsai, M.C.: The effects of online peer-facilitated learning and distributed pair programming on students' learning. Comput. Educ. **203**, 104849 (2023)
109. 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)
110. United Nations: Policy brief: education during COVID-19 and beyond. Retrieved from: https://www.un.org/development/desa/dspd/wp-content/uploads/sites/22/2020/08/sg_policy_brief_covid-19_and_education_august_2020.pdf (2020)
111. Unsworth, N., McMillan, B.D.: Attentional disengagements in educational contexts: a diary investigation of everyday mind-wandering and distraction. Cognit. Res.: Principles Implicat. **2**(1), 1–20 (2017)

112. Vauras, M., Volet, S., Iiskala, T.: Socially-shared metacognitive regulation in collaborative science learning. In: Trends and Prospects in Metacognition Research across the Life Span: A Tribute to Anastasia Efklides, 83–102, Springer (2021)
113. Ventura Roque-Hernández, R., Armando Guerra-Moya, S., Carmina Caballero-Rico, F.: Acceptance and assessment in student pair-programming: a case study. Int. J. Emerg. Technol. Learn. **16**(9), 4–19 (2021)
114. Vlachopoulos, P., Hatzigianni, M.: Online learning and self-regulation: Balancing between personal and social dimensions. In: Anastasiades, P., Zaranis, N. (eds) Research on e-Learning and ICT in Education. Springer, Cham. Retrieved from: https://doi.org/10.1007/978-3-319-34127-9_13 (2017)
115. Volet, S., Summers, M., Thurman, J.: High-level co-regulation in collaborative learning: how does it emerge and how is it sustained? Learn. Instr. **19**(2), 128–143 (2009)
116. Volet, S., Vauras, M., Salo, A.E., Khosa, D.: Individual contributions in student-led collaborative learning: insights from two analytical approaches to explain the quality of group outcome. Learn. Individ. Differ. **53**, 79–92 (2017)
117. Wang, X., Kollar, I., Stegmann, K.: Adaptable scripting to foster regulation processes and skills in computer-supported collaborative learning. Int. J. Comput.-Support. Collab. Learn. **12**(2), 153–172 (2017)
118. 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. Technol. Res. Dev. **65**(6), 1655–1671 (2017)
119. Webb, N.M.: The teacher's role in promoting collaborative dialogue in the classroom. Br. J. Educ. Psychol. **79**, 1–28 (2009)
120. Wei, X., Lin, L., Meng, N., Tan, W., Kong, S.C.: The effectiveness of partial pair programming on elementary school students' computational thinking skills and self-efficacy. Comput. Educ. **160**, 104023 (2021)
121. Wong, K.W., Barford, J.P.: Teaching excel VBA as a problem solving tool for chemical engineering core courses. Educ. Chem. Eng. **5**(4), e72–e77 (2010)
122. Wong, Z.Y., Liem, G.A.D.: Student engagement: current state of the construct, conceptual refinement, and future research directions. Educ. Psychol. Rev. **34**, 107–138 (2022)
123. Yan, L., Whitelock-Wainwright, A., Guan, Q., Wen, G., Gašević, D., Chen, G.: Students' experience of online learning during the COVID-19 pandemic: a province-wide survey study. Br. J. Edu. Technol. **52**(5), 2038–2057 (2021)
124. Zhao, L., Liu, X., Su, Y.S.: The differentiate effect of self-efficacy, motivation, and satisfaction on pre-service teacher students' learning achievement in a flipped classroom: a case of a modern educational technology course. Sustainability **13**(5), 2888 (2021)
125. Zheng, L.: Improving programming skills through an innovative collaborative programming model: a case study. In: Data-Driven Design for Computer-Supported Collaborative Learning (pp. 75–85). Springer, Singapore. https://doi.org/10.1007/978-981-16-1718-8_6#Sec2 (2021)
126. Zheng, L., Zhong, L., Niu, J., Long, M., Zhao, J.: Effects of personalized intervention on collaborative knowledge building, group performance, socially shared metacognitive regulation, and cognitive load in computer-supported collaborative learning. Educ. Technol. Soc. **24**(3), 174–193 (2021)
127. Zhu, Y., Zhang, J.H., Au, W., Yates, G.: University students' online learning attitudes and continuous intention to undertake online courses: a self-regulated learning perspective. Educ. Technol. Res. Dev. **68**(3), 1485–1519 (2020)



## Authors and Affiliations

**Chia-Wen Tsai[1] · Michael Yu-Ching Lin[2] · Yih-Ping Cheng[3] · Lynne Lee[4] · Chih-Hsien Lin[5] · Jian-Wei Lin[6] · Min-Ling Hung[7] · Wen-Yu Chen[8]**

✉ Chia-Wen Tsai
jawen12b@gmail.com

Michael Yu-Ching Lin
myl@mail.mcu.edu.tw

Yih-Ping Cheng
ypcheng@mail.mcu.edu.tw

Lynne Lee
lynne@mail.mcu.edu.tw

Chih-Hsien Lin
chlin0112@mail.mcu.edu.tw

Jian-Wei Lin
jwlin@g2.usc.edu.tw

Min-Ling Hung
mlhong@mail.mcu.edu.tw

Wen-Yu Chen
wenyuchen@mail.nptu.edu.tw

[1] Department of Information Management, Ming Chuan University, No. 5 De-Ming Rd., Guishan Township 333, Taoyuan County, Taiwan, R.O.C.

[2] Information Technology and Management Program, Ming Chuan University, 250 Zhong-Shan N. Road Sec. 5, Taipei, Taiwan, R.O.C.

[3] Department of Information Management, Ming Chuan University, 250 Zhong-Shan N. Road Sec. 5, Taipei, Taiwan, R.O.C.

[4] International Business and Trade Program, Ming Chuan University, 250 Zhong-Shan N. Road Sec. 5, Taipei, Taiwan, R.O.C.

[5] International Academic Publications Research Center, Ming Chuan University, 250 Zhong-Shan N. Road Sec. 5, Taipei, Taiwan, R.O.C.

[6] Department of Information Technology and Management, Shih Chien University, No. 70, Dazhi St., Zhongshan Dist., Taipei City 104, Taiwan, R.O.C.

[7] Teacher Education Center, Ming Chuan University, 5 De Ming Rd., Gui Shan District 333, Taoyuan County, Taiwan, R.O.C.

[8] Department of Leisure Management, National Pingtung University, No. 4-18, Minsheng Rd., Pingtung City, Pingtung County 90003, Taiwan, R.O.C.