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Exploring the key influencing factors on college students' computational thinking skills through flipped-classroom instruction

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Abstract

To better understand students' computational thinking skills (CTS) within the context of flipped-classroom instruction, a structural equation modeling analysis is employed to examine the key factors that influence student learning and students' CTS when learning through flipped-classroom instruction. A total of 406 first-year college students responded to the survey. The results of this study show that student-to-student connectedness, learning motivation, and learning strategy have a direct impact on students' CTS. In addition, indirect effects were found between student-to-student connectedness and CTS through learning motivation. Indirect effects were also found between learning motivation and CTS through the learning strategy in a flipped-classroom instruction situation. The findings of this research have practical implications for instructors, in that they should focus on the key factors that predict students' computational thinking skills.

Keywords: Computational thinking, Flipped classroom, Student-to-student connectedness, Connected classroom climate, Learning motivation, Learning strategy

Introduction

The flipped classroom has gained considerable academic attention for its pedagogical success in higher education (Cai et al., 2019; Mok, 2014). A literature review by Akçayır and Akçayır (2018) indicates that approximately 80% of studies of flipped-classroom situations have been conducted at a higher education level. The *flipped classroom* (inverted classroom or reverse classroom) refers to an instructional approach that employs "interactive group learning activities inside the classroom, and direct platform-based individual instruction outside the classroom" (Bishop & Verleger, 2013). Bergmann and Sams (2012) stated that the one unifying characteristic of flipped-classroom instruction is the desire to redirect attention in the classroom away from the instructors and onto the students and learning. In addition, existing research has found many advantages of flipped-classroom learning, such as providing peer-based learning (Sage & Sele, 2015), the potential for collaboration opportunities (Foldnes, 2016), promoting creativity (Al-Zahrani, 2015), increasing student-student interaction (Galway et al., 2014), improving motivation (Huang & Hong, 2016), and enabling individualized learning and flexible learning (González-Gómez et al., 2016; Nguyen et al., 2016). Although extensive research has been carried out with regard to students' learning performances in flipped-classroom situations (Akçayır & Akçayır, 2018), the impact of flipped-classroom instruction on college students' high-level thinking skills is relatively understudied. This is particularly true of students' computational thinking skills (CTS) (Cai et al., 2018).

The importance of CTS has been emphasized by policymakers, educators, researchers, and the general public (Durak & Saritepeci, 2018; Korkmaz et al., 2017; Voogt et al., 2015; Wing, 2006). Although the term *computational thinking* does not have a consensus definition (ISTE & CSTA, 2011; ISTE, 2015; Kalelioglu et al., 2016; Korkmaz et al., 2017;), there is general agreement that CTS is a set of thinking skills (Korkmaz et al., 2017; Mannila et al., 2014; Sysło & Kwiatkowska, 2013). For example, Kalelioglu et al. (2016) analyzed the various definitions of CTS as put forward by different researchers. The words "abstraction, problem, solving, algorithmic and thinking" are the most frequently mentioned. The inferred conclusion of the aforementioned research is that computational thinking covers more than one type of skill. Further, by summarizing previous studies, Korkmaz et al. (2017) conclude that students' computational thinking includes the following skills:*creativity*, *algorithmic thinking*, *cooperation*, *critical thinking*, and *problem solving*. Specifically, students' *creativity* is defined as self-expression, which is an ability not only related to art, but also for continuing lifelong use (Craft, 2003). In addition, creativity can introduce new relationships and form new combinations, allowing a person to look at events from different aspects and perspectives (Aksoy, 2004). Students' *algorithmic thinking* is an ability to understand, execute, evaluate and create algorithms (Brown, 2015). Students' *cooperation* means that individuals and their peers in one small group will try to maximize learning effectiveness (Veenman et al., 2002). Students' *critical thinking* is defined as "using cognitive skills or strategies to increase the possibility of the intended behaviors" (Halpern, 2013). Finally, students' *problem solving* means overcoming a problem while endeavoring to reach a certain purpose or intellection. Also, the problem is intended to be found as a numerical problem, and it is solved based on some values. The solution to the problem should be found in the area of education (Aksoy, 2004). Researchers have argued that these abovementioned skills are not just for computer scientists; rather, they are considered to be fundamental skills (e.g. reading, writing, and arithmetic) that everyone in today's world should have (Korkmaz et al., 2017; Wing, 2006). Therefore, identifying and using various teaching approaches to improve students' CTS has become one of the central issues for educators.

However, to our knowledge, few studies to date have explored the relationships between the key factors influencing student learning and students' CTS within a flipped-classroom instruction environment. Without understanding the key factors that influence student learning of CTS, the optimal flipped-classroom instruction model cannot be designed, developed, implemented, and evaluated. It is hoped that our research will address the existing research gap and contribute to a deeper understanding of the flipped-classroom instruction method on students' CTS. The following research question guides this research:

What are the relationships of the key factors influencing student learning and college students' CTS through the flipped-classroom instruction?

The context

To find the answers to the above research question, we conducted the study, using students enrolled in the *Computer Basics and Applications* course at a university in central China. Both the course and the university were purposely selected for two reasons. First, previous researches indicate that students' CTS are closely related to the computer science course (Wing, 2006, 2011). The *Computer Basics and Applications* course covers basic computer knowledge and skills, including computer operating systems, productive tools (e.g., word processing, spreadsheet, and presentation software), computer networking, and multimedia applications. Furthermore, the course is compulsory for first-year college students that are not majoring in computer science. As such, the number of students taking the course may provide a sufficient number of samples for the study. Second, the participating university has been encouraging its faculty and students to adopt the flipped-classroom instruction approach. Particularly, five classes of the *Computer Basics and Applications* course have adopted the flipped-classroom instruction objectives of this course since the fall 2018 semester.

At this university, *Computer Basics and Applications* is a semester-long course that usually lasts for twelve weeks. Instructors and students meet four times per week, and all classes use the same learning materials and facilities. Due to the nature of the course and the fact that not all students have their own computers and applications, instead of combining class and home learning activities, all learning activities are completed within the typical traditional classroom and computer laboratory settings. Therefore, the flipped-classroom instruction method of this study is slightly different than the typical flipped-classroom instruction, which usually reverses the traditional classroom by delivering learning content and activities outside of the classroom or computer laboratory, usually at home. However, the teaching subject, teaching place, and teaching period used in the flipped instruction method are all flipped, compared to the traditional lecture-based instruction method.

Specifically, in a traditional lecture-based instruction class, three-quarters of course time is spent on the instructor delivering lectures to pass on the related knowledge and skills to students. This mainly occurs in a typical classroom. The remaining one-quarter of course time is spent with students practicing and reviewing what they have learned during the lectures. This time is spent in the computer laboratory. During this latter period of time, students are required to digest and absorb knowledge through individual practice sessions and group activities.

In the flipped-classroom instruction setting, three-quarters of course time is spent in the computer laboratory, where students examine learning materials that are preloaded by the instructor on the learning management system. This is followed by students digesting and absorbing knowledge through individual practice and group activities. During the remaining one-quarter of course time, the instructor and students meet in a typical classroom setting, where the instructor facilitates discussions on the key concepts and skills students will need, as well as reinforcing students' understanding of what they have learned and practiced.

Research framework

No research to date has specifically investigated the factors that influence students' CTS within a flipped-classroom instruction situation. Rather, previous studies have explored the various student factors that are associated with student achievements in terms of skills and knowledge. In general, the key factors that influence student learning include student-to-student connectedness (Dwyer et al., 2004; MacLeod et al., 2019), students' learning motivation (Pintrich et al., 1993; Ryan & Deci, 2000), and the learning strategy (Mayer, 1998; Pintrich et al., 1993).

Student-to-student connectedness

Student-to-student connectedness (SSC) was originally defined by Dwyer et al. (2004) as "student-to-student perceptions of a supportive and cooperative communication environment between peers in the classroom". After a systematic literature review, MacLeod et al. (2019) more recently described SSC as the socio-psychological result of interpersonal communication and behavior in the classroom. In essence, SSC emulates belonging, cohesiveness, and supportiveness among peers. Connectedness for students means feeling a strong bond within their learning groups, where they can more openly express themselves and actively communicate with others (Allen, 2000).

Previous studies indicate that SSC is positively related to student achievement on skills and knowledge in a traditional face-to-face environment. For example, researchers have previously found that SSC is positively associated with students' communication skills and peer learning (Sidelinger et al., 2015; Sidelinger et al., 2011). This concept has been argued by Korkmaz et al. (2017) to be the basis of the *cooperation*, *critical thinking,* and *problem solving* of CTS.

Learning motivation

Learning motivation (LM) usually leads individuals to take actions that will help them achieve a goal or fulfill a need or expectation in the learning process (Gopalan et al., 2017). There are various theories about learning motivation (Bandura, 1989; Keller, 1987; Pintrich et al., 1993; Ryan & Deci, 2000; Van Eerde & Thierry, 1996). One of the most well-known and commonly used theories is probably the general social cognitive model of motivation proposed by Pintrich et al. (1993), which includes the three general motivational constructs of expectancy, value and affect.

Previous studies point out that student motivation is a fundamental and important factor in linking student learning performance to achievement (Di Serio et al., 2013; Gopalan et al., 2017). For example, researchers (Mayer, 1998; Song & Grabowski, 2006) find that learning motivation plays an important role in successful *problem-solving*.

Learning strategy

Learning strategy (LS) usually refers to "a set of processes or steps that can facilitate the acquisition, storage, and/or utilization of information" (Dansereau, 1985). Although there is no consensus with regard to the constructs of the learning strategy, a study by Pintrich et al. (1993) has been well-received. This study identifies three components of LS: (1) cognitive component, (2) metacognitive component and (3) resource management component.

It has been proven that LS positively influences student achievements related to skills and knowledge learning. For example, Mayer (1998) finds that the cognitive and metacognitive components of LS have an important influence on successful *problem-solving* in academic settings.

The relationships between SSC, LM, and LS

Previous studies have explored the relationships between SSC, LM and LS in traditional face-to-face environments (Frisby & Martin, 2010; Gascoigne, 2012; Johnson, 2009; Prisbell et al., 2009; Sidelinger et al., 2011). For instance, Sidelinger et al. (2011) conclude that SSC can positively influence students' affective learning, which is an important component of LM. Moreover, Gascoigne (2012) finds that SSC is positively related to students' cognitive learning, which in turn belongs to a sub-dimension of LS.

In addition, existing research has indicated that motivation is a factor that critically affects strategy choices (Ellis & Ellis, 1994). For example, Ellis (1997) found that a person's LM has a significant causal relationship with the quantity of LS that a person adopts. Xu (2011) reported that a person's LM is significantly and positively correlated with overall LS use.

The relational model and hypotheses

Based on our review of related studies, three key factors (student-to-student connectedness, learning motivation, and learning strategy) clearly influence the student achievements related to skills and knowledge within traditional lecture-based instruction settings (Dwyer et al., 2004; MacLeod et al., 2019; Mayer, 1998; Pintrich et al., 1993; Ryan & Deci, 2000). However, we know little about these key factors impact students' CTS, particularly within the context of flipped-classroom instruction. Therefore, as shown in Fig. 1, we propose that student-to-student connectedness, learning motivation, and learning strategy will influence students' CTS within a flipped-classroom instruction environment. Our research hypotheses for these factors are as follows:

Hypothesis 1 (H1): The level of SSC will be positively related to the degree of students' CTS within a flipped-classroom instruction environment.

Hypothesis 2 (H2): The level of LM will be positively related to the degree of students' CTS within a flipped-classroom instruction environment.

Hypothesis 3 (H3): The level of LS will be positively related to the degree of students' CTS within a flipped-classroom instruction environment.

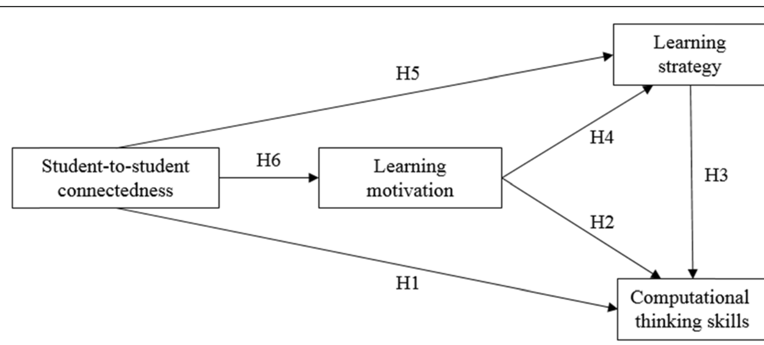

Fig. 1 Proposed research model and hypotheses

Hypothesis 4 (H4): The level of LM will be positively related to the degree of students' LS within a flipped-classroom instruction environment.

Hypothesis 5 (H5): The level of SSC will be positively related to the degree of students' LS within a flipped-classroom instruction environment.

Hypothesis 6 (H6): The level of SSC will be positively related to the degree of students' LM within a flipped-classroom instruction environment.

Methods

Participants

The 406 students were purposely selected from five classes of the *Computer Basics and Applications* course that carried out the flipped-classroom instruction approach.

Instrumentations

The survey utilized Computational Thinking Scales (CT-S), the Connected Classroom Climate Inventory (CCCI), and the Motivated Strategies for Learning Questionnaire (MSLQ) to measure the dependent and independent variables.

The CT-S was developed by Korkmaz et al. (2017). The scale consists of 29 items and a five-dimensional construct, including *creativity* (eight items), *cooperation* (six items), *algorithmic thinking* (four items), *critical thinking* (five items) and *problem solving* (six items). Each item was measured on a 5-point Likert scale, ranging from 1 (*never*) to 5 (*always*). The reliability of the original scale was 0.92, and the original reported dimensional reliabilities were as follows: *creativity* (alpha = 0.84), *algorithmic thinking* (alpha = 0.87), *cooperation* (alpha = 0.87), *critical thinking* (alpha = 0.78), and *problem solving* (alpha = 0.73).

The CCCI used by Dwyer et al. (2004) was adopted to measure student-to-student connectedness. In this case, the CCCI consisted of a single dimension with four items. An introductory stem was added to the scale statement: "Based on my experience in the flipped classroom...". One representative item of this scale is "The students in my class feel comfortable with one another." The overall reliability of the original scale was 0.94 (Dwyer et al., 2004). All CCCI items were measured using a 5-point Likert scale, which ranged from 1 (*strongly disagree*) to 5 (*strongly agree*).

The MSLQ in a study by Pintrich et al. (1993) includes motivation scales and learning strategies scales. The motivation scales were adopted as the means to measure learning motivation, and they are divided into three areas: *value,* which includes intrinsic goal orientation, extrinsic goal orientation, and task value; *expectancy,* which includes control of learning beliefs, and self-efficacy for learning and performance; and *affect*, which contains test anxiety. The original motivation scale consists of 27 items, and the reliabilities of the six sub-dimensions were respectively 0.74, 0.62, 0.90, 0.68, 0.93, and 0.80. The original learning strategies scales are also divided into two areas: *cognitive and metacognitive strategies*, which include rehearsal, elaboration, organization, critical thinking, and metacognitive self-regulation; *resource management strategies,* which include the time and study environment, effort regulation, peer learning, and help-seeking strategies. The original strategies scale consists of 27 items, and the reliabilities of the nine sub-dimensions were respectively 0.69, 0.75, 0.64, 0.80, 0.79, 0.76, 0.69, 0.76, and 0.52. All items in MSLQ were measured in our survey using a 5-point Likert scale, ranging from 1 (*not at all true of me*) to 5 (*very true of me*).

The CT-S, CCCI, and MSLQ items were translated from English to Chinese so that the survey could be administered in the participants' native language. Three researchers translated the survey items in parallel (Guillemin et al., 1993), with committee reconciliation as the means for pre-assessing the translated draft. The completed translation then received bilingual assessments (Harkness & Schoua-Glusberg, 1998) from an educational technology expert with over 20 years of university teaching experience in both the USA and China. Feedback was collected from the expert and used to adjust the wording for several items, thereby improving the overall readability of the CT-S, CCCI, and MSLQ.

Data collection and analysis

Data were collected at the end of the semester. Before the survey was administered, the university granted permission to conduct the research. All participants were introduced to the purpose of the research by a researcher of this study during the instructor's absence. Participants had also been promised that their information would only use for educational research, and their survey results would not in any way be connected to their grades in this course. All responses were both anonymous and voluntary and were issued via paper format during a mid-class break, then imported into SPSS 22.0 and AMOS 22.0 for data analysis. The structural equation modeling analysis was conducted to analyze the relationships between the key influencing factors and students' CTS.

Results

Confirming the measurement model

As can be seen in Table 1, the average variance extracted (AVE) shows a range of 0.59–0.80. These results are all greater than 0.50, which validates the convergent validity of the constructs (Segars, 1997). In addition, the square root of each AVE is greater than the respective correlation coefficients, which validates the discriminant validity of the constructs (Fornell & Larcker, 1981). Accordingly, the constructs of the survey used in this study have good validity. Furthermore, Table 1 provides data that supports the reliability and validity of the survey. The alpha values of participants' responses show a range of 0.91–0.96; the composite reliability (CR) coefficients show a range of 0.84–0.94. All variables display values of greater than 0.70 (Chin, 1998), which confirms the presence of highly satisfactory reliability. Accordingly, the constructs of the survey used in this study also have good reliability.

Table 1 Validity and reliability analysis

	Reliability		Convergent validity	Discriminant validity			
	Alpha	CR	AVE	CT	SSC	LM	LS
CTS	0.96	0.87	0.59	**0.77**			
SSC	0.94	0.94	0.80	0.70	**0.89**		
LM	0.92	0.84	0.66	0.75	0.58	**0.81**	
LS	0.91	0.84	0.63	0.70	0.56	0.77	**0.79**
Criteria	> 0.70	> 0.70	> 0.50				

As shown in Table 2, the absolute fit indices and incremental fit measurements were examined to check the felicitousness of the solution and goodness-of-fit of the model. All the absolute fit indices and incremental fit measurements also reached their commonly acceptable levels, which demonstrates that the measurement model exhibits satisfactory values.

Structural equation modeling analysis

To verify the research hypotheses, a structural equation modeling analysis was conducted. Figure 2 shows the path coefficients marked by standardized regression weights (β value) and p values. As shown in Table 3, the results of five of six paths were significant, with the exception of the influence of student-to-student connectedness on the learning strategy. This is to say that H1, H2, H3, H4, and H6 are supported, while H5 is rejected. Student-to-student connectedness ($\beta = 0.463$, $p < 0.001$), learning motivation ($\beta = 0.391$, $p < 0.001$), and the learning strategy ($\beta = 0.155$, $p < 0.05$) were positively related to computational thinking, collectively accounting for 83.5% of R^2. In addition, learning motivation ($\beta = 0.873$, $p < 0.001$) had significantly positive effects on the learning strategy, collectively accounting for 78.8% of R^2. Furthermore, student-to-student connectedness ($\beta = 0.683$, $p < 0.001$) had significantly positive effects on learning motivation, collectively accounting for 46.7% of R^2.

Analysis of indirect and total effects among key factors

In order to examine the mediation effect, this study analyzes the direct and indirect effects of each hypothesis (Ullman & Bentler, 2003). As shown in Fig. 2 and Table 4, there were three direct and indirect paths of SSC on CTS. In addition, the indirect effect of SSC on CTS accounted for 43.7% (0.359/0.822) of the total effect. Therefore, LM and LS act as partial mediators between SSC and CTS. In addition, an indirect effect was found between the LM and CTS through the LS, due to the indirect effect of the LM on CTS accounting for 25.6% (0.135/0.526) of the total effect. Thus, LS acts as the partial mediators between LM and CTS.

Discussion and conclusions

Up to now, very few empirical studies have specifically investigated students' CTS within a flipped-classroom instruction environment (Cai et al., 2018). Our research addresses this gap in the existing literature by adding important information regarding flipped-classroom instruction and students' CTS.

Table 2 Goodness-of-fit analysis

	Fit index	Actual value	Recommended value	Judgment
Absolute fit indices	χ^2/df	2.249	≤3.00	Yes
	GFI	0.950	≥0.90	Yes
	AGFI	0.916	≥0.90	Yes
	RMSEA	0.056	≤0.08	Yes
Incremental fit measurements	CFI	0.983	≥0.90	Yes
	TLI	0.975	≥0.90	Yes
	NFI	0.970	≥0.90	Yes

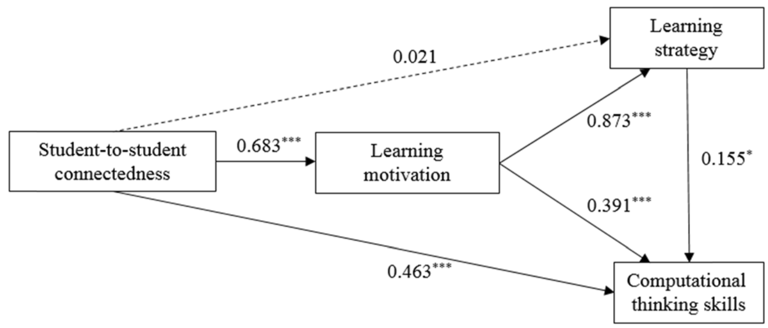

Fig. 2 Structural model of computational thinking

A structural equation modeling analysis was used to explore the relationships between students' CTS and the key influencing factors within a flipped-classroom instruction environment. A research model was proposed in an effort to explain and predict the relationships between three key factors that influence student learning (student-to-student connectedness, learning motivation, and learning strategy) and students' CTS. The most obvious finding to emerge from the analysis is that student-to-student connectedness, learning motivation, and learning strategy are positively related to students' CTS within the flipped-classroom instruction environment. This finding is supported by previous research, suggesting that student-to-student connectedness, learning motivation, and learning strategy are directly related to students' learning knowledge and skills in general (Mayer, 1998; Sidelinger et al., 2015; Song & Grabowski, 2006). Therefore, instructors and instructional designers should consider promoting student-to-student connectedness, learning motivation, and learning strategy when analyzing, designing, developing, implementing, and evaluating the flipped-classroom instruction process and its effect on students' CTS.

It is interesting to note that student-to-student connectedness is the most important determinant of students' CTS in a flipped-classroom. Student-to-student connectedness not only directly influences students' CTS, but also influences students' learning motivation and strategy. This result may be explained by the fact that the students' role is changed in the flipped-classroom instruction settings. In our study, students were more responsible for their own learning. It was up to the students themselves to cultivate knowledge and skills through individual and group activities. It's possible that student-to-student connectedness could be very crucial to the development of students' CTS, learning motivation and strategy. Conversely, the absence of connectedness between

Table 3 Test of hypotheses

Hypotheses		Path coefficient	CR	Result of hypotheses	R^2
H1	SSC → CTS	0.463***	11.781	Supported	0.835
H2	LM → CTS	0.391***	4.350	Supported	
H3	LS → CTS	0.155*	1.996	Supported	
H4	LM → LS	0.873***	9.115	Supported	0.788
H5	SSC → LS	0.021	0.450	Not Supported	
H6	SSC → LM	0.683***	8.913	Supported	0.467

Note. $^{***}p < 0.001$; $^{*}p < 0.05$

Table 4 Analysis of indirect and total effects between key factors

	Path	Effect value		Account (indirect/total)
LM → CTS				25.6%
Direct effect	LM → CTS		0.391	
Indirect effect	LM → LS → CTS	0.873*0.155 = 0.300	0.135	
Total effect			0.526	
SSC → CTS				43.7%
Direct effect	SSC → CT		0.463	
Indirect effect	SSC → LM → LS → CT	0.683*0.873*0.155 = 0.092		
	SSC → LM → CTS	0.683*0.391 = 0.267	0.359	
Total effect			0.822	

students has been linked with some negative effects, such as low self-esteem, loneliness, and depression (Baumeister & Leary, 1995). This finding indicates that peer relationships should be strategically cultivated in instructional design and learning activities (Yang et al., 2019). Instructors should pay particular attention to student-to-student connectedness when using the flipped-classroom instruction method. For example, instructors should actively encourage peer interaction and engagement in individual and group learning activities (Bishop & Verleger, 2013).

Furthermore, students' learning motivation within a flipped-classroom instruction environment was found to directly influence students' CTS and their learning strategies. This result is in accord with previous research, indicating that students' learning motivation is a positive factor in promoting students' learning strategy and academic achievement in the traditional lecture-based instruction environment (Ellis, 1997; Linnenbrink & Pintrich, 2002). It can thus be suggested that students' learning motivation should be the primary focus in the flipped-classroom instruction setting (Yilmaz, 2017; Zainuddin, 2018). Tallent-Runnels et al. (2006) maintained that an understanding of learners' motivation is the key to effective instructional design.

While the present research has important implications for educational practice, it is not without some limitations. It should be noted that this study investigates only three key influencing factors of students' CTS within one subject area and one particular type of flipped-classroom instruction environment (learning activities flipped between the traditional classroom and the computer laboratory). Further research is needed that involves different subject areas and different types of flipped-classroom instructions (i.e. learning activities flipped between inside and outside classroom instruction), and other related factors (i.e. students' preferences regarding the different learning environments should be taken into account).

In conclusion, our research investigates the relationships between students' CTS and the key influencing factors within a flipped-classroom instruction environment. As a result, student-to-student connectedness, learning motivation, and learning strategy are revealed to be the key factors that are directly related to students' CTS in the flipped-classroom instruction environment. Student-to-student connectedness and learning motivation are two particularly noteworthy factors for instructors to consider when striving to improve students' CTS through flipped-classroom instruction.

Abbreviations
CTS: Computational thinking skills; SSC: Student-to-student connectedness; LM: Learning motivation; LS: Learning strategy; CR: Composite reliability; AVE: Average variance extracted; χ^2: Chi-square; df: Degree of freedom; GFI: Goodness of fit index; AGFI: Adjusted goodness of fit index; RMSEA: Root mean square error of approximation; CFI: Comparative fit index; TLI: Tucker-Lewis index; NFI: Normed fit index

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Authors contributions
DG undertook the research, analyzed the data, and prepared the initial manuscript. HY provided the intellectual input, revised and finalized the manuscript. JC provided on-site guidance and supervision. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate
This study has gained the approval of the ethical committee of the School of Computer at Hubei University of Education.

Competing interests
The authors declare that they have no competing interests.

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References
Akçayır, G., & Akçayır, M. (2018). The flipped classroom: A review of its advantages and challenges. *Computers & Education*, *126*, 334–345. https://doi.org/10.1016/j.compedu.2018.07.021.

Aksoy, B. (2004). *Coğrafya öğretiminde probleme dayalı öğrenme yaklaşımı*. Gazi Üniversitesi, Eğitim Bilimleri Enstitüsü, Ankara: Unpublished master thesis.

Allen, T. (2000). Creating community in your classroom. *The Education Digest*, *65*(7), 23.

Al-Zahrani, A. M. (2015). From passive to active: The impact of the flipped classroom through social learning platforms on higher education students' creative thinking. *British Journal of Educational Technology*, *46*(6), 1133–1148. https://doi.org/10.1111/bjet.12353.

Bandura, A. (1989). Human agency in social cognitive theory. *American Psychologist*, *44*(9), 1175. https://doi.org/10.1037/0003-066X.44.9.1175.

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, *117*(3), 497. https://doi.org/10.1037/0033-2909.117.3.497.

Bergmann, J., & Sams, A. (2012). Flip your classroom: Reach every student in every class every day. In *International society for technology in education* Retrieved from http://doi.wiley.com/10.1111/teth.12165.

Bishop, J. L., & Verleger, M. A. (2013, June). The flipped classroom: A survey of the research. In ASEE national conference proceedings, Atlanta, GA (Vol. 30, no. 9, pp. 1-18). Retrieved from http://www.asee.org/file_server/papers/attachment/file/0003/3259/6219.pdf.

Brown, W. (2015). Introduction to algorithmic thinking. Retrieved from https://www.cs4fn.com/algoritmicthinking.php.

Cai, J., Yang, H. H., Gong, D., MacLeod, J., & Jin, Y. (2018, July). A case study to promote computational thinking: The lab rotation approach. In International Conference on Blended Learning (pp. 393-403). Springer, Cham. https://doi.org/10.1007/978-3-319-94505-7_32.

Cai, J., Yang, H. H., Gong, D., MacLeod, J., & Zhu, S. (2019). Understanding the continued use of flipped classroom instruction: A personal beliefs model in Chinese higher education. *Journal of Computing in Higher Education*, *31*(1), 137–155. https://doi.org/10.1007/s12528-018-9196-y.

Chin, W. W. (1998). The partial least squares approach to structural equation modeling. In G. A. Marcoulides (Ed.), *Modern methods for business research*, (pp. 298–336). Mahwah, NJ: Erlbaum Retrieved from https://www.researchgate.net/publication/232569511.

Craft, A. (2003). Creative thinking in the early years of education. *Early Years: An International Journal of Research and Development*, *23*(2), 143–154. https://doi.org/10.1080/09575140303105.

Dansereau, D. F. (1985). Learning strategy research. *Thinking and learning skills*, *1*, 209–239.

Di Serio, Á., Ibáñez, M. B., & Kloos, C. D. (2013). Impact of an augmented reality system on students' motivation for a visual art course. *Computers and Education*, *68*, 586–596. https://doi.org/10.1016/j.compedu.2012.03.002.

Durak, H. Y., & Saritepeci, M. (2018). Analysis of the relation between computational thinking skills and various variables with the structural equation model. *Computers and Education*, *116*, 191–202 https://doi.org/10.1016/j.compedu.2017.09.004.

Dwyer, K. K., Bingham, S. G., Carlson, R. E., Prisbell, M., Cruz, A. M., & Fus, D. A. (2004). Communication and connectedness in the classroom: Development of the connected classroom climate inventory. *Communication Research Reports*, *21*(3), 264–272. https://doi.org/10.1080/08824090409359988.

Ellis, R. (1997). SLA Research and Language Teaching. Oxford University press, 198 Madison avenue, New York, NY 10016-4314. Retrieved from https://eric.ed.gov/?id=ED421866.

Ellis, R., & Ellis, R. R. (1994). *The study of second language acquisition*. Oxford University Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.46.5294andrep=rep1andtype=pdf.

Foldnes, N. (2016). The flipped classroom and cooperative learning: Evidence from a randomised experiment. *Active Learning in Higher Education*, *17*(1), 39–49. https://doi.org/10.1177/1469787415616726.

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, *18*(1), 39–50. https://doi.org/10.1177/002224378101800104.

Frisby, B. N., & Martin, M. M. (2010). Instructor–student and student–student rapport in the classroom. *Communication Education*, *59*(2), 146–164. https://doi.org/10.1080/03634520903564362.

Galway, L. P., Corbett, K. K., Takaro, T. K., Tairyan, K., & Frank, E. (2014). A novel integration of online and flipped classroom instructional models in public health higher education. *BMC Medical Education*, *14*(1), 181. https://doi.org/10.1186/1472-6920-14-181.

Gascoigne, C. (2012). Toward an understanding of the relationship between classroom climate and performance in postsecondary French: An application of the classroom climate inventory. *Foreign Language Annals*, *45*(2), 193–202. https://doi.org/10.1111/j.1944-9720.2012.01186.x.

González-Gómez, D., Jeong, J. S., & Rodríguez, D. A. (2016). Performance and perception in the flipped learning model: An initial approach to evaluate the effectiveness of a new teaching methodology in a general science classroom. *Journal of Science Education and Technology*, *25*(3), 450–459. https://doi.org/10.1007/s10956-016-9605-9.

Gopalan, V., Bakar, J. A. A., Zulkifli, A. N., Alwi, A., & Mat, R. C. (2017, October). A review of the motivation theories in learning. In AIP Conference Proceedings (Vol. 1891, no. 1, p. 020043). AIP publishing. https://doi.org/10.1063/1.5005376.

Guillemin, F., Bombardier, C., & Beaton, D. (1993). Cross-cultural adaptation of health-related quality of life measures: Literature review and proposed guidelines. *Journal of Clinical Epidemiology*, *46*(12), 1417–1432. https://doi.org/10.1016/0895-4356(93)90142-N.

Halpern, D. F. (2013). *Thought and knowledge: An introduction to critical thinking*. Psychology Press.

Harkness, J. A., & Schoua-Glusberg, A. (1998). Questionnaires in translation. In J. A. Harkness (Ed.), *Cross-cultural survey equivalence*, (pp. 87–126). Mannheim, Germany: Open Access Repository Retrieved from https://nbn-resolving.de/urn:nbn:de:0168-ssoar-49733-1.

Huang, Y. N., & Hong, Z. R. (2016). The effects of a flipped English classroom intervention on students' information and communication technology and English reading comprehension. *Educational Technology Research and Development*, *64*(2), 175–193. https://doi.org/10.1007/s11423-015-9412-7.

ISTE. (2015). CT leadership toolkit. Retrieved from http://www.iste.org/docs/ct-documents/ct-leadershipt-toolkit.pdf?sfvrsn=4.

ISTE, & CSTA. (2011). Operational definition of computational thinking for Ke12 education. Retrieved from http://www.iste.org/docs/ct-documents/computational-thinking-operational-definition-flyer.pdf.

Johnson, D. I. (2009). Connected classroom climate: A validity study. *Communication Research Reports*, *26*(2), 146–157. https://doi.org/10.1080/08824090902861622.

Kalelioglu, F., Gulbahar, Y., & Kukul, V. (2016). *A framework for computational thinking based on a systematic research review*.

Keller, J. M. (1987). Development and use of the ARCS model of instructional design. *Journal of Instructional Development*, *10*(3), 2. https://doi.org/10.1007/bf02905780.

Korkmaz, Ö., Çakir, R., & Özden, M. Y. (2017). A validity and reliability study of the computational thinking scales (CTS). *Computers in Human Behavior*, *72*, 558–569. https://doi.org/10.1016/j.chb.2017.01.005.

Linnenbrink, E. A., & Pintrich, P. R. (2002). Motivation as an enabler for academic success. *School Psychology Review*, *31*(3), 313–327 Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.520.1534&rep=rep1&type=pdf.

MacLeod, J., Yang, H. H., & Shi, Y. (2019). Student-to-student connectedness in higher education: A systematic literature review. *Journal of Computing in Higher Education*, *31*(2), 426–448. https://doi.org/10.1007/s12528-019-09214-1.

Mannila, L., Dagiene, V., Demo, B., Grgurina, N., Mirolo, C., Rolandsson, L., & Settle, A. (2014, June). Computational thinking in K-9 education. In Proceedings of the working group reports of the 2014 on innovation and technology in computer science education conference (pp. 1-29). ACM. https://doi.org/10.1145/2713609.2713610.

Mayer, R. E. (1998). Cognitive, metacognitive, and motivational aspects of problem solving. *Instructional Science*, *26*(1–2), 49–63. https://doi.org/10.1023/A:1003088013286.

Mok, H. N. (2014). Teaching tip: The flipped classroom. *Journal of Information Systems Education*, *25*(1), 7 Retrieved from https://eric.ed.gov/?id=EJ1043380.

Nguyen, B., Yu, X., Japutra, A., & Chen, C. H. S. (2016). Reverse teaching: Exploring student perceptions of "flip teaching". *Active Learning in Higher Education*, *17*(1), 51–61. https://doi.org/10.1177/1469787415616727.

Pintrich, P. R., Smith, D. A., Garcia, T., & McKeachie, W. J. (1993). Reliability and predictive validity of the motivated strategies for learning questionnaire (MSLQ). *Educational and Psychological Measurement*, *53*(3), 801–813. https://doi.org/10.1177/0013164493053003024.

Prisbell, M., Dwyer, K. K., Carlson, R. E., Bingham, S. G., & Cruz, A. M. (2009). Connected classroom climate and communication in the basic course: Associations with learning. *Basic Communication Course Annual*, *21*(1), 11 Retrieved from https://ecommons.udayton.edu/bcca/vol21/iss1/11.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology*, *25*(1), 54–67 https://doi.org/10.1006/ceps.1999.1020.

Sage, M., & Sele, P. (2015). Reflective journaling as a flipped classroom technique to increase reading and participation with social work students. *Journal of Social Work Education*, *51*(4), 668–681. https://doi.org/10.1080/10437797.2015.1076274.
Segars, A. H. (1997). Assessing the unidimensionality of measurement: A paradigm and illustration within the context of information systems research. *Omega*, *25*(1), 107–121. https://doi.org/10.1016/S0305-0483(96)00051-5.
Sidelinger, R. J., Bolen, D. M., Frisby, B. N., & McMullen, A. L. (2011). When instructors misbehave: An examination of student-to-student connectedness as a mediator in the college classroom. *Communication Education*, *60*(3), 340–361. https://doi.org/10.1080/03634523.2011.554991.
Sidelinger, R. J., Bolen, D. M., McMullen, A. L., & Nyeste, M. C. (2015). Academic and social integration in the basic communication course: Predictors of students' out-of-class communication and academic learning. *Communication Studies*, *66*(1), 63–84. https://doi.org/10.1080/10510974.2013.856807.
Sidelinger, R. J., Myers, S. A., & McMullen, A. L. (2011). Students' communication predispositions: An examination of classroom connectedness in public speaking courses. *Basic Communication Course Annual*, *23*(1), 13 Retrieved from https://ecommons.udayton.edu/bcca/vol23/iss1/13.
Song, H. D., & Grabowski, B. L. (2006). Stimulating intrinsic motivation for problem solving using goal-oriented contexts and peer group composition. *Educational Technology Research and Development*, *54*(5), 445–466. https://doi.org/10.1007/s11423-006-0128-6.
Sysło, M. M., & Kwiatkowska, A. B. (2013, February). Informatics for all high school students. In International conference on Informatics in Schools: Situation, Evolution, and Perspectives (pp. 43-56). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-36617-8_4.
Tallent-Runnels, M. K., Thomas, J. A., Lan, W. Y., Cooper, S., Ahern, T. C., Shaw, S. M., & Liu, X. (2006). Teaching courses online: A review of the research. *Review of Educational Research*, *76*(1), 93–135. https://doi.org/10.3102/00346543076001093.
Ullman, J. B., & Bentler, P. M. (2003). Structural equation modeling. *Handbook of Psychology*, 607–634 Retrieved from https://onlinelibrary.wiley.com/doi/pdf/10.1002/9781118133880.hop202023.
Van Eerde, W., & Thierry, H. (1996). Vroom's expectancy models and work-related criteria: A meta-analysis. *Journal of Applied Psychology*, *81*(5), 575. https://doi.org/10.1037/0021-9010.81.5.575.
Veenman, S., van Benthum, N., Bootsma, D., van Dieren, J., & van der Kemp, N. (2002). Cooperative learning and teacher education. *Teaching and Teacher Education*, *18*(1), 87–103. https://doi.org/10.1016/S0742-051X(01)00052-X.
Voogt, J., Fisser, P., Good, J., Mishra, P., & Yadav, A. (2015). Computational thinking in compulsory education: Towards an agenda for research and practice. *Education and Information Technologies*, *20*(4), 715–728. https://doi.org/10.1007/s10639-015-9412-6.
Wing, J. (2011). Research notebook: Computational thinking—What and why. *The Link Magazine*, *6* Retrieved from http://people.cs.vt.edu/~kafura/CS6604/Papers/CT-What-And-Why.pdf.
Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, *49*(3), 33–35 Retrieved from https://www.microsoft.com/en-us/research/wp-content/uploads/2012/08/Jeannette_Wing.pdf.
Xu, X. (2011). The relationship between language learning motivation and the choice of language learning strategies among Chinese graduates. *International Journal of English Linguistics*, *1*(2), 203–212 Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.935.4393&rep=rep1&type=pdf.
Yang, H. H., Feng, L., & MacLeod, J. (2019). Understanding college students' acceptance of cloud classrooms in flipped instruction: Integrating UTAUT and connected classroom climate. *Journal of Educational Computing Research*, *56*(8), 1258–1276. https://doi.org/10.1177/0735633117746084.
Yilmaz, R. (2017). Exploring the role of e-learning readiness on student satisfaction and motivation in flipped classroom. *Computers in Human Behavior*, *70*, 251–260. https://doi.org/10.1016/j.chb.2016.12.085.
Zainuddin, Z. (2018). Students' learning performance and perceived motivation in gamified flipped-class instruction. *Computers and Education*, *126*, 75–88. https://doi.org/10.1016/j.compedu.2018.07.003.

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