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Computational Thinking Development: Validating an Instrument for Self-regulated Learning Using Animation

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Abstract: Animation is a useful tool for supporting students' self-regulated learning (SRL). We present the validation of an instrument for assessing students' SRL using animations during their computational thinking (CT) development. The participants were 442 junior secondary students who took part in an initiative using block-based programming for CT development. Animations were created for each curriculum unit, and the students could use these animations to monitor their own learning. Following the SRL literature, we identified four theoretical SRL sub-constructs: goal setting, performance monitoring, time management, and self-reflection. The items were adapted from existing instruments for use in assessing students' SRL using animations. Confirmatory factor analysis showed that the four-factor model fitted the data well. This result indicated a better fit than a three-factor model based on a three-phase theoretical model for SRL. The four-factor model also indicated invariance across genders. The results provide evidence for the validity of the instrument; therefore, it can be used to assess students' improvements based on their SRL using animations.

Keywords: Animation, computational thinking, self-regulated learning

1. Introduction

Computational thinking (CT) is an essential skill set for the next generation (Wing, 2006). While several block-based programming environments have been developed to support CT development activities, students' CT development should not be taken for granted (Zhang & Nouri, 2019). Self-regulated learning (SRL) emphasises students' role in monitoring their own learning (Zimmerman, 2000), which follows the importance of student empowerment in CT education (Kong, Chiu, & Lai, 2018). Animation is a useful tool for supporting students' SRL (Iyer, Sharma, Sahasrabudhe, Garg, & Lokhande, 2021) and addressing learner diversity (Barak & Dori, 2011). However, the relationships among animation, SRL, and CT are less explored. In this study, we develop and validate an instrument for assessing students' SRL using animations during their CT development. Following the development of this instrument, we can explore students' learning using animations during their CT development and evaluate whether animations can be a possible way to address the issue of learner diversity, which is identified as a problem in CT education (Angeli & Giannakos, 2020). We address the following research questions: What factors should be included in the instrument for students' SRL using animations? Can the factor models be confirmed using the students' data?

2. Literature review

2.1 Self-regulated Learning

Garcia, Falkner and Vivian (2018) described SRL as students' active control of their learning process through managing their thoughts, behaviours and emotions to navigate their learning experiences successfully and achieve their learning goals. In addition, SRL has been recognised as a critical predictor of students' academic motivation and achievement. Scholars have shown that young learners are engaged by SRL activities (Alvi & Gillies, 2021). Zimmerman (2000) developed a three-phase cyclical model using forethought, performance, and self-reflection phases. The forethought phase concerns preparing for and increasing learning attempts, the performance phase concerns self-control and the self-monitoring of one's performance during the learning process, and the self-reflection phase concerns performance evaluation, which helps students generate their self-reactions on how to improve their performance of the task in the future.

2.2 Computational Thinking and Self-regulated Learning

Peters-Burton, Cleary and Kitsantas (2018) highlighted the relationship between SRL and CT as involving a goal-directed process whereby the learner is required to identify a problem, examine relevant data to inform a solution and develop and evaluate their solution. According to Wing (2006), CT is a universal attitude and ability that anyone can acquire, not just computer scientists. Students are exposed to CT during programming activities, which involves resolving problems through the application of computer science concepts and practices, such as abstraction, debugging, remixing and iteration (Wing, 2006). Programming activities can efficiently assist kindergarten to year 12 (K-12) students in their CT development (Fessakis, Gouli, & Mavroudi, 2013). However, students do not learn programming skills easily (Angeli & Giannakos, 2020). Compared with traditional programming language learning, block-based programming languages, such as Scratch and App Inventor, reduce unnecessary syntax; therefore, they are frequently used in K-12 contexts (Lye & Koh, 2014).

2.3 SRL using animations for CT Development

Animation-based learning interactively combines text, images, sound, and video to assist student learning (Sastradika, Iskandar, Syefrinando, & Shulman, 2021). Animations help students to understand their learning materials, for enhancing their learning outcomes (Dori, Barak, & Adir, 2003) and motivation to learn (Rosen, 2009). Educators extensively use animations to provide their students with immediate, engaging feedback (Morales Díaz & Gaytán-Lugo, 2016). Iyer et al. (2021) found that interactive animations can play a role in students' learning by helping them to observe their learning process and reflect on their learning outcomes via feedback, which fosters their SRL (Zimmerman, 2000). Moreover, Animations provide students with enjoyable and interactive learning experiences, making it an effective tool for teaching CT (Morales Díaz & Gaytán-Lugo, 2016). Therefore, SRL using animations is a potential scaffold in assisting students' CT development.

2.4 Measurement of SRL

Several survey instruments have been developed to measure SRL (e.g., Barnard, Lan, To, Paton, & Lai, 2009; Schraw & Dennison, 1994) and can be mapped onto the three-phase theoretical model for SRL by Zimmerman (2000). Important sub-constructs in each of these three phases were also identified (Peters-Burton et al., 2018; Schunk, 1990; Wolters & Brady, 2021). In the forethought phase, 'goal setting' is one of the first steps for students to engage in learning activities since it provides standards for assessing learning performance. (Schunk, 1990). In the performance phase, 'time management' is crucial to academic success (Wolters & Brady, 2021) because it helps students use time effectively to achieve learning goals (Claessens, van Eerde, Rutte, & Roe, 2007). In addition, it is important for students to monitor their performance using strategies and resources (Barnard et al., 2009). Therefore, 'performance monitoring' is also important during this phase. In the self-reflection phase, students evaluate and react to their performance to judge how well they performed and why. The students can adjust their learning strategies afterward (Peters-Burton et al., 2018). Despite all of these being important SRL sub-constructs in the literature, they have seldom been included in a single instrument for assessing students' SRL (Jansen, van Leeuwen, Janssen, Kester, & Kalz, 2017). To the best of our knowledge, no measurement assesses the role of animations in students' SRL. In studying the importance of SRL and how the use of animations facilitates students' SRL for CT development, an instrument is needed to measure students' SRL using animations.

3. Method

3.1 Research Context

The background of this study is a pilot scheme for promoting students' SRL about programming using animations in their CT development in junior secondary high school. Four local secondary schools were recruited. The students learned a curriculum across eight teaching units using App Inventor to create mobile apps in a block-based programming language. After completing the eight units, the students were required to create an open-ended final project. To ensure that the teachers could guide their students to learn programming using animations in CT development, a 1.5-hour workshop was organised for the teachers to help them understand the basics of CT, how to use App Inventor for CT development, the curriculum structure, and how to guide their students' engagement in SRL using animations and worksheets. All of the learning and teaching materials, including the unit outlines, worksheets, and animations for each teaching unit, were presented to the teachers at the workshop.

3.2 Design of the Animation

The design of the animation was according to the steps outlined by the seven-step model of CT teaching (Kong & Lai, 2021) based on the technological pedagogical content knowledge (TPACK) framework (Mishra & Koehler, 2006). It began with the introduction of the new technological components such as list in App Inventor, followed by the CT concepts and practices involved, such as data structures and testing and debugging respectively. Then the animation guided the students to think how to approach the programming task, such as decomposing it into sub-tasks. Then it guided the students to code in the programming environment of App Inventor for finishing the app. Afterwards, the students were guided to think about the possible use of the technological components in other occasions and reflect on the concepts and practices that they had learned.

3.3 Participants and Procedures

The participants were 442 S2 (year two of junior high school) and S3 (year three of junior high school) students (aged 13 and 14 years) from four local schools (S2: N = 338, 76.6%; S3: N = 103, 23.4%), with 39.8% male (N = 176) and 60.2% female (N = 266) students. Before they started learning the programming curriculum for CT development using animations, the students were asked to complete an online SRL survey for programming using animations, which took them around 10 minutes.

3.4 Development of the SRL Instrument

In developing our SRL using animations instrument based on Zimmerman's four sub-constructs, namely goal setting, performance monitoring, time management and self-reflection, we searched for existing instruments and identified two instruments: the Online Self-regulated Learning Questionnaire (OSLQ) (Barnard et al., 2009) and the Metacognitive Awareness Inventory (Schraw & Dennison, 1994). We adapted the items from these two instruments to make them suitable for assessing SRL using animations. For example, for goal setting, we adapted the item '*I set short-term (daily or weekly) goals as well as long-term goals (monthly or for the semester)*' (Barnard et al., 2009) by modifying it into '*I know how to set up sub-goals to achieve the goal of watching the animation*'. Sub-goals could include problem formulation and problem-solving in finishing the final project. The resulting instrument has 12 items (i.e., four goal-setting items, three performance-monitoring items, three time-management items and two self-reflection items), which are each answered using a 5-point Likert scale (see Table 1). To ensure face validity of the instrument, all items were reviewed and revised by an expert with computer science and educational research backgrounds, followed by another expert with computer science background and teaching experience in secondary schools to further ensure that the items could be understood by secondary students.

3.5 Data Analysis

We first checked whether the assumption of normal data distribution could be verified. The skewness and kurtosis values were all within an absolute value of 1, suggesting that there was no violation of the assumption (see Table 1). We then validated our instrument by checking whether the collected data were compatible with the theoretically constructed factor model through a confirmatory factor analysis (CFA). To check the model's goodness of fit, we used the root mean square error of approximation (RMSEA) with a value smaller than .08 indicating a reasonable error of approximation, in addition to the Tucker–Lewis index (TLI) and comparative fit index (CFI), both with a value larger than .90 indicating an acceptable fit and .95 indicating a good fit. We compared the four-factor model described above with the three-factor model based on the three-phase model for SRL (Zimmerman, 2000).

4. Results

4.1 Confirmatory Factor Analysis

The goodness-of-fit indices showed that the four-factor model provided an acceptable fit to the data, (Chi square / degree of freedom (χ^2/df) = 3.121, $p < .001$, RMSEA = .069, CFI = .975, TLI = .965). The standardised factor loading estimates from the factors to the observed variables were all higher than the benchmark value of .50 (Raykov & Marcoulides, 2008). The 12 items and their corresponding factors are presented in Table 1. To check whether the two 'performance phase' factors of time management and performance monitoring could be combined as suggested by the three-phase model for SRL (Zimmerman, 2000), we fitted the three-factor model to the data. We kept goal setting as Factor 1 and self-reflection as Factor 3, whereas the items belonging to time management and performance monitoring formed Factor 2. The CFA results indicated the inadequate fit of the three-factor model to the data (χ^2/df = 5.584, $p < .001$, RMSEA = .102, CFI = .942, TLI = .966). In the comparison of the two models, a significant χ^2 reduction ($\Delta\chi^2$ = 134.967, Δdf = 3, $p < .01$) was found from the three-factor to the four-factor model, indicating that the latter had a better fit to the data.

Table 1. *Loadings of the Items based on the Four-factor Model and their Descriptive Statistics*

Sub-constructs	*Factor loading*	*Mean*	*SD*	*Skewness*	*Kurtosis*
Goal setting					
1. I know how to set up sub-goals to achieve the goal of watching the animations.	0.81	3.42	1.01	−.258	−.196
2. I receive guidance from my teachers on how to achieve the goals in stages.	0.81	3.45	.99	−.442	.156
3. I have autonomy to achieve the goals in my own way.	0.83	3.49	1.05	−.412	−.094
4. I am clear about the main goal for watching the animations.	0.72	3.63	.96	−.295	−.188
Performance monitoring					
5. I shall use the animations and student guide when I have difficulties during the coding process.	0.83	3.43	1.11	−.330	−.371
6. I watch the animations because they help me to understand coding and computational thinking.	0.86	3.41	1.07	−.287	−.247
7. If I cannot understand the concepts and coding practices in the animation fully, I will watch it again.	0.81	3.49	1.10	−.356	−.392
Time management					
8. I can arrange an appropriate time and location to watch the animation.	0.77	3.44	1.05	−.315	−.214

9. I can schedule enough time to watch the animations.	0.78	3.60	1.03	−.416	−.203
10. I make sure I keep up with the overall progress in the course by watching the animations.	0.85	3.59	1.06	−.446	−.214
Self-reflection					
11. I like the part of the animations that lead my reflection on the goal of coding and connection to daily life.	0.84	3.43	1.03	−.269	−.136
12. In my learning process for coding, I continuously reflect on what I have learned in completing my final programming project.	0.85	3.44	1.04	−.274	−.200

Note: SD stands for Standard Deviation

To evaluate the measurement invariance across genders, we conducted a multi-group analysis (male and female students) based on the four-factor model. The results are presented in Table 2, with the fitting of a configural invariance model (baseline, Model 1), a metric invariance model (Model 2) and a scalar invariance model (Model 3), which all indicated an acceptable fit. The comparison between Models 1 and 2 indicated metric invariance because there was no significant change in χ^2 ($\Delta\chi^2 = 3.520$, $\Delta df = 8$, $p = .898$). The comparison between Models 1 and 3 also indicated scalar invariance ($\Delta\chi^2 = 9.259$, $\Delta df = 20$, $p = .980$). Therefore, the four-factor model indicated invariance across genders.

Table 2. Measurement Invariance across Genders

	χ^2	df	p-value	RMSEA	CFI	TLI
Configural invariance (Model 1)	283.527	96	<.001	.067	.954	.937
Metric invariance (Model 2)	287.047	104	<.001	.063	.955	.943
Scalar invariance (Model 3)	292.786	116	<.001	.059	.957	.951

5. Conclusion and Implication

Empowerment is an important aspect in students' development of CT (Kong et al., 2018). The emphasis on SRL in education facilitates students' control of their learning process, which subsequently empowers them in their learning. Animations have been found to be useful in supporting students' SRL (Iyer et al., 2021). As such, they can be used as a teaching resource in students' CT development through programming activities (Kong & Lai, 2021). In this study, we developed and validated an instrument for assessing students' SRL using animations for CT development. Using this instrument, we can assess students' learning gains when they use animations for CT development. Based on the SRL literature, we identified goal setting, performance-monitoring, time-management and self-reflection sub-constructs, which can be mapped onto the three-phase theoretical SRL model proposed by Zimmerman (2000), with goal setting belonging to the forethought phase, performance monitoring and time management belonging to the performance phase and self-reflection belonging to the self-reflection phase. This four-factor model was confirmed by the CFA results, which indicated a better fit compared to the three-factor model with the middle two sub-constructs combined as one sub-construct. The invariance analysis also suggested that the four-factor model can be verified among both male and female students. The establishment of this instrument allows researchers to further investigate changes in students' SRL using animations following interventions. Animation-based learning enhances students' engagement and knowledge transfer (Rosen, 2009). Teachers can use our instrument to explore whether the involvement of animations in teaching can help students to achieve a higher level of SRL. To this end, it is important for schools and policymakers to provide financial support for the creation of learning-oriented animations, as well as teacher development programs to facilitate animation-based learning in schools. A limitation of this study is that since the project is ongoing, we have not yet collected sufficient post-test data for CFA. The data analysed were based on pre-test findings, before the students started learning CT using animations. We will continue to examine students' improvement in SRL after using the animations to support their CT development.

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