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Nurture interest-driven creators in programmable robotics education: an empirical investigation in primary school settings

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Abstract

In response to the call from the founders of the Interest-Driven Creator (IDC) theory, this study aimed to explore the relationship of the interest loop with creativity in the context of robotics education. Specifically, we designed a programmable robotics course for primary school students. We attempted to explore in detail how interest loop, i.e., triggering interest, immersing interest, and extending interest, exerts influences on students' robotics creation. Eight hundred one online questionnaires were collected from students who participated in our designed programmable robotics activities. Confirmatory factor analysis (CFA) was first used for validation of each study variable, and results suggested a good fit of the study variables in terms of convergent and discriminant validity. Then, structural equation modeling (SEM) was conducted for examining the potential relationships between them, and results indicated significant and positive paths from triggering interest to immersing interest, and from immersing interest to extending interest, suggesting the valid theoretical proposition of interest loop of IDC theory. In addition, immersing interest is positively related to robotics creation, which in turn increases the chance of extending interest. Our findings suggested the importance of raising students' interest in robotics learning such that young students can become life-long interest-driven creators. Implications of the study were discussed at the end of the paper.

Keywords: Interest loop, Interest-driven creator, Primary school education, Programmable robotics education, Robotics creation

Introduction

The orientation of Asian education is considered as examination driven. A lot of Asian students, including those in Taiwan, Hong Kong, Singapore, China, and India, consider learning hard as the only way of scoring high in examinations (Chan et al., 2018; Lee, Johanson, & Tsai, 2008). To them, high examination scores are considered as a criterion to prove a student's worth at school, and a green light for being admitted to ideal schools for further education (Kirkpatrick & Zang, 2011). Previous researchers cautioned that Asian students demonstrate low interest, and lack confidence in their learning as examination-orientated culture seems to have been entrenched within the Asian education system, leading to the inevitable drawback: students find it hard to develop interest in learning (Chan et al., 2018). However, those researchers do not object to such high-stakes examinations per se; they pointed out the necessity of recognizing the adverse effects of the examination-driven system on students' learning and meanwhile advocated government-initiated reforms to improve the current situation. To succeed in this fast-paced era, the young generation must adopt habits of lifelong learning and equip themselves with real-life skills (Chan, 2013). In modern society, technology foresees accelerated changes in our daily life: cloud computing, virtual reality, robotics, artificial intelligence, etc. have increasingly penetrated every aspect of our life. Particularly, it is expected that robotics in the coming future will have even broader applications in social, medical, work, military domains, etc. For example, more robots will work in high-risk environments in order to save people from life-threatening work tasks. Automation equipment will be planted to factories, firms, and organizations to enhance work efficiency and ensure quality output. Researchers indeed realized that technology plays an increasingly preeminent role in our daily life (Chan et al., 2018). Equipping the young generation with essential knowledge and skills of technology use seems to be a must in the coming future. Therefore, educators should inspire the young generation to engage in the learning of new technology, to undertake creative activities exploring technology, and to maintain the learning interest in technology.

Recently, Chan et al. (2018) have formulated the Interest-Driven Creator (IDC) theory for promoting learning with interest and creativity. The theory is operationalized through the design principal of three components: interest loop, creation loop, and habit loop. To answer the call from those authors, we attempted to explore potential applications of those loop models that guide learning reforms in the programmable robotics context. A growing body of literature suggested that programmable robotics enhances the development of students' critical thinking, problem-solving, and metacognitive skills (Atmatzidou, Demetriadis, & Nika, 2018) and helps effective learning of a programming language (Álvarez & Larrañaga, 2016). In addition, other researchers found that programmable robotics promotes a joyful learning environment for fostering students' motivation, collaboration, self-efficacy, and creativity (Toh, Causo, Tzuo, Chen, & Yeo, 2016). Therefore, programmable robotics seems to be an effective tool which not only stimulates students' interest and motivation, but also fosters their essential skills to excel in this technological world.

In our study, we focused on the interest loop model. According to the IDC theory, interest is considered as the very basic factor that motivates young students to start learning and is the first anchored concept to facilitate creation loop and habit loop at later stages (Chan et al., 2018). The target participants of this current research are primary school students; thus, we believed that it is of utmost importance to first trigger interest in those young students before they can immerse themselves in relevant activities and internalize their learning interest to become habitual interest-driven creators.

Literature review

Robotics education in the twenty-first century

Robotics education is defined as the application of educational robotics activities in the context of teaching and learning (Misirli & Komis, 2014). A wide range of choices of robots is available for accommodating different requirements and age groups among students (Mubin, Stevens, Shahid, Al Mahmud, & Dong, 2013). There are generally three types of robots, namely, mechanical robotics kit, electronic robotics kit, and humanoid robotics kit. For instance, mechanical robotics kit can be utilized to perform a single function, such as reacting or responding to sources of sound or following a line (McComb, 2008). For electronic robotics kit, it refers to kits that are fully programmable and students can upload scripts onto them (Mubin et al., 2013). Furthermore, humanoid robotics kit is considered as fully embodied agents that can be used in both informal and formal education (Tanaka & Matsuzoe, 2012). Humanoid robots can engage in social interaction through facial expressions and talking. In recent years, programmable robotics is considered as a valuable tool for students from preschool to high school across different school subjects and disciplines (Alimisis, 2013). According to Eguchi (2013), programmable robotics can offer fun activities in an attractive learning environment, feeding students with curiosity and interest. Indeed, studies in the field of robotics education found that robotics has a positive impact on students' learning in different subject areas, such as Physics, Mathematics, and Computer Sciences; meanwhile, it also has impact on personal development including creative thinking, problem solving, and decision making, which are the essential skills in the twenty-first century (Benitti, 2012).

IDC theory and interest loop

IDC theory posited three concepts, namely, interest, creation, and habit, which respectively formed a loop model that consists of three phases. Specifically, for interest loop, it starts from triggering to immersing to extending (see more details of discussion on the loop models in Chan et al., 2018). Interest is very crucial because when students learn with interest, learning becomes enjoyable and effective. This is particularly the case when they learn for the sake of themselves. Hidi (2006) defined interest as a psychological state in which an individual exhibits greater positive feelings, concentration, and attention. Students are more willing to make discoveries if they show a greater interest in programmable robotics. Indeed, when students with learning interest encounter obstacles, they are more determined and persistent to seek creative solutions and more confident in overcoming task difficulties (Kong & Wang, 2019; Ryan & Deci, 2017). Figure 1 shows the conceptual framework of interest loop.

Triggering interest

Triggering interest is characterized by curiosity, which is the first phase of the interest loop model. Previous studies evidenced that robotics can be a great motivational and inspirational tool for students to increase their curiosity and interest in learning (Apiola, Lattu, & Pasanen, 2010; Hashimoto, Kato, & Kobayashi, 2011). Robotics activities are new to young students' daily learning environment, and therefore, the innovative way of using robots in teaching and learning may raise students' curiosity. In addition, robotics activities facilitate a more student-centric approach that provides learning-by-doing and hands-on experience, which is more entertaining compared to the conventional teacher-centric practice (Zawieska & Duffy, 2015).

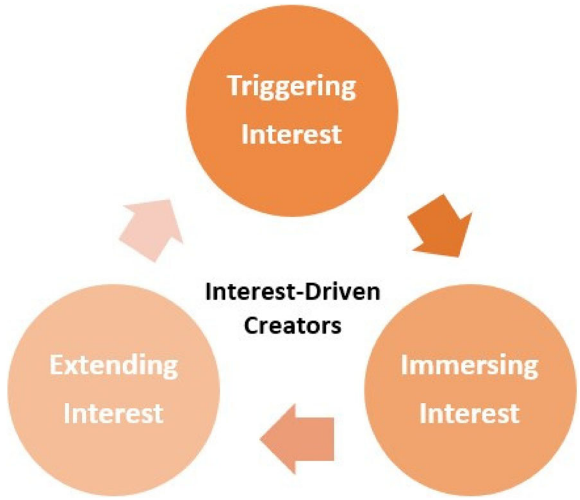

Fig. 1 Conceptual framework of interest loop

Immersing interest

People may find themselves immersed in the activity, which is the second phase of the interest loop model—immersing interest. The full immersion can also be regarded as entering flow. Flow is posited as a subjective state when people are completely involved in something to the point of forgetting time, fatigue, and everything else but the activity itself (Csikszentmihalyi, 1991). When students are fully immersed in the programmable robotics activities, they maintain a high level of confidence in balancing the perceived challenges and skills (Chan et al., 2018). Thus, they can effectively generate new artifacts through integrating and transforming existing ideas (Liu, Chen, Lin, & Huang, 2017).

Extending interest

When young students start to make sense of their experience in doing programmable robotics activities and relate what they have learned to their daily life, they enter the last phase of the interest loop model—extending interest. Extending interest is characterized by meaningfulness (Chan et al., 2018). If individuals believe that their accomplishment of a task is meaningful, they will become more self-motivated and make extra effort to complete the task (Spreitzer, Kizilos, & Nason, 1997). Many researchers pointed out that robotics is a potentially rich source of meaningful learning (e.g., Ali & Goh, 2014). Liu (2010) carried out a survey investigating the learning experience of robotics among 318 elementary school students. Students reported that they should learn robotics because it is their future.

Hypothesis testing

Triggering interest ➔ immersing interest ➔ extending interest

According to the interest loop, triggering interest is the first and inevitable phase when students start to develop interest in new learning activities. To maintain students' interest and engagement in programmable robotics, IDC theory suggested that learning activities should be designed to promote immersing interest, i.e., entering flow by awaking students' curiosity at first (Chan et al., 2018). Curiosity arises when individuals are motivated to close the knowledge or information gap presented (Loewenstein, 1994). The interest of doing programmable robotics activities will be reinforced if students successfully fix the identified bug, as the correct fixation is considered as a clear reward for closing the knowledge gap (Wilson et al., 2003). In short, curiosity motivates students to start searching for explanations and solutions for activities that they are interested in.

IDC theory proposed that in order to further sustain students' interest, extending interest must be cultivated. Extending interest is referred to as meaningfulness. Researchers suggested that meaningfulness is a source of intrinsic motivation to buttress task commitment and persistence (Thomas & Velthouse, 1990). Past studies revealed that people who are interested in a subject are more likely to appreciate its meaningfulness. For example, Kong, Chiu, and Lai (2018) suggested that interest in programming is crucial for fostering perceived meaningfulness among primary school students. They further argued that interested students are more likely to engage in programming activities and to discover the impacts of programming. Therefore, according to the above review, we concluded the following hypothesis:

H1: Trigger interest will increase the chance of immersing interest which further increases the chance of extending interest among young students who learn programmable robotics.

Immersing interest ➔ robotics creation

According to the IDC theory, in order to cultivate lifelong creators, it is important to design learning activities that trigger, immerse, and extend interests of students. We argued that the connection between interest and creation stems from the flow of creativity. Csíkszentmihályi first came up with the concept of flow when he was exploring creativity in the visual arts (Nakamura & Csíkszentmihályi, 2005). Cseh (2016) also described that "Flow and creativity have been closely intertwined from the very beginning." For example, recent studies revealed that the creativity ratings of the music composed by university students are positively related to the level of flow experienced by them (Byrne, MacDonald, & Carlton, 2003). These findings suggested that experiencing flow could foster creative behaviors. We proposed a term called "robotics creation" in this study. Programmable robotics by its nature is a combination of engineering design and computer programming, which comprises a series of creative procedures, such as generating ideas, designing, problem-solving, and presenting products (Yildiz-Durak, 2018). Here, we tried to capture students' creative efficacy in order to depict flow rather than examining their real-time flow experience during programmable robotics activities. It is because the efficacious belief of challenge-skill balance is the critical precondition of flow experience and the fundamental dimension of flow measurement (Csikszentmihalyi, 1988). Yang and Cheng (2009) suggested that programmers with computer efficacy are capable of learning new technological skills that provide them resources and flexibility when engaging in programming activities. In a similar vein, we argued that when students have creative efficacy in programmable robotics, they will perceive themselves capable of tackling technical problems with innovative solutions. In order to enter flow, students must perceive a skill-challenge balance: they have to possess not only the required knowledge and skills but also the creative efficacy that they believe they have to produce creative outcomes. Thus, we concluded the following hypothesis:

> H2: Immersing interest will increase the chance of robotics creation among young students who learn programmable robotics.

Robotics creation ➔ extending interest

Robotics creation may further foster perceived meaningfulness of programmable robotics activities. Meaningfulness is cultivated by learning the interconnection between new knowledge and old concept in daily life (Reigeluth, 1983). Creation activities are the means to make this connection more salient. During the process of robotics creation, students learn from the feedback and gain the experience and ability to identify good ideas. They then gradually realize the value and significance of their creation (Chan et al., 2018). Kong et al. (2018) argued that successful task completion will foster students' empowerment, of which perceived meaningfulness is one of its key ingredients. Students will be further motivated to create as they recognize the benefits towards their own personal development (Kong, Wang, & Lai, 2019; Schöber, Schütte, Köller, McElvany, & Gebauer, 2018). This type of motivation is called "identified regulation" (Ryan & Deci, 2017) which implies students' internalized experiences of meaningfulness. Similarly, students who engage in robotics activities with "identified regulation" will find a close connection between programmable robotics and their daily life, which further enhances the sense of meaningfulness of programmable robotics activities. Therefore, based on the above review, we concluded the following hypothesis:

> H3: Robotics creation will increase the chance of extending interest among young students who learn programmable robotics.

Methodology

Participants

Survey questionnaires were created online using Google Form. The invitation link was generated and sent to the target schools. The students who enrolled in our research show great intention in learning programmable robotics. More specifically, grade 5 students from 31 primary schools participated in this study. On average, 26 students from each participating school joined. Students were asked to submit answers to the questionnaire online before the end of a class. On average, it took about 5 min for them to complete the survey. Among the resulting sample of 801 primary school students, 69.8% were boys and 30.2% were girls. Most students (85.9%) came from aided school, while the remaining students (14.1%) came from direct subsidy schools and government-funded schools, which was comparable with type of schools in the region.

Course implementation

All participants in the current study enrolled in the programmable robotics course we developed. The course content is the same for all participating schools, but it can be tailored according to the needs of each school. Basically, the course is designed with 10 units of teaching materials to guide students through programmable robotics activities. Students spend around 60 to 70 min to complete each unit and approximately 10 to 12 h to complete the entire course. Each unit is designed with one problem-solving task in which robotics activities are involved. Each problem-solving task covers the core concepts that students should learn and master. Teachers introduced the core concepts at the beginning of each class with practical demonstrations. In class, students had full access to the mBot robots, computers, and tablets. They were strongly encouraged to discuss the potential solutions with their group members because interactive problem-solving allows knowledge construction and provides opportunities for students to engage in creative activities. One example is "Mars exploration." It is a robotics activity where the mBot detects light intensity with ultrasonic sensors in a simulated environment of Mars. Students learned to program for the two different conditions: the mBot rotated when lights out; it stopped when lights on. Through this task, students learned the core concepts such as conditionals, operators, events, data manipulation, testing, and debugging. More specifically, when students programed the mBot with "if…then…" blocks, they practiced the concept of conditionals. In addition, when students wanted their mBot to detect light intensity, they used operators, such as "<" and "=", to define the intensity. Moreover, students were also taught the key concept of testing and debugging in this unit to make sure that the mBot could function normally as they expected. The ultimate goal of the course is to stimulate and sustain students' interests toward robotics learning and to equip them with critical knowledge and skills, so that they can be effective in problem-solving with more creative solutions in the future.

Instrumentation

Six experts (i.e., psychology, education, and computer sciences backgrounds) from research and curriculum development team were involved in the instrumentation development. Six topics, namely interest, meaningfulness, impact, creative efficacy, robotics creation, and collaborative learning, were proposed by the team in order to capture students' learning process of programmable robotics based on the literature review on the IDC theory, design thinking, robotics education, and empowerment theories (e.g., Brown, 2008; Chan et al., 2018; Kong et al., 2018). Conceptual definitions for each topic are further discussed for item development. These experts brainstormed and generated an initial pool of potential items for each specific topic. The most frequently proposed items were listed and modified until each expert reached a consensus. For evaluation on content validity, the experts reviewed the newly created items and revised the ambiguous ones. Finally, a group of research assistants, who were not involved in item development, was invited to discuss and examine the face validity of the new instrument in terms of its relevance and comprehensiveness within each topic. Finally, 21 items in total were remained: interest (3 items), creative efficacy (4 items), meaningfulness (4 items), impact (3 items), robotics creation (3 items), and collaborative learning (4 items).

Measures

In the current study, we focused on the following four subscales as they are the key study variables depicting the interest loop model and the potential relationship between interest and creation according to our theoretical framework. All the subscales were developed in English and then translated into Chinese. Potential discrepancies were modified for the instrument after back-translation. All items were anchored on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). Demographic variables such as gender, class, school type, and school district were collected as control variables for this study.

Triggering interest is measured by the three-item subscale of interest. The sample item is "I am curious about the content of programmable robotics activities." *Immersing interest* is measured by the three-item subscale of creative efficacy. One item was deleted in the study due to the cross-loading issues. The sample item is "I have the skills and knowledge to complete tasks of programmable robotics activities." *Extending interest* is measured by the 4-item subscale of meaningfulness. The sample item is "Programmable robotics activities will help me achieve my goals." *Robotics creation* is measured by the three-item subscale of robotics creation. The sample item is "I design things through programmable robotics activities." For details of the instrument, please refer to Appendix 1.

Results

Descriptive statistics

The descriptive statistics and reliabilities of the key variables were computed in SPSS 25. Cronbach's alpha coefficients of the key variablesranged from .81 to .87, indicating a good internal consistency. In addition, positive correlations were found among the four variables: triggering interest, immersing interest, extending interest, and robotics creation. Table 1 presents the descriptive results and Pearson correlation.

Confirmatory factor analysis (CFA)

As previously mentioned, the reliabilities of the four study variables which ranged from .81 to .87 were considered satisfying. In order to further examine the construct validity, multiple CFAs were conducted for the four study variables in Mplus 7.4. Results showed that each variable demonstrates strong convergent validity. Specifically, the factor loadings for trigger interest (.83–.84), immersing interest (.73–.79), extending interest (.71–.84), and robotics creation (.76–.82) were all satisfying.

Moreover, competing models analysis was conducted to ensure the four study variables were distinct from each other. Fourteen alternative models were compared to our default four-factor model (M0). Specifically, different key variables were forced to load on one bigger latent factor. For example, for an alternative three-factor model (M1), the two factors (i.e., triggering interest and immersing interest) merged as one big factor, and thus, all the measuring items of these two factors loaded on the common big

Table 1 Mean, standard deviations, and reliability coefficients of the study variables (N = 801)

	Mean	SD	Skewness	Kurtosis	1	2	3	4
1. Triggering interest	4.11	.94	− 1.16	1.03	(.87)			
2. Immersing interest	3.84	.93	− .67	− .01	.66**	(.84)		
3. Extending interest	4.02	.81	− .87	.77	.77**	.67**	(.86)	
4. Robotics creation	4.15	.81	− 1.15	1.46	.72**	.63**	.79**	(.81)

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; * denotes p-values at different significance levels

factor, while extending interest and robotics creation remained as distinctive factors in M1. In this study, the model fit statistics evidenced that M0 has the optimal fit (see Table 2). According to Hu and Bentler (1999), CFI and TLI which are greater than .90 indicates a good fit, and greater than .95 indicates an excellent fit. RMSEA in the range of .05 to .08 also indicates acceptable fit (Browne & Cudeck, 1993), and smaller RMSEA indicates better model fit. In addition, chi-square difference tests were conducted to test if the models are different at statistical significance level. We also included ΔCFI. A value smaller than − .01 indicates invariance (Dimitrov, 2010). Results indeed suggested that M0 is statistically better than the rest of the models (see Table 3). Therefore, according to our findings, the four key variables were distinctive from each other. Thus, the discriminant validity of the four study variables was also supported.

Structural equation model

SEM analysis was conducted for hypothesis testing using Mplus 7.4. In this study, the hypothesized theoretical model showed a good fit with the data collected (χ^2 (60) = 336.36, p < .000, CFI = .96, TLI = .95, and RMSEA = .08). We provided a summary table for the variances explained of each study variable (Appendix 2).

Hypothesis 1 posited that students' triggering interest is positively related to immersing interest, and their immersing interest is positively related to their extending interest. The SEM results showed significant paths from triggering interest to immersing interest (β = .92, S.E. = .01, p < .001) and from immersing interest to extending interest (β = .34, S.E. = .09, p < .001). Thus, hypothesis 1 was supported. Hypothesis 2 posited

Table 2 Results of competing models of study variables

	χ2	df	χ^2/df	CFI	TLI	RMSEA
Four-factor models:						
M0 (default model)	224.39	59	3.80	.98	.97	.06
Three-factor models:						
M1 (triggering and immersing)	491.26	62	7.92	.94	.92	.09
M2 (triggering and extending)	377.61	62	6.09	.95	.94	.08
M3 (triggering and creation)	355.62	62	5.74	.96	.95	.08
M4 (immersing and extending)	502.61	62	8.11	.93	.92	.09
M5 (immersing and creation)	482.20	62	7.78	.94	.92	.09
M6 (extending and creation)	247.84	62	4.00	.97	.97	.06
Two-factor models:						
M7 (triggering and immersing + extending and creation)	514.67	64	8.04	.93	.92	.09
M8 (triggering and extending + immersing and creation)	626.55	64	9.79	.92	.90	.11
M9 (triggering and creation + immersing and extending)	623.19	64	9.74	.92	.90	.10
M10 (triggering and immersing and extending)	642.15	64	10.03	.91	.90	.11
M11 (triggering and immersing and creation)	614.39	64	9.60	.92	.90	.10
M12 (triggering and extending and creation)	407.60	64	6.37	.95	.94	.08
M13 (immersing and extending and creation)	534.29	64	8.35	.93	.91	.10
One-factor models:						
M14 (single factor model)	678.76	65	10.44	.91	.89	.11

Triggering triggering interest, *Immersing* immersing interest, *Extending* extending interest, *Creation* robotic creation

Table 3 Results of chi-square difference tests

	Comparison	χ^2 diff	ΔCFI
Four-factor vs. three-factor (best)	M0-M6	23.45***	− 0.01
Three-factor (best) vs. two-factor (best)	M6-M12	159.76***	− 0.02
Two-factor (best) vs. one-factor	M12-M14	271.16***	− 0.04

that immersing interest is positively related to robotics creation. Results indicated that this relationship is significant (β = .90, S.E. = .02, p < .001). Therefore, hypothesis 2 was also supported. Hypothesis 3 proposed that robotics creation is positively related to extending interest. Results indicated that this relationship is significant as well (β = .63, S.E. = .09, p < .001). Thus, hypothesis 3 was supported. To summarize, the overall findings provided supporting evidence for our theoretical framework. Figure 2 shows the results of path coefficients of this study.

Additional analysis

The main focus of our study is to investigate the interest model proposed in the IDC theory. Therefore, it is important for us to obtain a clear understanding of how interest forges in different phases. According to the theory, triggering interest in the students is the first critical step before they can sustain their interest and remain in flow for specific tasks they enjoy. Only with the sustainable interest can they have the chance to realize the autotelic nature of their actions, and the higher purpose resides in them. Therefore, we conducted a more robust analysis for interest loop with mediation analysis for the relationship of triggering interest ➔ immersing interest ➔ extending interest. The latent factor scores for each study variables were generated and saved. We conducted mediation test with bias-corrected bootstrapping method (2000 resamples).

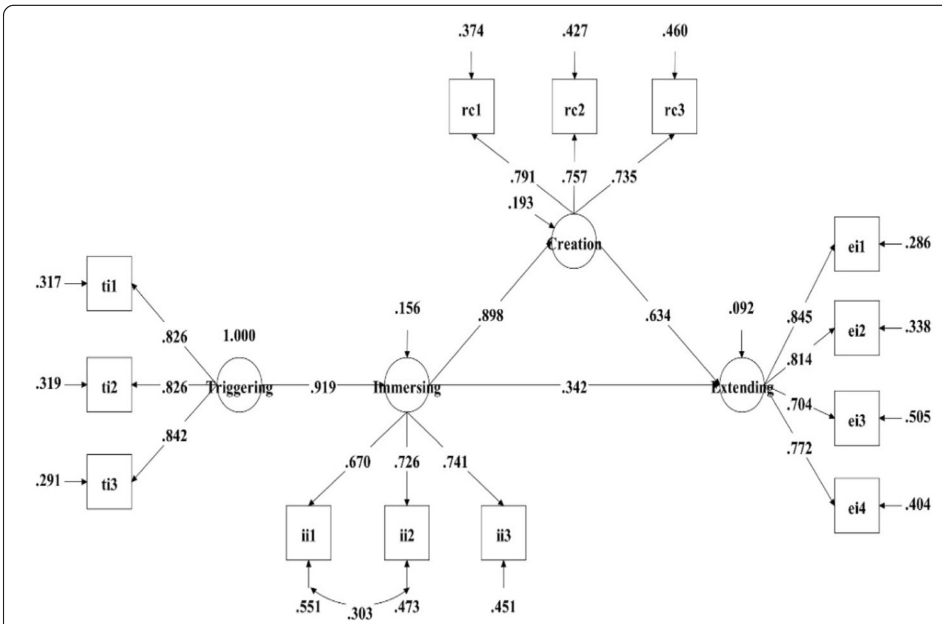

Fig. 2 Results of path coefficients. *Note*. Triggering = triggering interest; Immersing = immersing interest; Extending = extending interest; Creation = robotic creation

Results revealed significant indirect effect of triggering interest on extending interest through the mediator of immersing interest (indirect effect = .86; 95% CI = [.83, .89]), which provides further support for the theoretical validation of interest loop.

Discussion

This study aimed to explore how to nurture interest and creation in programmable robotics education among young students. According to the IDC theory, in order to grow young students into habitual interest-driven creators in learning, it is important to ignite students' curiosity in the subject matter as the first step. Previous researchers pointed out that interest is the outcome brought by the interaction between a person and a particular content, meaning that interest is always content-specific and not a personal attribute that can be applied across activities (e.g., Krapp, 2000). For example, a boy who shows interest in math is likely to be influenced by his family background, where his father is a data scientist and his mother is a math teacher. However, his interest in math is unlikely to be transferred to painting, if he finds no situational interest to stimulate his curiosity and positive feelings in painting. In educational research, there are two main types of interest, namely situational interest and individual interest. Situational interest is triggered by environmental stimuli, which may not last over time, whereas individual interest is a person's relatively enduring predisposition over time (Harackiewicz, Durik, Barron, Linnenbrink-Garcia, & Tauer, 2008). Based on the past research, situational interest may be a precursor to the predisposition to reengage particular content for the development of individual interest (e.g., Alexander, 2004; Renninger & Hidi, 2002; Hidi & Renninger, 2006; Harackiewicz et al., 2008). For example, in an entertaining drama class for pre-school children, class teachers first try to catch students' attention and stimulate their interest by adopting interactive teaching approaches that encourage students to explore and interact. In addition, these teachers try to provide course materials that are designed to be personally meaningful and valued for their students such that students' interest can be maintained in the class. Supported by past evidence, if classroom factors (e.g., friendly and supportive learning environment, encouraging teachers, autonomy in learning, opportunities to think and question) promote the development of meaning and value among students, situational interest may be maintained over time. If this maintained interest can further endure beyond the particular situation and is associated with the accumulation of knowledge and value, it may eventually become a deeply-held individual interest (Hidi & Renninger, 2006; Krapp, 2002). The development from situational interest to individual interest echoes the process of interest development in the IDC theory. More specifically, this theory proposed the interest loop model for articulating the theoretical assertion of interest development in different phases, that is triggering interest, immersing interest, and extending interest. The three phases are considered as sequential and distinct. They are also accumulative in terms of progressive development. For each phase of interest development, varying amounts of effort, self-efficacy, goal setting, and self-regulated behaviors are found to characterize each phase of interest development (Lipstein & Renninger, 2006). More specifically, the later phases ignite more effort and engagement than the earlier phases. Previous researchers (Alexander, 2004; Krapp, 2002; Renninger & Hidi, 2002) also pointed out that early phases of interest development primarily consist of focused attention and positive feelings. However, the later phases are found to include not only positive feelings but also stored value and knowledge that ask for deliberate practice, task engagement, and person-object interactions. For example, in Lipstein and Renninger's (2006) study, they found that students in the earlier phases of interest development (i.e., the phase of triggering interest) for writing put limited effort in writing practice and also show little self-efficacy about their abilities to write. In addition, these students reported that they simply want to get assigned writing tasks done and did not show much interest to persevere to write. In contrast, students in later phases of interest development (i.e., the phase of extending interest) showed an emerging individual interest, and they devoted a lot of time to their writing. Unlike their counterparts in the earlier phases, they were found with a higher level of self-efficacy about writing; moreover, they reported themselves scaffolded by the presence of interest and persistence in writing.

There are several contributions that should be noted in the current study. Firstly, our study adopted the interest loop model for a thorough examination of how students start to develop interest in programmable robotics, and more importantly, how interest will contribute to robotics creation. Our research is among the few studies that go in-depth for investigation of interest in different phases. To our best knowledge, it is the first study that has conducted mediation investigation for the interest loop model proposed by the IDC theory (Chan et al., 2018). More importantly, this current study attempted to provide a comprehensive picture of how interest in different phases is related to robotics creation. Indeed, findings of the study supported that programmable robotics as an effective pedagogical tool can successfully trigger students' interest in learning (triggering interest), which leads to a greater chance for active engagement of students in programmable robotics activities (immersing interest), and consequently leads to students' greater awareness of the value in programmable robotics activities (extending interest). Our findings also indicated that when young students are in the phase of immersing interest, that is a phase with more intensive focus, happiness, and efficacy, they are more likely to involve in robotics creation, and consequently, they grow a stronger sense of meaningfulness regarding their creations as well as robotics education as a whole.

Secondly, though we believed that robotics activities have tremendous potential to improve learning, previous researchers cautioned for inadequate empirical evidence to prove the impact of robotics on the K-12 curriculum (Williams, Ma, Prejean, Ford, & Lai, 2007). Many of us believed that robotics provides a source of energy that can be used to motivate children's learning. In general, results of past studies showed a learning gain with the use of robotics (e.g., Álvarez & Larrañaga, 2016; Atmatzidou et al., 2018; Toh et al., 2016). However, some other studies also found that there are indeed cases where the use of robotics has not brought any significant increase in young students' learning (e.g., Barker & Ansorge, 2007; Hussain, Lindh, & Shukur, 2006; Lindh & Holgersson, 2007; Nugent, Barker, Grandgenett, & Adamchuk, 2009; Sullivan, 2008; Williams et al., 2007). Therefore, robotics may be reduced to fashion, if researchers do not provide empirical evidence to support its impact on young students' academic outcomes. These mixed findings on robotics education could be due to the fact that previous research tends to be descriptive in nature, rather than empirical designs that utilize quantitative data collections, experiments, or comparative methods (Chambers, Carbonaro, & Murray, 2008; Petre & Price, 2004). More specifically, most previous studies relied on observation and interview results with small sample sizes (e.g., Barker & Ansorge, 2007 [n = 14]). In this regard, we felt the urge to explore robotics education with a more rigorous empirical design. Unlike the previous research, our study employed a relatively large student sample (N = 801) for the empirical investigation of how students' interest in programmable robotics will develop and how interest will eventually convert into robotics creation (one of the indicators of students' learning outcome) using SEM analytical approach. In this study, we provided additional evidence that validates the assertion of past studies: robotics activities are useful and beneficial to young students in terms of academic outcomes, especially in primary school contexts.

Practical implication

In our study, programmable robotics activities are considered successful to trigger, immerse, and extend the interest among young students. Our results showed that in order to promote robotics education successfully, a sharp focus on raising students' interest and curiosity is of the uttermost importance. This finding served as a reminder for educators and teachers to design the pedagogical approaches that can trigger and maintain students' interest. As previously discussed, when situational interest is elicited and maintained over time through repeated engagements, effort, and self-efficacy, a more stable and enduring form of interest, namely individual interest, is expected to emerge. Therefore, teachers may realize the critical importance of providing situational interest for robotics activities before their students are able to form individual interest, and consequently become interest-driven creators. In our study, we considered teachers as the most important facilitator in robotics education. Yet, many of them do not realize their potential role in helping students to develop interest in programmable robotics (Lipstein & Renninger, 2006). In fact, most teachers show fixed mindset: they think that students either have or do not have interest, without realizing that they can actually contribute to their students' development of interest. Based on the review on existing interest literature, there are several pedagogical suggestions to offer for teachers who strive to improve educational practice. In the earlier phases of interest development, teachers should put more effort in fostering students' positive feelings towards robotics education to ensure solid content knowledge to be obtained by their students. Orchestration of a supportive environment for learning programmable robotics may also enhance students' positive affective for interest development. For example, Long and Murphy (2005) demonstrated the impact of classroom teachers' own interest for the subject matter on students' interest. Their findings highlighted the importance of teachers' friendly communication and role-modeling in students' development of interest. We considered these external supports particularly critical in the earlier phases of interest development, because teachers are most able to help students feel positive about their emerging abilities within the context. Positive feelings may be facilitated by offering choice in tasks (Flowerday & Schraw, 2003), promoting a sense of autonomy (Hascher & Hagenauer, 2016), being supportive for developing the knowledge, and building a sense of competence (Hidi & Renninger, 2006).

What can be said is that programmable robotics has great potential to assist in teaching and learning. However, positive learning outcomes are not guaranteed just by the simple application of robotics, as it depends on how teachers play their roles as facilitators in class. As previously mentioned, their knowledge, attitudes, and behaviors all impact students' learning effectiveness. Teachers are strongly encouraged to put more effort in pedagogical designs in order to increase responsiveness, strengthen supportive behaviors, and reinforce interest-driven learning for better student outcomes (Kong & Wang, 2018). However, a general lack of teacher professional development is one major obstacle for teachers to come up with effective pedagogical approaches that can stimulate students' interest in learning. This fact brings up another issue in robotics education. Vollstedt, Robinson, and Wang (2007) pointed out that another obstacle in implementing effective robotics education is rooted in insufficient teachers' trainings on computer use. They observed that many teachers show discomfort when using computers, which impedes their confidence in answering students' questions. This discomfort with the use of computers makes the teachers reluctant to teach programming to their students. Even worse is that students' motivation of learning will be further impeded when they receive negative signals from their teachers.

In addition, the Curriculum Development Council (2015) pointed out that most students lack the hands-on experience in school. Therefore, they pointed out the necessity of strengthening students' ability by applying their skills and knowledge to real practice. Previous researchers and educators questioned whether the traditional, teacher-centered curriculum can meet the diverse learning needs of students. Traditional teacher-centered approach focuses on the transmission of knowledge. The content of knowledge, learning activities, and goals are set by teachers. On the other hand, student-centered approach focuses on the cognitive learning process of students. This approach addresses different needs of students and encourages them to take initiates by exploring what they want to know with more autonomy (Pedersen & Liu, 2003). As researchers suggested (McCombs & Whisler, 1997), one of the major advantages of student-centered approach is that the students are likely to develop interest in the learning process. Therefore, more educational practitioners should realize that student-centered approach can be a key element in the successful implementation of robotics education in class. In our study, the programmable robotics course was designed for teachers who can adopt an interactive problem-solving approach by fully engaging students to learn and use technological devices, such as mBot robots and computers, for the creation of robotics artifacts. In this course, teachers are facilitators, rather than dominators. They play a supportive role by providing timely feedback and instructions, when students are in face of difficulties.

Our programmable robotics course may serve as a stepping-stone, and we encourage that more interested researchers invest their effort in the further refinement of the course content that we developed for more effective learning of students. Only a well-designed course on programmable robotics will stimulate and maintain students' curiosity and interest in learning.

Limitations and future research

Like any other research, several limitations will be discussed as follows. Firstly, all participants were given a self-rated survey questionnaire to report their learning interest in programmable robotics. According to previous researchers (Demetriou, Ozer, & Essau, 2014), one major limitation of self-report method might be the possibility of providing untruthful answers, because participants tend to answer the questions in a socially acceptable way. This phenomenon is known as social desirability bias. In addition, response bias might also impair the validity and reliability of the questionnaire, which is an individual's tendency to respond in a certain way regardless of the question (e.g., disengaged participants will rate all questions identically). These biases in answering the survey are likely to contaminate the data quality. Thus, we highly suggested that multiple sources of ratings (e.g., teachers', peers', parents' ratings) and more objective scores (e.g., project scores, test scores) can be adopted in the future research so as to derive a more accurate and precise examination on how robotics education can benefit young students. Moreover, we also encourage the inclusion of qualitative data in future quantitative studies, especially for empirical studies adopting survey designs. Although survey designs are known to be cost-effective, easy to administer, and capable of collecting data from a relatively large number of respondents, they still face the vulnerability of lower validity rate (see discussions above) than some other types of design, for example, in-depth interviews and focused group discussions (Wright, 2005). Unlike a survey questionnaire with rating scales, these approaches are conducted with an intention of revealing participants' views and attitudes in great details. Thus, empirical studies that include interviews or discussions might reach more comprehensive findings as qualitative data can triangulate the statistical evidence of which numbers sometimes fall short of a good explanation.

Secondly, this study adopted a cross-sectional design to investigate the relationships of the study variables. Specifically, we attempted to investigate the interest loop model proposed by the IDC theory. Though our results showed preliminary mediation evidence for the validation of interest loop: triggering interest ➔ immersing interest ➔ extending interest, this cross-sectional design was inadequate to test the recursive loop (i.e., a virtuous circle of enhanced interest) proposed by the theory, that is extending interest can further trigger interest in programmable robotics. In the future, longitudinal designs with multiple waves of observations are preferred in order to test the recursive loop of the interest model.

Thirdly, according to the IDC theory, we should seriously consider how and why students' interest can be triggered, immersed, and extended before we design learning activities for the purpose of encouraging students to create. Our study has not yet explored in details how different pedagogical designs can contribute to the cultivation of lifelong interest of students in the programmable robotics context. Past studies revealed that problem-based learning approach increases the perceived meaningfulness of learning (Sobral, 1995) and project-based learning approach encourages innovation and triggers interest of learning (Marasco & Behjat, 2013). Therefore, future studies should be conducted to further our knowledge regarding the impact of various pedagogical designs on students' learning interest, more specifically, how these pedagogical designs uniquely benefit the cultivation of interest in different phases.

Up till now, most of the applications of robotics introduced in educational settings are unnecessarily narrow (Rusk, Resnick, Berg, & Pezalla-Granlund, 2008). Mitnik, Nussbaum, and Soto (2008) also pointed out that the use of robots in programmable robotics is very often treated as an end or a passive tool in learning activities, where the robots have been constructed or programmed (Mitnik et al., 2008). They further emphasized the importance of providing multiple pathways into robotics to ensure active engagement of young students by taking care of their diverse interests and learning styles. For example, young students who show no interest in traditional approaches of teaching and learning of robotics are likely to be motivated when robotics activities are introduced in a more innovative way (e.g., storytelling), or in connection with other disciplines and interested areas, such as music and art (e.g., Rusk et al., 2008). We advocate that future researchers devote more attention to exploring a broader way of robotics activities in school settings, where students' learning interest can be successfully triggered and sustained.

Appendix 1

Instrument items:

Triggering interest

1. Programmable robotics activities are interesting.
2. I am curious about the content of programmable robotics activities.
3. I am very attracted to programmable robotics activities.

Immersing interest

1. I am good at programmable robotics activities.
2. I have the skills and knowledge to compete tasks of programmable robotics activities.
3. I have confidence in my ability to complete tasks of programmable robotics activities.

Extending interest

1. Programmable robotics activities are useful to me.
2. Programmable robotics activities will help me achieve my goals.
3. I want to be good at programmable robotics activities.
4. Programmable robotics activities are important to me.

Robotics creation

1. I like to design things through programmable robotics activities.
2. I learn through programmable robotics activities that there are many different ways to solve a problem.
3. When I am doing programmable robotics activities, being creative is important.

Appendix 2

Table 4 R^2 for the theoretical model

	R^2
Triggering interest:	–
ti1	0.690
ti2	0.688
ti3	0.697
Immersing interest:	0.799
ii1	0.613
ii2	0.550
ii3	0.520
Extending interest:	0.918
ei1	0.711
ei2	0.661
ei3	0.501
ei4	0.595
Robotic creation:	0.640
rc1	0.626
rc2	0.742
rc3	0.650

Abbreviations

CFA: Confirmatory factor analysis; IDC: Interest-driven creator; SEM: Structural equation modeling

Authors' contributions

Both authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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References

Alexander, P. A. (2004). A model of domain learning: Reinterpreting expertise as a multidimensional, multistage process. In D. Y. Dai & R. J. Sternberg (Eds.), *Motivation, emotion, and cognition: Integrative perspectives on intellectual functioning and development* (pp. 273–298). Mahwah: Lawrence Erlbaum Associates, Inc..

Ali, M. B. B., & Goh, H. (2014). Robotics as a tool to stem learning. *International Journal of Innovation Education and Research, 2*(10), 66–78.

Alimisis, D. (2013). Educational robotics: Open questions and new challenges. *Themes in Science and Technology Education, 6*(1), 63–71.

Álvarez, A., & Larrañaga, M. (2016). Experiences incorporating lego mindstorms robots in the basic programming syllabus: lessons learned. *Journal of Intelligent & Robotic Systems, 81*(1), 117–129.

Apiola, M., Lattu, M., & Pasanen, T. (2010). Creativity and intrinsic motivation in computer science education: Experimenting with robots. In *Proceedings of the 15th Annual Conference on Innovation and Technology in Computer Science Education* (pp. 199–203). Ankara: ACM.
Atmatzidou, S., Demetriadis, S., & Nika, P. (2018). How does the degree of guidance support students' metacognitive and problem solving skills in educational robotics? *Journal of Science Education and Technology, 27*(1), 70–85.
Barker, B. S., & Ansorge, J. (2007). Robotics as means to increase achievement scores in an informal learning environment. *Journal of Research on Technology in Education, 39*(3), 229–243.
Benitti, F. B. V. (2012). Exploring the educational potential of robotics in schools: A systematic review. *Computers & Education, 58*(3), 978–988.
Brown, T. (2008). Design thinking. *Harvard Business Review, 86*(6), 84.
Browne, M. W., & Cudeck, R. (1993). Alternative ways of assessing model fit. In K. A. Bollen & J. S. Long (Eds.), *Testing Structural Equation Models* (pp. 136–162). Newbury Park: Sage Focus Editions.
Byrne, C., MacDonald, R., & Carlton, L. (2003). Assessing creativity in musical compositions: Flow as an assessment tool. *British Journal of Music Education, 20*(3), 277–290.
Chambers, J. M., Carbonaro, M., & Murray, H. (2008). Developing conceptual understanding of mechanical advantage through the use of Lego robotic technology. *Australasian Journal of Educational Technology, 24*(4), 387–401.
Chan, T. W. (2013). L4C: 21st century core competencies and school transformation through digital learning. *Global Chinese Journal on Computers in Education, 8*(1-2), 169–183 In Chinese.
Chan, T. W., Looi, C. K., Chen, W., Wong, L. H., Chang, B., Liao, C. C., et al. (2018). Interest-driven creator theory: towards a theory of learning design for Asia in the twenty-first century. *Journal of Computers in Education, 5*(4), 435–461.
Cseh, G. M. (2016). Flow in creativity: a review of potential theoretical conflict. In *Flow Experience* (pp. 79–94). Cham: Springer.
Csikszentmihalyi, M. (1988). The flow experience and its significance for human psychology. In M. Csikszentmihalyi & I. S. Csikszentmihalyi (Eds.), *Optimal experience: Psychological studies of flow in consciousness* (pp. 15–35). New York: Cambridge University Press.
Csikszentmihalyi, M. (1991). *Flow: The psychology of optimal experience*. New York: Harper Perennial.
Curriculum Development Council (2015). Promotion of STEM education – Unleashing potential in innovation. Retrieved June 28, 2019, from https://www.edb.gov.hk/attachment/en/curriculum-development/renewal/Brief%20on%20STEM%20(Overview)_eng_20151105.pdf.
Demetriou, C., Ozer, B. U., & Essau, C. A. (2014). Self-report questionnaires. *The Encyclopedia of Clinical Psychology*, 1–6.
Dimitrov, D. M. (2010). Testing for factorial invariance in the context of construct validation. *Measurement and Evaluation in Counseling and Development, 43*, 121–149.
Eguchi, A. (2013). Educational robotics for promoting 21st century skills. *Journal of Automation Mobile Robotics and Intelligent Systems, 8*(1), 5–11.
Flowerday, T., & Schraw, G. (2003). Effect of choice on cognitive and affective engagement. *Journal of Educational Research, 96*, 207–215.
Harackiewicz, J. M., Durik, A. M., Barron, K. E., Linnenbrink-Garcia, L., & Tauer, J. M. (2008). The role of achievement goals in the development of interest: Reciprocal relations between achievement goals, interest, and performance. *Journal of educational psychology, 100*(1), 105–122.
Hascher, T., & Hagenauer, G. (2016). Openness to theory and its importance for pre-service teachers' self-efficacy, emotions, and classroom behaviour in the teaching practicum. *International Journal of Educational Research, 77*, 15–25.
Hashimoto, T., Kato, N., & Kobayashi, H. (2011). Development of educational system with the android robot SAYA and evaluation. *International Journal of Advanced Robotic Systems, 8*(3), 51–61.
Hidi, S. (2006). Interest: A unique motivational variable. *Educational Research Review, 1*(2), 69–82.
Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 41*, 111–127.
Hu, L. T., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal, 6*(1), 1–55.
Hussain, S., Lindh, J., & Shukur, G. (2006). The effect of LEGO training on pupils' school performance in mathematics, problem solving ability and attitude: Swedish data. *Journal of Educational Technology & Society, 9*(3), 182–194.
Kirkpatrick, R., & Zang, Y. (2011). The negative influences exam-oriented education on Chinese high school students: Backwash from classroom to child. *Language Testing in Asia, 1*, 36–45.
Kong, S. C., Chiu, M. M., & Lai, M. (2018). A study of primary school students' interest, collaboration attitude, and programming empowerment in computational thinking education. *Computers & Education, 127*, 178–189.
Kong, S. C., & Wang, Y. Q. (2018). Assessing perceptions of programming education among P-12 school teachers and principals: A multigroup invariance analysis. *Journal of Psychoeducational Assessment* 0734282918787670.
Kong, S. C., & Wang, Y. Q. (2019). Positive youth development from a "3Cs" programming perspective: A multi-study investigation in the university. *Computer Science Education*, 1–22.
Kong, S. C., Wang, Y. Q., & Lai, M. (2019). Development and validation of an instrument for measuring digital empowerment of primary school students. In *Proceedings of the ACM Conference on Global Computing Education* (pp. 172–177). ACM.
Krapp, A. (2002). Structural and dynamic aspects of interest development: Theoretical considerations from an ontogenetic perspective. *Learning and Instruction, 12*, 383–409.
Lee, M. H., Johanson, R. E., & Tsai, C. C. (2008). Exploring Taiwanese high school students' conceptions of and approaches to learning science through a structural equation modeling analysis. *Science Education, 92*, 191–220.
Lindh, J., & Holgersson, T. (2007). Does lego training stimulate pupils' ability to solve logical problems? *Computers & Education, 49*(4), 1097–1111.
Lipstein, R., & Renninger, K. A. (2006). "Putting things into words": 12–15-year-old students' interest for writing. In P. Boscolo & S. Hidi (Eds.), *Motivation and writing: Research and school practice*. New York: Kluwer Academic/Plenum.
Liu, C. C., Chen, W. C., Lin, H. M., & Huang, Y. Y. (2017). A remix-oriented approach to promoting student engagement in a long-term participatory learning program. *Computers & Education, 110*, 1–15.
Liu, E. Z. F. (2010). Early adolescents' perceptions of educational robots and learning of robotics. *British Journal of Educational Technology, 41*(3), E44–E47.
Loewenstein, G. (1994). The psychology of curiosity: A review and reinterpretation. *Psychological Bulletin, 116*(1), 75–98.

Long, J. F., & Murphy, P. K. (2005). *Connecting through content: The responsiveness of teacher and student interest in a core course*. Montreal: Paper presented at the Meetings of the American Educational Research Association.
Marasco, E., & Behjat, L. (2013). Integrating creativity into elementary electrical engineering education using CDIO and project-based learning. In *Proceedings of the 2013 IEEE International Conference on Microelectronic Systems Education (MSE)* (pp. 44–47). Austin: IEEE.
McComb, G. (2008). Getting kids into robotics. *Servo magazine, 10*, 73–75.
McCombs, B. L., & Whisler, J. S. (1997). *The learner-centered classroom and school: strategies for increasing student motivation and achievement*. San Francisco: Jossey-Bass Publishers.
Misirli, A., & Komis, V. (2014). Robotics and programming concepts in early childhood education: a conceptual framework for designing educational scenarios Anastasia. In *Research on E-Learning and ICT in Education*. New York: Springer.
Mitnik, R., Nussbaum, M., & Soto, A. (2008). An autonomous educational mobile robot mediator. *Autonomous Robots, 25*(4), 367–382.
Mubin, O., Stevens, C. J., Shahid, S., Al Mahmud, A., & Dong, J. J. (2013). A review of the applicability of robots in education. *Journal of Technology in Education and Learning, 1*, 1–7.
Nakamura, J., & Csíkszentmihályi, M. (2005). The concept of flow. In C. R. Snyder & S. Lopez (Eds.), *Handbook of positive psychology* (pp. 89–105). Oxford, UK: Oxford University Press.
Nugent, G., Barker, B., Grandgenett, N., & Adamchuk, V. (2009). The use of digital manipulatives in k-12: robotics, GPS/GIS and programming. In *2009 39th IEEE Frontiers in Education Conference* (pp. 1–6). IEEE.
Pedersen, S., & Liu, M. (2003). Teachers' beliefs about issues in the implementation of a student-centered learning environment. *Educational Technology Research and Development, 51*(2), 57–76.
Petre, M., & Price, B. (2004). Using robotics to motivate 'back door' learning. *Education and Information Technologies, 9*(2), 147–158.
Reigeluth, C. M. (1983). Meaningfulness and instruction: Relating what is being learned to what a student knows. *Instructional Science, 12*(3), 197–218.
Rusk, N., Resnick, M., Berg, R., & Pezalla-Granlund, M. (2008). New pathways into robotics: Strategies for broadening participation. *Journal of Science Education and Technology, 17*(1), 59–69.
Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory*. New York: The Guilford Press.
Schöber, C., Schütte, K., Köller, O., McElvany, N., & Gebauer, M. M. (2018). Reciprocal effects between self-efficacy and achievement in mathematics and reading. *Learning and Individual Differences, 63*, 1–11.
Sobral, D. T. (1995). The problem-based learning approach as an enhancement factor of personal meaningfulness of learning. *Higher Education, 29*(1), 93–101.
Spreitzer, G. M., Kizilos, M. A., & Nason, S. W. (1997). A dimensional analysis of the relationship between psychological empowerment and effectiveness, satisfaction, and strain. *Journal of Management, 23*(5), 679–704.
Sullivan, F. R. (2008). Robotics and science literacy: Thinking skills, science process skills and systems understanding. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching, 45*(3), 373–394.
Tanaka, F., & Matsuzoe, S. (2012). Children teach a care-receiving robot to promote their learning: field experiments in a classroom for vocabulary learning. *Journal of Human-Robot Interaction, 1*(1), 78–95.
Thomas, K. W., & Velthouse, B. A. (1990). Cognitive elements of empowerment: An "interpretive" model of intrinsic task motivation. *Academy of Management Review, 15*(4), 666–681.
Toh, L. P. E., Causo, A., Tzuo, P. W., Chen, I. M., & Yeo, S. H. (2016). A review on the use of robots in education and young children. *Educational Technology & Society, 19*(2), 148–163.
Vollstedt, A. M., Robinson, M., & Wang, E. (2007). Using robotics to enhance science, technology, engineering, and mathematics curricula. In *Proceedings of American Society for Engineering Education Pacific Southwest Annual Conference*. Honolulu.
Williams, D. C., Ma, Y., Prejean, L., Ford, M. J., & Lai, G. (2007). Acquisition of physics content knowledge and scientific inquiry skills in a robotics summer camp. *Journal of Research on Technology in Education, 40*(2), 201–216.
Wilson, A., Burnett, M., Beckwith, L., Granatir, O., Casburn, L., Cook, C., Durham, M., & Rothermel, G. (2003). Harnessing curiosity to increase correctness in end-user programming. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems* (pp. 305–312). Lauderdale: ACM.
Wright, K. B. (2005). Researching Internet-based populations: Advantages and disadvantages of online survey research, online questionnaire authoring software packages, and web survey services. *Journal of Computer- mediated Communication, 10*(3), JCMC1034.
Yang, H. L., & Cheng, H. H. (2009). Creative self-efficacy and its factors: An empirical study of information system analysts and programmers. *Computers in Human Behavior, 25*(2), 429–438.
Yildiz-Durak, H. (2018). Digital story design activities used for teaching programming effect on learning of programming concepts, programming self-efficacy, and participation and analysis of student experiences. *Journal of Computer Assisted Learning, 34*(6), 740–752.
Zawieska, K., & Duffy, B. R. (2015). The social construction of creativity in educational robotics. In *Progress in Automation, Robotics and Measuring Techniques* (pp. 329–338). Cham: Springer.

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