So, H. J. et al. (Eds.) (2020). Proceedings of the 28th International Conference on Computers in Education.
Asia-Pacific Society for Computers in Education

Investigating the effectiveness of composite making instructions on secondary school integrated STEM education

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Abstract: Researchers are exploring efficient approaches to promote integrated STEM education. Though some studies have adopted making as an instructional design to develop K-12 students, few of them have purposely explored the effectiveness of different composite making instructions in cultivating learners' multiples capabilities. To fill the gap, this empirical study proposes to evaluate the effectiveness of using making only, with mentoring, and with authentic problem instructional strategies on secondary school integrated STEM education. It aims to exam the changes of students' creativity, critical thinking, STEM identity, and STEM interest development after participating in the pre-designed STEM making interventions. In this proposal, we will illustrate our research motivations, research questions, methodology, and the expected implications of the study, hoping to gain some constructive suggestions to improve this dissertation work-in-progress.

Keywords: Integrated STEM education, making, mentoring, authentic problem

1. Introduction

As maker movement becomes a cultural trend in the education field, people started to regard making as an instructional strategy to foster students' 21st century skills and psychological perceptions towards STEM education (Godhe et al., 2019; Honey, et al., 2014). Although some scholars have assessed the performance of making approach in promoting K-12 student development, few attentions have been paid to search about the mechanisms of different composite making instructions, of which the elements of mentoring and authentic problem-solving could be involved, in integrated STEM (Vongkulluksn et al., 2018). Particularly, it is desirable for educators to acquire more experience of applying various composite making instructions in the context K-12 integrated STEM education. To meet the research need, we plan to implement an empirical study to investigate the effectiveness of diverse making instructional strategies in developing secondary school students' cognitive skills (e.g., creativity and critical thinking) and non-cognitive skills (e.g., STEM identity and STEM interest). Three experimental conditions, of which the instructional strategies of making only, with mentoring, and with authentic problem, will be manipulated. Accordingly, there are a series of guiding questions for the current study:

- *Does a making with mentoring instructional design improve students' creativity, critical thinking, STEM identity, and STEM interest compared to a making instructional design?*
- *Does a making with mentoring instructional design improve students' creativity, critical thinking, STEM identity, and STEM interest compared to a making with authentic problem instructional design?*
- *Does a making with authentic problem instructional design improve students' creativity, critical thinking, STEM identity, and STEM interest compared to a control condition?*

2. Literature review

The popularity of integrated STEM education activities in K-12 schools is attracting people's attention (Honey, et al., 2014). This phenomenon mainly due to the potentials of using STEM education to prepare youth to face the uncertainties that we have never encountered before in the future world. For example, problems of public health, education equity, and environmental protection in the modern industrial society (Chiu & Lim, 2020; Jong, 2020). While, developing students' skills through STEM education reform is a challenging task (Chai et al., 2020; Geng et al., 2019). In the practice, one of the strategies adopted by educators to realize this cross-disciplinary innovation is to introduce making instruction to students. The hands-on experience of making activities can bring students opportunities to cultivate their interest in learning STEM (Vongkulluksn et al., 2018), practice their creativity and critical thinking skills (Jeng et al., 2020), and build their identities of being a member in the STEM related areas (Schlegel et al., 2019). Besides the promising outcomes of using making approach, this method is compatible with other instructional elements to facilitate integrated STEM education. It is noticeable that some studies have involved mentors and authentic problem strategies while implementing the making activity designs (Sheffield et al., 2017).

Though some scholars have investigated the feasibilities of adopting making activities, mentorships, and authentic problems to enhance integrated STEM education (Yin et al., 2019), it is rare for the existing research to compare the effectiveness of making instruction, making with mentoring instructional method, and making with authentic problem design in promoting secondary students' multiple capabilities (Jeng et al., 2020; Schlegel et al., 2019). However, from the perspective of educational practice, it is crucial to investigate different instructional designs and identify their effectiveness to maximize the learning outcomes for K-12 students. Thus, a careful mix of different instructional elements to facilitate integrated STEM education is highly recommendable in the area. The proposed study will implement three diverse making programmes in secondary schools. Students' creativity, critical thinking, STEM identity, and STEM interest changes affected by the research interventions will be detected. Educators can identify the efficiency of different making instructional designs from this investigation and pinpoint the most effective strategy to implement making activities to cultivate students' competences in integrated STEM.

3. Methodology

3.1 Research samples

A convenient sample method will be adopted to approach the research sites. Researchers will try to get access from the secondary school teachers to conduct the making programmes. Three classes of secondary students will be invited to participate in the study. They will be asked to accomplish the STEM making projects, named Smart Traffic Light Design, by using Arduino kits.

3.2 Experimental interventions

The researchers propose to use Design-Based Implementation Research (DBIR) method (Fishman et al., 2013; Jong et al., 2017) as the investigation approach. One control group and two experimental groups will conduct the research interventions respectively. The teacher in the control group will adopt making instruction to implement the making programme. Teachers of the two experimental groups will introduce other elements, including mentorships and authentic problems, to their integrated STEM making activities. For instance, students in experimental group one will receive help from the mentors while designing and making their artifacts, students in experimental group two will be assigned authentic problems to solve. This study will last for seven weeks in the participating schools, of which students will have the integrated STEM class every week. There will be four phases of the intervention, including pre-test, programme implementation, post-test, and semi-structured interviews.

3.3 Research scales

A 5-point Likert-type questionnaire, of which the scales solicited ordinal responses from 1 = strongly disagree to 5 = strongly agree, will be distributed to all the student participants. The questionnaire is designed to measure students' creativity, critical thinking, STEM identity, and STEM interest. All the items of the questionnaire should be adapted from the previously published academic works, and the Cronbach Alpha value of each subscale will be checked.

3.4 Semi-structured interviews

Semi-structured group interviews will be conducted to probe into the effectiveness of adopting making only, with mentoring, and with authentic problem approaches on students' creativity, critical thinking, STEM identity, and STEM interest development. Additionally, participants' perceptions of using different making instructional strategies to promote integrated STEM education will be explored by semi-structured interviews.

3.5 Data analysis

This study will use mixed research method. ANCOVAs will be operated to analyze the differences between the pre-test and post-test of the three groups, grounded theory (Taber, 2000) will be adopted to process the interview data.

4. Expected implications

This research will contribute to the development of integrated STEM education both from the academic and practical perspectives. It provides empirical evidence for the effectiveness of three instructional strategies (including making only, with mentoring, and with authentic problem) in promoting secondary school students' multiple capabilities (Schlegelet al., 2019; Vongkulluksn et al., 2018). As the corresponding effects of the three instructions will be identified, educators can learn from this experience and design the most effective approach accordingly (Chiu & Churchill, 2016) to cultivate students' creativity, critical thinking, STEM identity, or STEM interest.

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