The Effectiveness of Interdisciplinary Learning on 21st Century Skills for Taiwanese Elementary School Students

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Abstract
The World Economic Forum has proposed a vision of Education 4.0 in 2022, pointing out that innovative pedagogies and emerging technologies should be applied to place students at the center of learning and develop their ability to solve real-world problems. This study implemented STEAM project-based learning (PBL) combined with emerging technologies in Taiwanese elementary schools, hoping to improve students' 21st century skills (communication, collaboration, and problem solving). Seven experimental schools with 343 students from grades 4-6 participated in this study. Each school had an experimental group and a comparison group. There were 173 students in the experimental group and 170 students in the comparison group. The experimental group received STEAM PBL combined with emerging technologies, and the comparison group received traditional pedagogy. Both groups completed pre- and post-test questionnaires on communication, collaboration, and problem solving. Considering the differences in pedagogical background between the seven schools, this study applied meta-analysis to calculate the overall effect size to obtain more accurate results. The results found that the experimental group was more effective than the comparison group in improving students' communication, collaboration, and problem solving, all of which achieved medium effect sizes. It shows that STEAM PBL combined with emerging technologies can effectively increase students' 21st century skills, which is of great help to their future learning performance and career development.

Keywords: Interdisciplinary Learning, 21st Century Skills, Emerging Technologies

Introduction

World Economic Forum proposed Education 4.0 to enable students to acquire Industry 4.0 skills for future career development (World Economic Forum, 2022). Education 4.0 pointed out that it is necessary to cultivate students' 21st century skills (such as communication, collaboration, and problem solving skills) through interdisciplinary learning, innovative pedagogies, and emerging technologies to enhance global economic prosperity (World Economic Forum, 2022). STEAM project-based learning (STEAM PBL) is an innovative interdisciplinary pedagogy that integrates science, technology, engineering, arts, and mathematics (Lu et al., 2022). STEAM PBL uses real-world problems to put students at the center of learning. Students actively apply interdisciplinary knowledge and emerging technologies to develop problem-solving products (Fernández-Morante et al., 2022). In the process of developing products, students need to constantly discuss and cooperate with their group members, stimulating collective intelligence to solve problems effectively (Lu et al., 2022). In addition, emerging technologies can support students to interact with the real world more frequently and develop products that are closer to real needs (Mota-Valtierra et al., 2019). However, there is still insufficient empirical research on STEAM PBL for students' 21st century skills, so it is necessary to verify the effectiveness of STEAM PBL with empirical evidence (Perignat & Katz-Buonincontro, 2019).

According to the above research objectives, this study can be divided into the three research questions:

1. Is STEAM PBL combined with emerging technologies better for elementary school students' communication skills than traditional instruction?
2. Is STEAM PBL combined with emerging technologies better for elementary school students' collaboration skills than traditional instruction?
3. Is STEAM PBL combined with emerging technologies better for elementary school students' problem solving skills than traditional instruction?

Methods

Participants

The participants in this study came from 7 elementary schools, with a total of 343 students in grades 4-6 (170 in the experimental group and 173 in the comparison group). All seven schools participated in Taiwan's advanced interdisciplinary project for K-12 schools of the Ministry of Education. This project aims to promote STEAM PBL combined with emerging technologies to all K-12 schools in Taiwan, cultivating students' interdisciplinary knowledge, 21st century skills, and global competence.

Experimental procedure

Each of the seven schools had an experimental group and a comparison group. The experimental group received STEAM PBL combined with emerging technologies, and the comparison group received traditional instruction. Both groups received the pretests on 21st century skills before the course was implemented, and the posttests after the course ended (one semester). STEAM PBL will apply the K-12 P^5BL theory modified by Yang et al. (2022) from Fruchter (1998) to design learning activities. K-12 P^5BL includes five phases: 1) problem; 2) project; 3) product; 4) process; and 5) place. Problem means meaningful real-

world problems. Project means the learning activities related to the project. Product means authentic product. Process means students use higher order thinking skills and metacognition to optimize their products. Place means the product connects with the community and supports the United Nations Sustainable Development Goals. The emerging technologies used by the seven schools include artificial intelligence of things (AIoT), augmented reality (AR), virtual reality (VR), and drone.

Materials

This study used the communication scale (12 questions), the collaboration scale (9 questions) and the problem solving scale (17 questions) developed by Yang et al. (2022) as research tools. The three scales were all 5-point Likert scales, and the Cronbach's α ranged from .90 - .93, which had good reliability and validity.

Data analysis

Firstly, this study used analysis of covariance to calculate the effect size of each school in the three 21st century skills. Since each school had different background factors (e.g., teaching content), meta-analysis was used to integrate an overall effect size to obtain a conclusion. Hedges's g was used to identify the effect size in small sample size because most experimental and comparison groups were less than 30 people (Borenstein et al., 2009). A g between .20 to .49 is defined as small effect size, a g between .50 and .79 is defined as medium effect size, and a g greater than or equal to .80 is defined as large effect size (Cohen, 1988).

Results and Discussion

Communication

As shown in Fig. 1, the effect sizes of the seven schools ranged from .13 to .87. The overall effect size was .55, and the p-value was less than .05. The overall result reached a medium effect size. Therefore, the experimental group had better communication improvement than the comparison group. It means that STEAM PBL combined with emerging technologies can effectively improve students' communication skills.

When developing solutions to real-world problems, students are constantly discussing the most feasible solution with group members (Rahmawati et al., 2022). After translating their solution into an authentic product, students introduce the functions and value of the product to peers, teachers, and community members (Miller et al., 2021). Therefore, students continue to practice communication skills throughout the learning process (Turcotte et al., 2022).

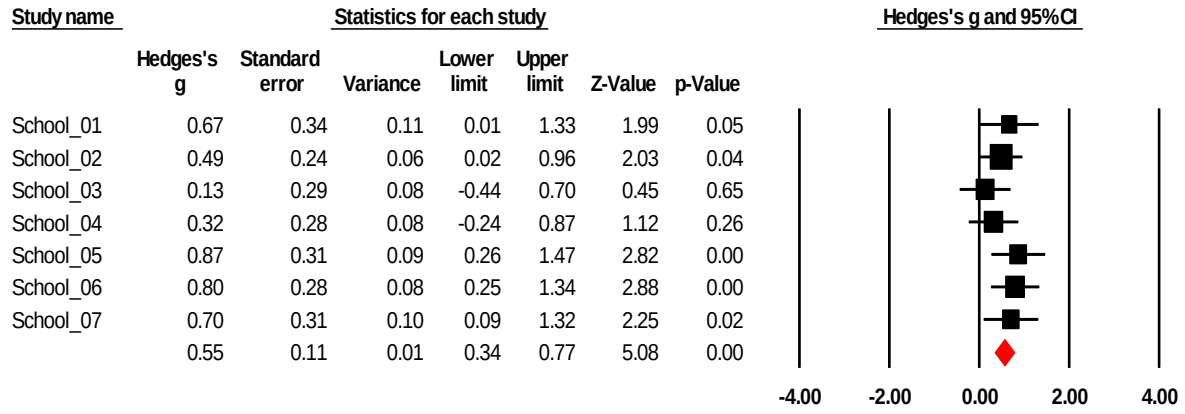

Figure 1: Effect sizes of communication of the seven schools.

Collaboration

As seen in Fig. 2, the effect sizes of the seven schools ranged from .13 to 1.16. The overall result was significant with a medium effect size (g = .51, p < .05). It showed that the experimental group had a better improvement effect in terms of collaboration. As a result, STEAM PBL combined with emerging technologies can improve students' collaboration skills.

At the beginning of the course, students need to cooperate with group members to collect information and explore the causes of real-world problems, and build a sense of responsibility toward teamwork (Melguizo-Garín et al., 2022). With the support of simulated scenarios created in AR and VR, students can brainstorm with group members to find the best solution, increasing their confidence in collaborative problem solving (Papanastasiou et al., 2019). Therefore, STEAM PBL combined with emerging technologies provides students with many opportunities for cooperative learning and develops their collaboration skills (Cheng et al., 2022).

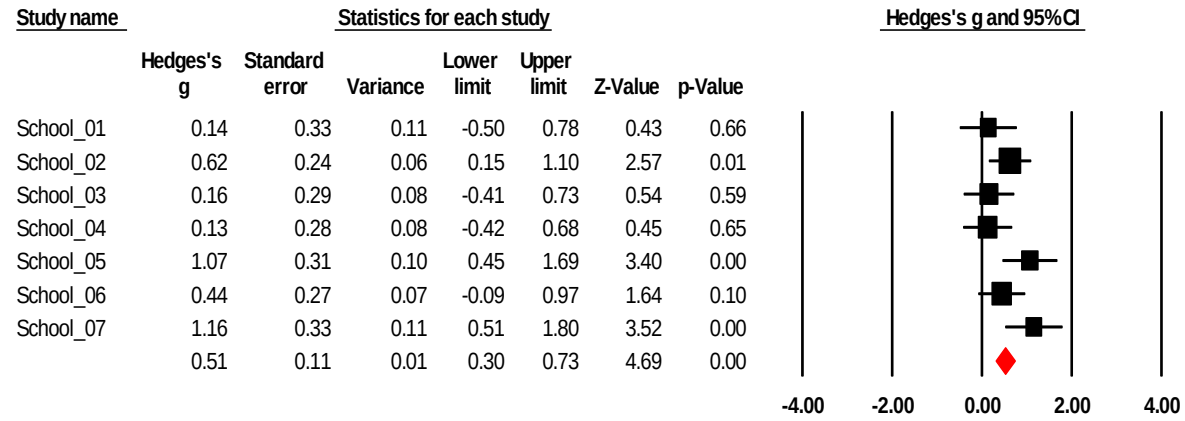

Figure 2: Effect sizes of collaboration of the seven schools.

Problem solving

As shown in Fig. 3, the effect sizes of the seven schools ranged from .14 to 1.01. The over results showed that the experimental group had a better effect on enhancing students' problem solving skills (g = .53, p < .05). It means that STEAM PBL combined with emerging technologies can positively enhance students' problem solving skills.

The real-world problems in students' lives can stimulate students' problem solving interest (Lu et al., 2022). As students develop meaningful products through hands-on activities, their motivation to solve problems increases (Mursid et al., 2022). AIoT allows students to interact frequently with the real world and improve their problem solving experience through trial and error (Auerbach et al., 2018). Therefore, the authentic situated learning created by STEAM PBL combined with emerging technologies can effectively enhance students' problem solving skills (Fernández-Morante et al., 2022).

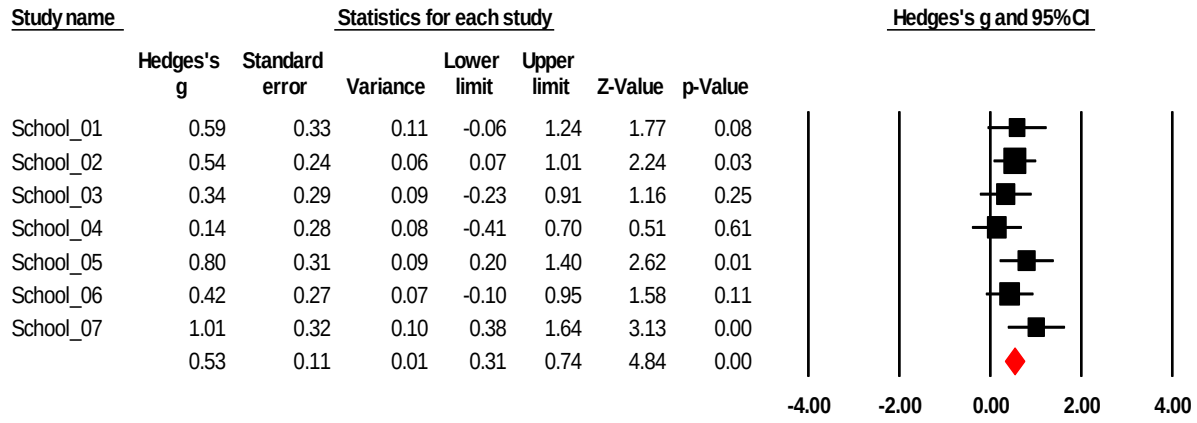

Figure 3: Effect sizes of problem solving of the seven schools.

Conclusions and Recommendations

In order to cultivate interdisciplinary talents required by Education 4.0, this study demonstrated that STEAM PBL combined with emerging technologies can improve students' 21st century skills (communication, collaboration, and problem solving skills). 21st century skills can enhance students' future learning performance and career development, and promote global economic development (World Economic Forum, 2022). In addition, creativity and critical thinking skills are 21st century skills and higher order thinking skills that are very important for students' learning growth (Wijnen et al., 2021). It is suggested that the effectiveness of STEAM PBL combined with emerging technologies on students' creativity and critical thinking skills can be further analyzed in the future.

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