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E-B Environment - Behaviour Proceedings Journal

ISSTM-TEd 2024

https://isstm-ted.uitm.edu.my/

e-IPH e-International Publishing House Ltd., United Kingdom

International Symposium on Strategy & Transformation Management For Tertiary Education

Virtual Symposium

14 – 16 Oct 2024

Main Organiser: Universiti Teknologi MARA (UiTM)
Co-Organiser: East Kazakhstan Technical University (EKTU)

ICT-Based Collaborative Learning: Effects and cultivation of university student problem-solving skills

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Abstract
Universities must deliver various types of learning, including collaborative approaches across institutions and the integration of ICT for virtual, ubiquitous education. This study implemented three activities: (1) hybrid learning combining experiential and virtual training, and (2) project-based collaborative learning linking university and high school students in community scenarios. Learning was facilitated without time limits using technologies like the metaverse, and the effectiveness of these methods was evaluated.

Keywords: Collaborative; ICT; Metaverse; PBL

DOI: https://doi.org/10.21834/e-bpj.v10iSI34.7474

1.0 Introduction

Global higher education systems face increasing pressure to equip graduates with the competencies needed for complex and evolving societal challenges. Rapid digital advancement, expanding virtual learning environments, and sustainability concerns highlight the limitations of traditional, lecture-based instruction (Bitar & Davidovich, 2024). The World Economic Forum (2023) identifies analytical thinking, problem-solving, collaboration, and digital literacy as essential future skills. UNESCO (2021, 2022) similarly emphasizes ICT-supported collaborative learning to strengthen engagement and skill development. Despite these priorities, many students still demonstrate gaps in higher-order thinking, and collaboration between schools and universities, though encouraged in Malaysia and Japan, remains inconsistently implemented and under-evaluated.

This study aims to addresses gaps in ICT-enhanced collaborative learning by examining structured hybrid models that connect theory to authentic contexts, integrating metaverse-supported experiential learning, and extending collaboration beyond universities and

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DOI: https://doi.org/10.21834/e-bpj.v10iSI34.7474

affiliated schools. Empirical evidence on cross-level partnerships involving universities, high schools, and communities remains limited, particularly regarding learning outcomes and student well-being.

2.0 Literature Review

ICT tools have transformed collaborative learning by enabling communication and knowledge co-construction across physical distances. Research from López et al. (2024, pp. 1-15) highlights that while the metaverse offers potential for immersive simulations, risk-free experimentation, and the use of digital twins in educational settings, there is currently a limited body of research on its effective implementation, particularly in Latin American contexts (Alfaisal et al., 2024; Zhang et al., 2022). Nevertheless, empirical studies on metaverse applications in collaborative learning across educational levels remain limited. PBL strengthens learners' communication, teamwork, and problem-solving abilities. When implemented in real-world contexts involving industry or community partners, PBL enhances students' motivation and application of knowledge. However, cross-institutional PBL involving high schools and university students together is relatively uncommon (Kitami & Yamauchi, 2022). Partnerships between universities and secondary schools promoted smoother transitions to tertiary education and broadened experiential learning opportunities. Yet, these collaborations typically involve affiliated schools only (Central Council for Education, 2018), creating a gap in widespread or community-embedded models. The

3.0 Methodology

Three types of collaborative educational activities were implemented in this study.

3.1 Hybrid Learning Combining On-site and Virtual Spaces

A hybrid learning system integrating experiential field visits and metaverse-based simulations was implemented in a compulsory third-year water and wastewater engineering course at a Malaysian public university. Designed to support SDG 6 (Clean Water and Sanitation), the approach enabled students to visualise complex treatment processes typically inaccessible in real settings. Surveys and interviews captured students' learning experiences. Through proposing treatment solutions, students evaluated system performance against local environmental standards while demonstrating understanding of sustainability and societal impacts, consistent with the Engineering Accreditation Council (EAC,2024) programme outcomes. The hybrid design enhanced participation, inquiry, and group analytical skills within authentic civil engineering contexts.

3.1.1 Learning Activities

The study involved 37 students, divided into five groups. Each group began by listing all possible water and wastewater treatment process alternatives and arranging them by operational stages. To gain practical understanding, the students conducted academic visits to water and wastewater treatment plants, enabling interaction with industry experts and direct observation of treatment processes. Tasks were assigned within each group as follows: (1) identifying treatment plants and requesting visitation approval, (2) gathering background information through online research, (3) preparing interview questions for plant specialists, and (4) consulting the college to secure official approval for the visits. This structured approach ensured active participation, collaborative planning, and practical learning experiences. Before the task execution, the students were given an explanation about commonly used water and wastewater treatment processes using a metaverse EON-XR created by the lecturer. An existing model from a library was used for a detailed explanation using AI, as shown in Figure 1.

The metaverse is an immersive digital environment that creates realistic virtual spaces to support interactive learning (Al Faisal, 2024). It allows students to safely explore complex ecological systems and sustainability issues while enabling experimentation not feasible in real settings (Damaševičius & Sidekerskienė, 2024). Through digital twins, VR, AR, and XR technologies, authentic and detailed learning scenarios can be constructed (Zhang, 2022). Its ability to replicate real-world processes, including water treatment systems, enhances conceptual clarity. In this study, insights from academic visits were integrated with EON XR activities, enabling students to analyse water and wastewater treatment impacts collaboratively within a virtual environment.

Fig. 1: Process of exchange learning

3.2 Learning through High School – University Collaborative Activities

This section presents an exploration of the contents and educational activities involving collaboration between Japanese university and high school students under a partnership in which the students engage in joint learning activities. This practice was started based on the 1999 report "The Improvement of the Connection between Elementary and Secondary Education and Higher Education," submitted by the Central Council for Education under the Ministry of Education, Culture, Sports, Science and Technology. Traditionally, this collaboration involved university-affiliated high schools (Central Council for Education, 1999).

3.2.1 Outline of Practical Activities

The high school-university collaborative activity described herein involves third-year students from High School A and university students. The participants in this activity had already studied 1) information processing-related subjects, 2) accounting-related subjects, and 3) management-related subjects. Students were engaged in a series of marketing activities: 1) target setting (consumer needs analysis), 2) product development, 3) price setting, 4) promotion (advertising and sales methods), and sales channel selection (Figure 2). In collaboration with a local business operator, the students developed both Western-style sweets and Japanese sweets.

The participants in this highly collaborative activity included 30 students, with 15 from High School A and 15 from the university. In the first session, students filled out a pre-implementation questionnaire, were briefed about the activity workflow, and introduced themselves. In the second session, the students were divided into six mixed groups of five students each. Of the six groups, three planned to develop Western-style sweets, whereas another three planned to develop Japanese sweets. In the third session, the high school and university students attended a marketing class to review the marketing process from target setting to sales practice. High school students served as leaders in three of the groups and summed up the opinions of their groups. In the fourth session, after reviewing the target-setting process for each group, students gathered information from the internet about products that matched the needs of their target audience. The fifth session involved representatives from a cooperating company, a business operator specializing in Japanese-style and Western-style sweets. The company representatives introduced themselves and held discussions with the student groups to address whether the necessary raw materials could be procured and whether it was technically feasible to manufacture the products to be developed. Based on these discussions, each group reviewed the product to be developed in the subsequent sixth and seventh sessions. The sixth session was held in high school classrooms for high school students, whereas university students participated from home online because of the spread of the COVID-19 pandemic. Each group then consolidated its ideas. In the eighth session, each group discussed and reviewed the related contents with the cooperating company and finalized the product to be developed.The ninth session specifically addressed fine adjustments to the design, size, and taste of the products in collaboration with the cooperating company. In the tenth session, students created trial visions of the products under the guidance of the cooperating company, using the cooking classroom at the College of Contemporary Education, Chubu University. The activity allowed them to understand the product-making process and the time necessary, and to experience taste testing. In the 11th session, students made further refinements after taste-testing the final products. Each group also considered the quantity to be sold and researched information about packaging options. By the end of the 12th session, students had chosen the packaging to be used and had set the prices. They determined the prices by considering what would be affordable for their target customers and the costs of raw materials. For the package selection, each group made decisions after discussing the sales price, sales venue, and target audience. The 13th and 14th sessions dealt with the creation of flyers, posters, and point of purchase (POP) displays.

The 15th session implemented sales practice activities. In the final 16th session, an evaluation meeting was held. A post-implementation questionnaire was administered. The results are discussed in the next section.

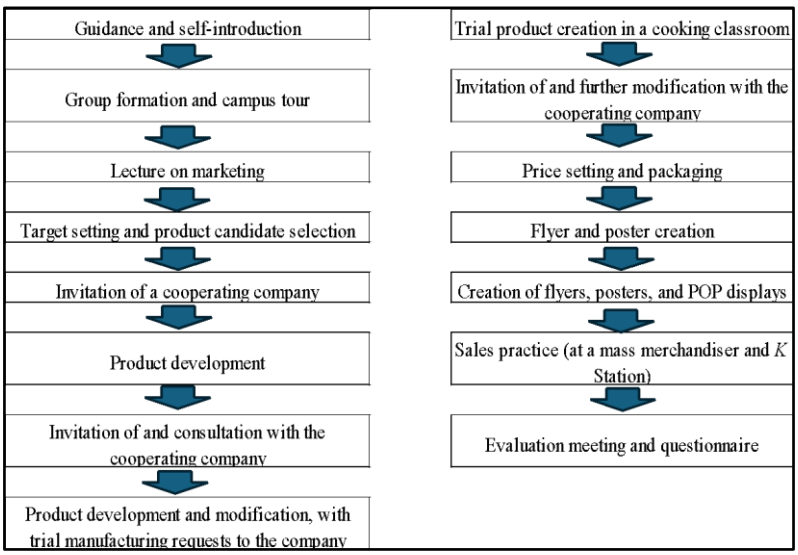

Fig. 2: Workflow of High School – University Collaborative Activities

3.3 Collaborative Learning for Local Community Revitalization and Student Well-being

In Society 5.0, not only university students but also elementary, junior high, and high school students must be trained to independently identify problems, explore solutions, and develop skills in problem-solving and presentation. At the university level, it is additionally important to learn data science methods to solve various problems effectively. We developed and implemented educational activities aimed at nurturing individuals who wish to contribute to community revitalization. The objectives of these activities are as follows:

(1) To learn about and deepen understanding of the local community through these activities. To achieve these aims, we foster a desire to contribute to the local community by enhancing student self-esteem and awareness of well-being.

(2) To cultivate a sense of cooperation through group activities. Collaboration with local communities, companies, and high school students supports activities from a broad range of perspectives, leading to creative activities.

The primary goal of this project is to foster a sense of ownership amongst young people over local issues and to inspire them to build relationships and contribute to their communities. By expressing and thoughtfully considering the local community, even in virtual spaces, young people can develop new communication skills and ideas, consequently fostering self-esteem. This development enables each to contribute to their community, find meaning in being actively engaged, and experience the positive effects of well-being.

3.3.1 Outline of Activities

The following specific activities were conducted:

(1) The students learned about a local community undergoing revitalization. The target area has a prosperous history as a temple town. Nevertheless, its revitalization has been delayed because of a decline in the younger population. Furthermore, town transportation options are limited to private cars and buses as a result of depopulation and the concomitant scarcity of public transportation. In fact, town development has been conducted mainly by medium-income local residents without official administrative support.

Students received explanations from mid-level residents actively engaged in activities in the area, as well as from individuals who started businesses and remained active after relocating from other prefectures. In addition, information was gathered through interviews conducted by students. The students gained an understanding of the concepts and future plans of various business operations and then discussed how each of them could get involved.

(2) After dividing into two groups, the participating university and high school students listed and organized the elements necessary for community activities. This exercise encouraged each student to think deeply about activities in the local community.

Using the metaverse, the virtual shops were recreated. Students observed these virtual shops, the products on display, how they were arranged, and what effects these displays brought about. The task provided opportunities to deepen their understanding of retail shop concepts, the challenges faced by shops, and ways to engage with local residents.

4.0 Findings

4.1 Hybrid learning effects

Student feedback indicated that combining academic visits with metaverse activities created engaging and effective learning experiences. Questionnaires showed 6.2% of students were very familiar with metaverses, 43.8% slightly familiar, 37.5% moderately familiar, and 12.5% not familiar. Most had limited prior experience with academic visits. Visits enhanced understanding of water and wastewater concepts, provided real-world applications of theory, and enabled interaction with industry professionals, strengthening analytical and problem-solving skills and awareness of sustainability and societal impacts. Metaverse simulations further supported collaborative learning through immersive visualization and virtual field trips. Despite technical and interaction concerns, most students preferred a hybrid approach integrating virtual and face-to-face learning.

4.2 University-high school collaboration outcomes

This section examined the educational effects of high school–university collaborative activities involving a university and a non-affiliated high school, using project-based learning (PBL) in practical marketing projects (Kitami & Yamauchi, 2022). University and high school students collaborated with a company to develop a product, applying marketing concepts learned in the classroom. High school students actively engaged in discussions, demonstrated deeper understanding, and showed enthusiasm throughout the activities. A high school teacher observed that students were more proactive, voiced opinions freely, and consistently attended sessions, unlike on regular school days. These findings highlight the effectiveness of collaborative learning through high school–university partnerships. Participants demonstrated increased confidence and communication abilities. High school students became more proactive and engaged, while university students strengthened leadership, teamwork, and project management skills.

4.3 Community-based learning outcomes

Students reported improved understanding of revitalization challenges, enhanced communication skills, and an increased sense of responsibility towards community issues. ICT tools supported the visualization of local needs and strengthened their involvement

This study expands existing literature by showcasing multi-institutional collaborative learning models and demonstrating the value of metaverse-supported activities in developing both cognitive and socio-emotional skills.

5.0 Discussion

The study found that hybrid learning, cross-institutional collaboration, and community-based activities collectively strengthen students' cognitive and socio-emotional competencies. Integrating academic visits with metaverse simulations enhanced conceptual understanding, authentic application, and collaborative engagement, consistent with evidence that immersive technologies deepen experiential learning (Bailenson, 2022; Radianti et al., 2020). University–high school partnerships fostered communication, confidence, and active participation through project-based tasks, supporting earlier studies on PBL effectiveness (Thomas, 2020). Community-based learning further promoted civic responsibility and contextual understanding (Bringle & Hatcher, 2016). Overall, these multi-institutional, technology-supported models demonstrate strong potential for improving engagement and 21st-century skill development.

6.0 Conclusion and Recommendation

This study revealed that university students recognize the importance of learning with diverse individuals through collaboration. This study found that university students value learning with diverse individuals through collaboration with industry partners, local communities, and high school students, further enhancing understanding by effectively using ICT tools, including the metaverse. ICT-enhanced collaborative learning strengthened students' problem-solving and communication skills while deepening their awareness of sustainability and community development. Engagement in community-based ICT activities also promoted a greater sense of belonging and well-being. Limitations of the study include a small sample size and the absence of longitudinal or context-specific impact assessment. Future research should explore sustained learning outcomes and global collaboration through combined virtual and face-to-face experiences.

Acknowledgments

These works were supported by JSPS KAKENHI Grant Number JP24K06206. We would like to acknowledge UiTM and the University of Toyama for their collaborative research and technical support under the Memorandum of Understanding between the two universities. We would also like to recognize the grant-in-aid of the Consortium of Universities in Toyama and Toyama Prefecture.

Paper Contribution to the Related Field of Study

This study contributes to the body of knowledge by providing empirical evidence on the implementation of ICT-enhanced collaborative learning across universities, high schools, and local communities. It demonstrates the practical value of metaverse environments in strengthening problem-solving, communication, and experiential learning. The study also introduces a replicable hybrid project-based learning (PBL) model that supports SDG-aligned educational transformation. Additionally, it highlights how ICT-supported activities promote student well-being, confidence, and civic engagement. These findings offer valuable insights for educators, institutions, and policymakers seeking to design future immersive learning ecosystems that effectively integrate virtual environments, collaboration, and community-based learning for comprehensive skill development.

Co-Author Contribution

The authors affirmed that there is no conflict of interest in this article. Author 1 carried out the fieldwork, prepared the literature review, and oversaw the write-up of the first case study. Author 2 wrote the second case study. Author 3 carried out the third case study and compiled all the write-ups.

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