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Science, Technology, Engineering, and Mathematics Curriculum Design for Teaching Mathematical Concept of Perspective at Indigenous Elementary School Using Robots

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In this study, the analysis, design, development, implementation, and evaluation (ADDIE) model was used to design a cross-domain science, technology, engineering, and mathematics (STEM) curriculum for primary school mathematics in indigenous schools. The research methods used included content analyses, interviews, and a questionnaire survey. Research participants were students aged 9–12 at an indigenous elementary school. The curriculum integrated with indigenous culture and the application of Kebbi robots included STEM courses such as mathematics, information technology, natural science, and culture. The courses adopted a collaborative problem solving (CPS) teaching strategy, allowing students to complete learning tasks in groups. During the teaching process, teachers gradually guided students to observe and stimulate their scientific imagination and thoughts regarding what robots could do. In the lessons, the students acquired an understanding of the concepts of mathematics regarding the division of labor and cooperation, and they used robots to complete learning tasks. Through this STEM cross-domain teaching activity, learning mathematics was made interesting and relevant to the living and cultural situation of the indigenous participants of this study. The students had a positive attitude towards learning using emerging technologies such as robots and digital teaching aids.

1. Introduction

Research on indigenous education in Taiwan has found that indigenous children are observant and creative, and prefer dynamic and practical learning situations. Visual aids such as pictures, videos, and objects are preferred by the children and helpful for their understanding.[1,2] It is difficult for them to learn mathematics, a subject with abstract concepts,[3,4] but they can improve their concentration through practical activities, allowing their study to progress.[1,2,5] The traditional indigenous society attaches great importance to the relationship between people,

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animals, plants, and the surrounding environment.(6) Therefore, the curriculum design of indigenous science education can respond to culture and life experience, and enable children to operate with their hands, which can trigger thinking and promote understanding.(5,7,8)

Indigenous children are typically easy-going, prefer group cooperation, and are willing to discuss and share.(9,10) Collaborative problem solving (CPS), proposed by Nelson in 1999, is a suitable teaching strategy for indigenous children's courses. This teaching strategy is learner-centered, establishes an integrated and collaborative learning environment, provides a highly authentic and natural collaborative learning process, and enables students to develop discipline knowledge, problem solving, critical thinking, and cooperative skills. Teaching activities can be divided into nine steps: (1) Prepare – instructors and learners prepare to carry out work in teams. (2) Learners form small and heterogeneous working teams. (3) Teams first discuss, define, and understand the problem. (4) Teams define and distribute the roles required for each project. (5) Teams discuss the problem repeatedly using a process of collaborative interaction and problem solving. (6) Teams present their conclusions. (7) Instructors help learners to recall the activity process and reflect on the learning experience. (8) Instructors and learners assess the learning outcome and process. (9) Instructors and learners terminate the learning activities.(11)

Technological progress is also driving the transformation of the teaching model. Studies have shown that integrating robots into the curriculum can enhance the interest of students in learning and encourage students with different backgrounds, interests, and experiences to actively participate in the project curriculum and express their creativity and ideas.(12) Researchers have also found that computer-based Lego robotics and a creativity course integrated with indigenous culture can effectively improve the creative performance of indigenous children.(13) Robotics requires the knowledge and complex integration of multiple independent disciplines; thus, it creates a new interdisciplinary content involving science, technology, engineering, and mathematics (STEM).(14) STEM integrates the knowledge and skills of science, technology, engineering, and mathematics, and cultivates the ability of students to use various fields of knowledge to solve problems in life situations through the course model of project-based learning. It enhances the comprehensive performance of mental and practical learning so that students can actually think and apply knowledge in real-life circumstances. Strengthening STEM practical courses is helpful for improving students' ability to integrate knowledge and for promoting the effectiveness of learning in various disciplines.(15,16) Research on the cross-domain STEM teaching of robotics in Taiwan has shown that digital teaching aids help students learn and improve learning motivation and outcomes.(17,18)

On the basis of the above discussion, we will design a STEM curriculum for mathematics concepts in indigenous schools. It will combine the uniqueness of indigenous culture, emerging technological advancements in robotics, and a CPS teaching strategy. Considering the children's age group, learning characteristics and styles, mathematical knowledge, the CPS teaching strategy, and the new "108 curriculum" STEM interdisciplinary teaching spirit, we will use the AI robot Kebbi Air S (https://www.nuwarobotics.com/zh-hant/product/steam/) to design an interdisciplinary mathematics STEM curriculum in this research. Kebbi Air S has a child-friendly "cute" appearance and movements. It can inspire children's interest in programming and mathematics learning through contextual tasks and game-based learning. It is suitable for group interactions of three to five people. Via the process of completing tasks through robotic cooperation, it helps to cultivate students' ICT literacy and CPS ability to prepare them for the future (https://www.worldclassarena.org/atc21s-case-study).

2. Materials and Methods

Research participants were 10 students aged 9–12 at an indigenous elementary school. The research methods used in this study included content analysis and the interview methodology. The researchers analyzed relevant literature and interviewed experts. Finally, the course was examined by experts. The analysis, design, development, implementation, and evaluation (ADDIE) model (Fig. 1) was used to design an interdisciplinary STEM curriculum, and the CPS teaching strategy was adopted in developing the course.

2.1 Curriculum design

In this study, we analyzed the characteristics of indigenous primary school students, the growth characteristics of millet, and programming grammar, and then designed and developed a teaching model.

In the stages of design and development, the curriculum involved constructing perspective concepts and carrying out teaching activities through presentations and teaching aids. Next, students were taught about and experienced working with Kebbi robots, for example, the basic operation of the Kebbi robot interface, the body movements of Kebbi robots, talking to Kebbi robots or giving commands by voice, and using the internal sensing components of Kebbi robots to scan and identify objects (Fig. 2), to help them with subsequent cross-domain courses.

We used Kebbi robots to carry out interdisciplinary teaching activities, such as operating a math app that was integrated with the indigenous cultural context (Fig. 3), controlling the arm-

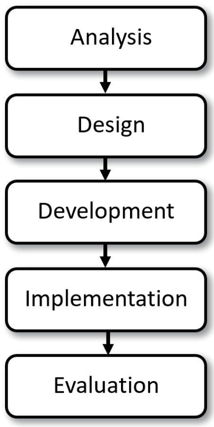
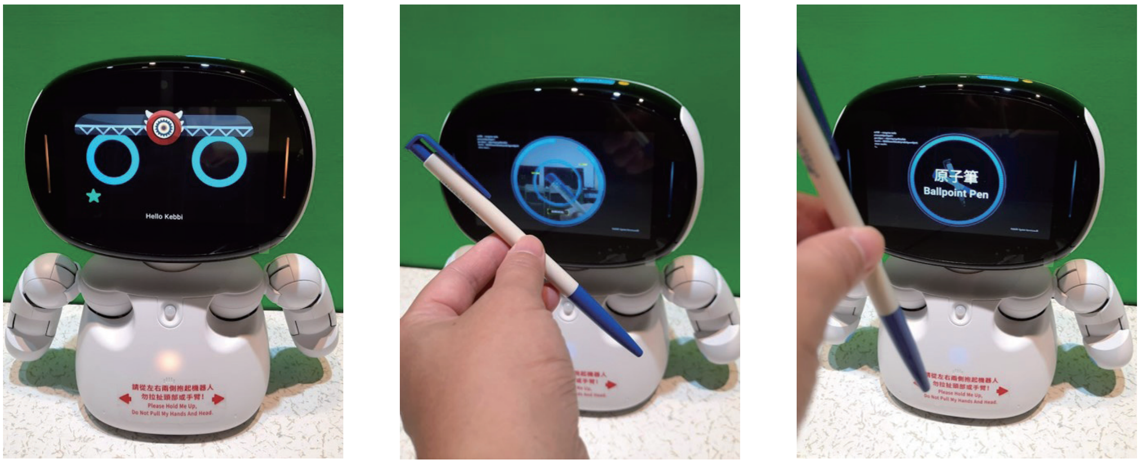


Fig. 1. Curriculum design with ADDIE model.



(a) (b) (c)

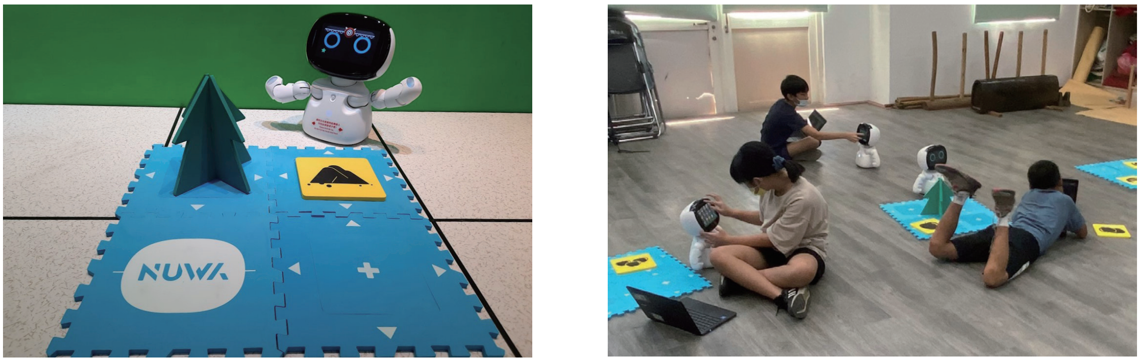
Fig. 2. (Color online) Kebbi robot (a) responding to voice commands and using its internal sensing components to (b) scan and (c) identify objects.

(a) (b)

Fig. 3. (Color online) (a) Operating the perspective concept app and (b) app on the robot interface.

waving and moving directions to learn about the mathematical concepts of perspective and rotation angles, and practicing visual programming to complete learning tasks.

The implementation of the learning task was based on the indigenous millet culture. Students discussed the task in groups and wrote programs so that the Kebbi robot could move, wave, and make sounds to protect a millet field from birds. We used a game mat as a millet field (Fig. 4) and let students operate the Kebbi robot and sensors to simulate the patrol of the millet field. Finally, a five-point Likert scale was used to investigate the students' learning attitude and satisfaction with this course.



(a) (b)

Fig. 4. (Color online) (a) Game mat used as a millet field and (b) students operating the Kebbi robot to simulate the patrol of the field.

2.2 Teaching strategy

The course adopted the CPS teaching strategy, which allowed students to complete learning tasks in groups. The context of the learning tasks was to protect the millet field from birds with the help of Kebbi robots. The teacher used the situation of indigenous people planting millet as an example and first encouraged the students to discuss the problems that may be encountered in planting millet and the impact of these problems on the growth of millet, asking the students to propose solutions to the problems (Fig. 5). After that, the teacher asked the students to think about how to apply robots and sensors to protect millet fields. The students needed to integrate the mathematical concept of perspective and robot programming concepts to complete this task (Figs. 6 and 7).

3. Results

The mathematical concept to be learned in this course pertained to perspective. The design of the interdisciplinary STEM curriculum, which combines the theme of the indigenous culture of millet cultivation and the interaction with the Kebbi robot, is detailed in Table 1.

During the teaching process, teachers gradually guided students to observe and stimulate their scientific imagination and thoughts about what robots could do. The students acquired an understanding of the mathematical concepts regarding the division of labor and cooperation, and used robots to complete learning tasks. A five-point Likert scale was used to investigate the students' learning attitude and satisfaction, and the average score was 4.57. The Cronbach's alpha value of the reliability analysis was 0.928. Details of the results on the Likert scale are shown in Table 2.

(a) (b)

Fig. 5. (Color online) Students (a) learning the natural science of millet planting and (b) discussing related topics.

Fig. 6. (Color online) Students programming robot movements.

Fig. 7. (Color online) Students interacting with the Kebbi robot.

Table 1
Mathematics STEM curriculum design using robots.

Course name	Understanding perspective: protecting millet from birds using robots
Time	9 classes, 360 min
Applicable objects	Indigenous elementary school students aged 9–12
Teaching objectives	(1) Cognition a. Understand perspective, rotation angle, and rotation direction and solve the problem of angle composition and decomposition. b. Understand millet and its growth process. (2) Emotion a. Practice discussing and answering questions in groups. b. Work together to complete the task of protecting millet from birds using robots. (3) Skills a. Learn to operate robot body movements related to perspective and rotation and apply the concepts of perspective and rotation in life. b. Design robot movements to drive birds away to protect planted millet.
Mathematical unit learning performance	In activities, learn about applying geometric concepts such as rotation angle, expansion graph, and spatial shapes.

Table 1
(Continued) Mathematics STEM curriculum design using robots.

Nine steps of CPS	Teaching activities and teaching aid preparation
Step 1: Prepare – Instructors and learners prepare to work in teams.	1. Teaching PowerPoint, website resources, teaching instruments, robots, and puzzle play mats. 2. PISA test (pre-test and post-test). Reward mechanism: verbal feedback; bonus points for class management.
Step 2: Learners form small and heterogeneous working teams.	1. There are 28 students in this class. 2. Class to be divided into seven teams with four people in each team. 3. Note: Instructors divide students into heterogeneous teams in advance.
Step 3: Teams first discuss, define, and understand the problem.	■ Concepts of perspective and rotation: 45°, 90°, 180°, and 270°. 1. Understand perspective and rotation direction. Ask students to list objects, tools, and houses with the above angles. 2. Ask students to find objects and buildings related to the above angles, take pictures of them with tablets, and note their angles. 3. Instructors explain the operation and process of robots. 4. Use simple programs to design robots to make body movements of 45°, 90°, 180°, and 270°. ■ Discuss millet and the concepts of its planting.
Step 4: Teams define the roles required for each project.	■ Instructors ask teams to practice their roles and to practice and discuss through perspective apps to present the definition of perspective. Teams discuss how to design the continuous movements of robots, and instructors take the robot operation as an example to explain the perspective, direction, and position after rotation.
Step 5: Teams discuss the problem repeatedly using a process of collaborative interaction and problem solving.	■ Instructors ask questions for discussion, guide students to think from the perspective of life situations using their imagination, and assist and guide students using teaching instruments and practical operations. ■ Instructors guide the discussion on how to design robot movements and sensors to drive birds away to protect growing millet. Each team continues to discuss and share views on learning tasks in the same way. Instructors and research teams focus on the problems students may encounter when operating.
Step 6: Teams start to present their conclusions.	Present the results of each team in the creative competition of robots protecting millet from birds. Instructors organize the content.
Step 7: Instructors help learners to recall the activity process and reflect on the learning experience.	Guide the class to discuss and reflect on the process and the results of the class, and guide the students to think about the possibility of using robots to assist in millet planting and give examples of similar environments to extend the discussion and promote the development of experience.
Step 8: Instructors and learners assess the learning outcome and process.	■ Unit assessment content: achievements of the objectives in cognition, emotion, and skills. ■ Team self-assessment content: presentation status and correctness of answers. ■ Instructor assessment content: classroom observation, robot operation, and PISA tests. Note: help review and understand the learning effectiveness through robot operation.
Step 9: Instructors and learners terminate the learning activities.	■ Review and summarize the main points of this unit. ■ Give praise. ■ Note: instructors summarize this unit, reward students, terminate the teaching activities, and remind students to do the PISA situational group tests of this unit on the assessment system.

Table 2
Descriptive statistics of students' learning attitude and satisfaction.

	N	Min	Max	Mean	SD
During class, I thought about the problems I had encountered.	10	4	5	4.70	0.483
Based on the above question, I tried to think about how to solve the problem.	10	3	5	4.50	0.707
Continuing from the above question, I used a variety of methods to solve it.	10	4	5	4.70	0.483
Following the above question, I thought about which solution was the most feasible.	10	3	5	4.70	0.675
I knew what the learning objectives of this class are.	10	4	5	4.60	0.516
I knew the methods to use to find answers to the questions.	10	3	5	4.50	0.707
I could actively participate in the division of labor and cooperation in the group.	10	3	5	4.50	0.707
I could actively participate in group discussions.	10	4	5	4.70	0.483
I enjoyed using the teaching materials on the tablet for learning activities.	10	3	5	4.40	0.699
I feel that studying with a tablet makes me more interested in the class.	10	2	5	4.50	0.972
I enjoy using robots for group collaboration activities.	10	2	5	4.40	0.966
I feel that learning with a robot ca make me more interested in taking classes.	10	2	5	4.30	0.949
I think this course is very helpful for my study.	10	3	5	4.50	0.707
I feel that learning with a robot can enhance my imagination.	10	4	5	4.50	0.527
I feel that this course has improved my problem-solving skills.	10	4	5	4.80	0.422
I think this course can help me and my classmates work together.	10	4	5	4.90	0.316
I think the tablet app is easy to operate.	10	3	5	4.30	0.675
I think the content of the tablet app is interesting and practical, and it helps me understand mathematical concepts.	10	3	5	4.60	0.699
I think the learning website is easy to operate and rich in resources.	10	3	5	4.60	0.699
In the future, I am willing to continue to use the learning resources provided by the learning website for learning.	10	3	5	4.70	0.675
Average	10			4.57	0.653

4. Conclusions

Through our STEM interdisciplinary teaching activity, learning mathematics became interesting and relevant to the living and cultural situation of the indigenous participants in this study. The activity helps indigenous children understand the mathematical concept of perspective through the operation of robot movements. Group tasks in indigenous cultural contexts guide students to apply mathematical concepts to real-life situations and enhance their collaboration and problem-solving skills. In addition to learning knowledge, the STEM cross-domain teaching form helps indigenous students understand their own culture and strengthens their information technology capabilities. Moreover, the indigenous students in our study had a positive attitude towards learning using emerging technologies such as robots, tablet apps, and websites.

In the future, teachers can design more courses that combine indigenous cultural situations with robots, such as hunting and indigenous-style meals. Teachers can guide students to think about how to use a robot's sensors and functions to solve the problems encountered in hunting and making indigenous-style meals and create better solutions to achieve the goal of cross-domain teaching.

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