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Development and Application of Convergence Education about a Support Vector Machines for Elementary Learners

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Abstract:
This paper proposes an artificial intelligence (AI) convergence education program that teaches the concept and principles of support vector machines (SVM). It was applied to elementary school students to check the effectiveness of education. The developed program describes the decision boundaries and margins of the SVM through the distance between the vertical and parallel lines of the elementary mathematics curriculum. The SVM education program was piloted to 18 3rd graders and 16 5th graders. Students' reactions were observed during classes, and learning output and self-evaluation results were analyzed after the classes. As a result, most students intuitively inferred the location of the trails, which represents the decision boundary. At this time, the overall activity performance accuracy of fifth-grade learners was higher, and the rate of reasonable inference on the principle of setting was also higher. The completion of the fourth-grade math curriculum also affected the students' understanding. However, in the self-evaluation of the understanding of learning content, contrary to the actual comprehension, the average value was higher in the third grade. This was because middle-grade learners had a greater tendency to feel satisfaction and achievement when they newly learned about the unfamiliar AI principle. However, higher-grade learners presented more meaningful post-class. The novelty of this paper can be found in that it attempted to educate the SVM for elementary learners. In the future, it is necessary to apply the program to a larger number of learners, supplement and develop the program and contribute to the AI principles education for elementary school students.

Keywords: support vector machines, artificial intelligence education, convergence education, elementary education, artificial intelligence algorithm.

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初级学习者支持向量机融合教育的开发与应用

摘要：
本文提出了一种人工智能融合教育计划，教授支持向量机的概念和原理。它被应用于小学生以检查教育的有效性。开发的程序通过初等数学课程的垂直线和平行线之间的距离来描述支持向量机的决策边界和边缘。支持向量机教育计划在 18 名三年级学生和 16 名五年级学生中进行了试点。课间观察学生反应，课后分析学习成果和自评结果。结果，大多数学生凭直觉推断出轨迹的位置，这代表了决策边界。此时，五年级学习者的整体活动表现准确率较高，对设置原则的合理推理率也较高。四年级数学课程的完成也影响了学生的理解。然而，在对学习内容理解的自我评价中，与实际理解相反，三年级的平均值更高。这是因为中年级学习者在新学习不熟悉的人工智能原理时更容易感到满足和成就感。然而，更高年级的学习者在课后表现出更有意义的表现。这篇论文的新颖之处在于它试图为初级学习者教授支持向量机。未来需要将该程序应用到更多的学习者中，对程序进行补充和发展，为小学生的人工智能原理教育做出贡献。

关键词：支持向量机、人工智能教育、融合教育、初等教育、人工智能算法。

1. Introduction

In the Korean national-leveled 2022 revised curriculum, artificial intelligence (AI) education will be introduced along with the expansion and deepening of software (SW) education. For example, the Ministry of Education emphasized digital literacy as a core competency for future generations in the 2022 revised curriculum general draft (Ministry of Education of Korea, 2021). This educational stance is also in the Ministry of Education's national task, which cultivates talents with SW and AI capabilities in response to the digital transformation in the era of the 4th Industrial Revolution.

Based on social consensus on the necessity of AI education, discussions and research on this are being conducted from various educational subjects. Based on SW education, the Ministry of Education of Korea (2021) announced the "Elementary and Secondary AI Education Content Standard," which proposes AI education plans suitable for the level of students at each school level. The Content standards are about understanding AI, the principle and usage of AI, and the social influence of AI. Among them, "the principle and usage of AI" aims to understand the elements and principles necessary for real-world AI to operate, covering the most content elements such as data, recognition, classification, exploration, reasoning, machine learning, and deep learning (Shin & Jo, 2021).

AI education research led by teachers and universities is also actively conducted. Research on domestic elementary AI education programs is mainly on fifth and sixth graders in elementary school, and the research topic is AI understanding education that focuses on having AI knowledge and functions such as terms, knowledge, concepts, principles, laws, and algorithms (Kim & Lee, 2022). Among them, previous studies on the development of educational programs for elementary school students based on AI algorithms conducted on the Decision Tree (Jang, 2019; Kim & Moon, 2021; Jang, 2020), Linear Regression (Jang, 2019), K-means (Jang, 2019), K-Nearest Neighbor (Choi & Park, 2021; Sim, 2021), and the Convolutional Neural Network (Jang, 2019).

In Korea, AI education has not been introduced into the national-level curriculum. This is due to the transitional characteristics of the introduction of AI education. There are various perspectives and opinions on the concept of AI education, teaching and learning methodology, and the areas and content elements of the AI curriculum. Additionally, despite the diversity of views, it has been commonly revealed in several studies that understanding the principles of AI occupies a large proportion of the contents and goals of AI education. Nevertheless, no training program has yet attempted to address the core principles of the Support Vector Machine (SVM), an AI classification algorithm.

Meanwhile, AI education from a subject convergence perspective is also drawing increasing attention. Today, in the digital native generation, elementary school students are expected to naturally develop AI literacy and usage skills based on the subject content (Cheong & Lee, 2022). Moreover, elementary school teachers are advantageous in attempting curriculum convergence AI education since they have theoretical knowledge and teaching experience for all subjects organized in the curriculum (Lee & Kim, 2021).

In this way, despite relatively active research on AI principles education targeting fifth and sixth graders in elementary school in AI education, no attempt was made to develop an education program for SVM. Therefore, this paper develops an AI convergence education program that teaches the concept and principle of SVM to learners in the upper grades of

elementary school or higher. Subsequently, the developed program was applied to the educational field to observe the learners' reactions.

2. Related Research

2.1. Artificial Intelligence Convergence Education

AI convergence education has two main perspectives. First, education uses AI technology as a learning tool to achieve the learning goals of a specific subject, i.e. is, AI education as a tool. In prior studies conducted on elementary school students, Jung Yu-Nam and Lee Young-Hee (2022) proposed a teaching and learning plan that imagined a backstory in the Korean language department and expressed it as entry block coding (Cheong & Lee, 2022). Han Kyu-Jung and Ahn Hyeong-Jun (2021) used entries in English -speaking and writing education (Han & Ahn, 2021). In science, Kim Hye-ran and Choi Sun-Young (2021), Lee So-Yul and Lee Young-Joon (2021), and Shin Won-Seop (2020) applied machine learning to animal and plant classification learning. Song Jung-Beom (2021) fused environmental education with unplugged AI education, and Cho Hyun-Ki (2021) applied machine learning techniques to global citizenship education.

Another perspective on AI convergence education is to combine other subjects to educate on AI as an extension of AI (Learning about AI) as content. In this regard, Shin Jin-Sun and Mi-Heon Cho (2021) developed and applied AI convergence education programs based on the convergence of other subjects and project learning (Shin & Jo, 2021). Yang Da-Ye and Han Sun-Kwan (2021) developed an art convergence education program using AI to improve the creativity of elementary school students (Yang & Han, 2021). In the study by Lee Young-Ho (2021), the social, ethical, and technical aspects of AI deal with the connection of the achievement standards of various subjects (Lee, 2021).

The Ministry of Education encourages cooperative activation of convergence education in information and mathematics subjects to strengthen AI education (Ministry of Education of Korea, 2020). In the analysis of previous studies, mathematics was one of the most linked subjects in AI convergence education. Additionally, the surrounding environment, animals, plants, culture, and art commonly encountered in life can be used as good material for understanding AI technology (Kim & Moon, 2021).

In particular, Jeju Island has been designated as a UNESCO Biosphere Reserve, a World Natural Heritage Site, and a World Geopark and has been widely recognized for its natural value. Therefore, this paper developed AI convergence education that combines mathematics and social studies subjects.

2.2. Support Vector Machine

A support vector machine (SVM) is an AI data classification algorithm. SVMs are divided into linear and nonlinear models according to data characteristics. In a linear model, the boundary used for the classification of dichotomous data is the Decision Boundary. Decision boundaries should be as far away as possible from all with each data class to minimize the possibility of classification errors when entering new data (Figure 1).

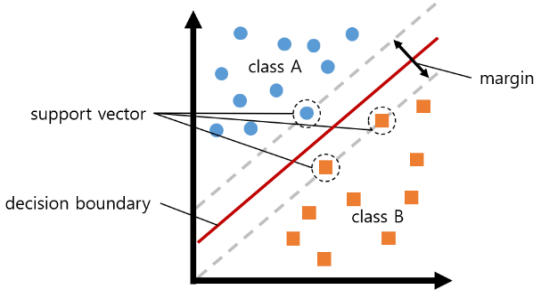


Figure 1. An example of a support vector machine

A support vector is a vector closest to another class in each data class. It was named a 'helping' vector in that it serves as the criterion for determining the crystal boundary. At this time, at least one more support vector is required than the number of data classes. The distance between two classes of support vectors is called a margin. The larger the margin, the better the classification was.

The SVM can expect an intuitive understanding of the model at the elementary school level through a typical schematic, as shown in Fig. 1. However, prior domestic studies related to the SVM focused on engineering system design and implementation. In the field of education, there are cases of education for specialized high school students (Park & Kim, 2022), but there are no related studies for elementary school students.

2.3. Vertical and Parallel

The decision boundary is related to parallel to the vertical, which is the element of mathematics and content. In the current curriculum, vertical and parallel are presented in the 'square' unit of the second semester of the fourth grade. Before learning the trapezoidal, parallelogram, and rhombus, learners learn the distance between vertical and mending, parallel, and parallel lines in order.

Table 1. Three-line representation

Lesson	Class Content and Activities
2nd	Understand verticality and vertical lines. Use a triangle and a protractor to draw a vertical line to the given line
3rd	Understand parallels and parallel lines. Learn how to draw a straight line parallel to the given line, and draw it. Draw a straight line passing a certain point and parallel to the given line
4th	Draw several lines connecting the two points on the parallel line and measure the length. Understand the distance between parallel lines and measure the distance between the given parallel lines.

Draw a parallel line so that the distance between the parallel lines is as long as the given length. Understand that the distance between parallel lines are the same no matter where they are measured

In elementary school, parallelism is intuitively introduced by the homogeneity of two straight lines. Moreover, two straight lines perpendicular to one straight line are parallel lines that do not meet each other (Ministry of Education of Korea, 2020). At the elementary school level, students can draw parallel lines with set squares, or a ruler and a set square.

The margin of the SVM can be explained by the distance between parallel lines. The line connecting two support vectors of the same class and the decision boundary are parallel. The decision boundary equally separates the distance of the support vectors. Therefore, the margin is the distance between two parallel lines. Among the various line segments that can be drawn between parallel lines, the shortest is the vertical line segment, and its length is called the distance between parallel lines. The distance between parallel lines is convenient when measured using a set square, as shown in Figures 2 and 3.

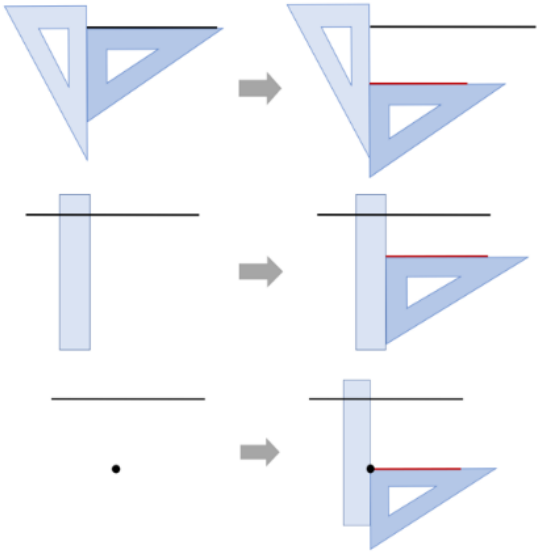


Figure 2. How to draw parallel lines

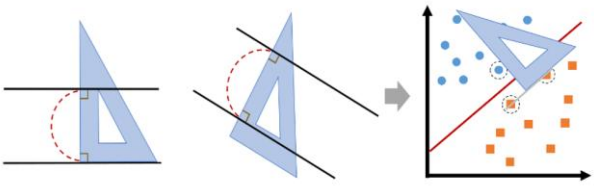


Figure 3. How to measure the distance between parallel lines

3. Methods

In this paper, we developed an AI convergence education program based on the ADDIE model. This model presents the process of developing teaching and learning programs in five stages: analysis, design, development, implementation, and evaluation. The procedure for developing and applying the support vector machine teaching and learning program performed according to ADDIE (Figure 4).

Analysis	*Task:* AI convergence education for teaching-learning AI algorithms, Core principles of SVM
	Learner: Characteristics of elementary learners, pre-learning experience
	Curriculum: National curriculum for elementary school
	Learning Environment: Learning space and materials
Design	*Learning Goal:* To understand the main concepts and principles of the SVM
	Evaluation Tools: Subjective and objective questions, observation
	Teaching Strategies: Learner-directed inquiry learning
Development	*Teaching-Learning Plan:* 2 classes
	Teaching-Learning Materials: Worksheets, presentation for explaining concepts and principles of SVM
Implementation	*Application:* Middle and upper-grade elementary learners
	Collection of materials: Worksheet outputs, learners' self-assessment
Evaluation	*Analysis:* Degree of comprehension, questions after the classes, collected materials, self-assessment
	Design for Program Revision

Figure 4. Procedure of program development and application

The developed educational program was conducted in two sessions for 18 3rd-grade students and 16 5th-grade students attending B School in Jeju Special Self-Governing Province (Figure 5). The learners had no prior learning experience in AI machine learning, and all students had first heard of the SVM. After completing the program, the learner performed a self-evaluation of class participation and recorded what they learned, felt, and wanted to know more.

Figure 5. Application of the developed program to students

Although the educational program was mainly designed for 5th-grade and older, we also applied the program to 3rd-grade learners. It was to ensure that the main application targets of this program were proper. Moreover, there was an intention to find an expansion plan for AI convergence education that can cover lower and middle grades of elementary school.

4. Results

4.1. Developed Convergence Education about the SVM

The developed AI convergence education program focuses on understanding the concept of SVM and the principle of setting decision boundaries. This program reflects social studies and mathematics achievement standards. For the connection with the social studies department, oreum, camellia, rape flowers, stone walls, and horses, which are characteristics of the natural and humanities environment of Jeju Island, were used as learning materials.

Table 2. Converged achievement standards

Subject (Field)	Achievement Standards
Mathematics (Shapes)	[4M02-03] Understand the vertical and parallel by finding verticality or straight lines that do not meet each other in the classroom and around life.
Social Studies (Natural Environment and Human Life)	[4S02-01] Investigate the geographical characteristics of our hometown and explore their impact on the lifestyle of the local people.

The unfamiliar concepts of decision boundary and margin were introduced through the vertical and the parallel. The main subjects of the program were upper grades of elementary school and above because vertical and parallel are in the second semester of the fourth grade based on the current math and curriculum.

In the first session, the instructor presents a figurative learning task of "creating an oreum trail through the middle of two oreum groups," providing an opportunity for learners to think about the principle of SVM classification through decision boundaries on their own. In the learning task, climbing data, and straight trails correspond to decision boundaries. After individual exploration, learners share opinions with fellow learners and expand their thinking.

The learners then look at the picture presented by the teacher and guess what the reason is for the trail to be located in the middle of the two oreum groups, that is, how the location of the trail could be set. Finally, the instructor introduces major concepts and principles related to the SVM, such as decision boundaries, margins, and support vectors (Figure 6).

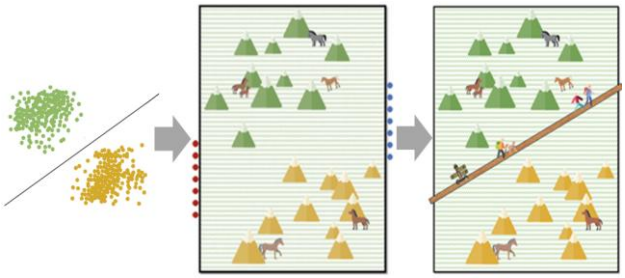
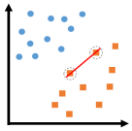
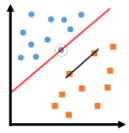
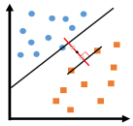
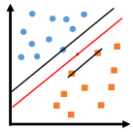


Figure 6. SVM represented by the natural environment of Jeju

In the second session, the learner will determine how to obtain the decision boundary based on the vertical, vertical line, parallel, and parallel lines (See Table 3). The margin can be understood by connecting to the distance between parallel lines.

Table 3. The procedure for determining the decision boundary

Step		Diagram
1	Determine two data points in class A closest to class B. Draw a straight line connecting the two data points.	
2	In class B, find a data point closest to class A. Draw a line passing this point and parallel to the line drawn in the previous step.	
3	Draw a vertical line between the two parallel lines and mark the midpoint of the vertical line.	
4	Draw a parallel line that passes through the middle of the vertical line. This is the decision boundary.	

Subsequently, the 'Flower Garden Stonewall Building Activity Site', a modified task of the oreum trail-making activity conducted in the first class, was designed to confirm the concept and principle of SVM through similar learning tasks. In this activity, we solve a given problem situation with the principle of SVM that the learner should classify two data classes, camellia, and rape flowers, as the decision boundary called stone walls (Figure 7).

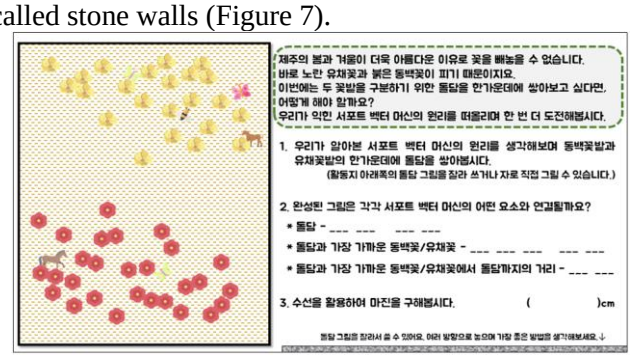


Figure 7. Developed worksheet for teaching SVM

4.2. Application of Education

In the first session, the instructor presents a figurative learning task of "creating an oreum trail through the middle of two oreum groups," providing an opportunity for learners to think about the principle of SVM classification through decision boundaries on their own. In the learning task, a straight trail corresponds to decision boundaries. After individual exploration, learners share opinions with fellow learners and expand their thinking.

The learners then look at the picture presented by the teacher and guess why the trail is located in the middle of the two oreum groups. That is, how they figured out the location of the trail. Finally, the instructor introduces concepts and principles related to the SVM, such as decision boundaries, margins, and support vectors (Figure 8).

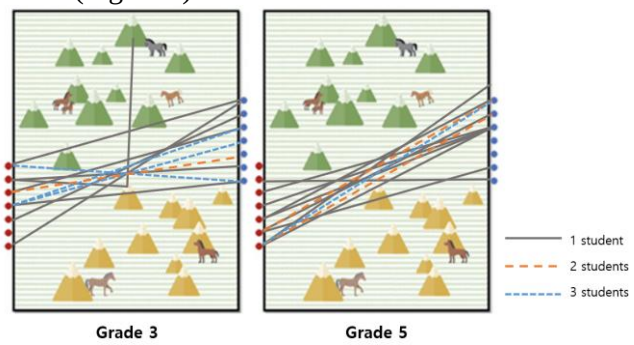


Figure 8. Students' responses for the 1st class

The trail suggested by the instructor in Figure 9 is the decision boundary. Before learning the meaning of decision boundaries in the SVM through lecture-style explanations in the next session, the learners answer the question, "How could the trail in the middle of the two oreum groups be made?"

In the 3rd-grade class, it was difficult to find answers that responded to the instructor's intention to ask questions, such as "Dug the road," "Made it in the middle/center," "Made it straight," and "I think a person installed a net." However, in the case of 5th graders, many guesses matched the principles of the decision boundary. Students' answers were "This middle is because the distance between each mountain is constant," "The two distances are measured and drawn in the middle," and so on.

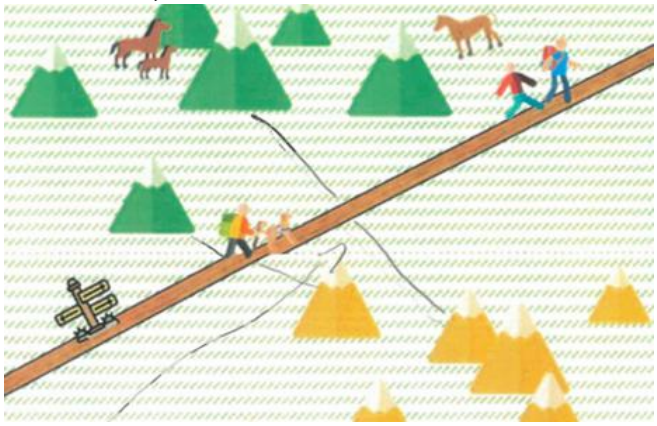


Figure 9. An example of an answer by 5th grader

Table 4 shows the results of the learner's response to the self-assessment item, "Did you get to know the support vector machine well?" after completing the learning on a 5-point Likert scale. The arithmetic mean of the response results was slightly higher in the third grade. Although the average class understanding of fifth-grade learners was significantly higher than that of third-grade students in all indicators such as observation history, activity paper performance, and learning result summary, these results were derived from differences in self-satisfaction with learning.

Table 4. Self-assessment of understanding SVM

Grade	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Mean
3rd (N = 18)	3	6	7	1	1	3.5
5th (N = 16)	4	7	3	1	0	3.44

After that, we analyzed the thoughts and feelings of the learners. In the 3rd grade class, there were relatively more positive expressions of emotions such as "proud," "delighted," and "satisfied" than in the 5th grade. Because of learner response analysis, this was due to a sense of self-efficacy from the experience of exploring unfamiliar elements from the learner's viewpoint, called a 'support vector machine,' apart from practical learning understanding. In the fifth-grade class, there were relatively more responses saying it was difficult, and simultaneously, most students said they wanted to learn more.

21 meaningful responses were made in 5th grade and 4 were made in 3rd grade to the post-learning question, "Is there anything else you want to know about the support vector machine?" Responses that were not related to the subject of the class, such as learning attitude, were excluded. These numerical differences support the pattern that there were much more learners who showed additional willingness to learn from the previous feelings of 5th-grade learners.

The collected responses could be classified as Table 5 under three categories: 'Origin of Support Vector Machine,' 'Principle of Support Vector Machine,' and 'usage of Support Vector Machine,' depending on the content.

Table 5. The procedure for determining the decision boundary

Category	The learners' questions after the classes
Origin of the SVM	Who created the SVM? When was the SVM created? How was the SVM created? (3 students) Why was the SVM created? Why is the SVM called 'SVM'?
Operational Principle of the SVM	Where does the SVM work? How does the SVM work? (2 students) How can SVM categorize the data? Can SVM categorize data in other ways? By what criteria does the SVM categorize? Is the classification process complex? How can the SVM be recorded? Is the SVM related to x, y(function)? I want to know more about the margin. If there is B data in the A data class, how does the SVM draw a boundary? What happens if the data are not in place? Who controls the SVM?
Application of the SVM	How can the SVM be applied in our everyday life? (3 students) What can the SVM categorize? How can we code the SVM? What more does the SVM give us?

5. Discussion and Conclusions

Today, the application area of AI is expanding and the demand for AI principle education is also growing in the education field. Therefore, this paper developed an AI convergence education program that teaches the concept and principles of SVM by converging with mathematics and social studies. Additionally, we applied the program to learners in the middle and upper grades of elementary school and examined the learners' cognitive performance and affective responses.

Most of the learners in both grades drew lines, which represented decision boundaries that extended from the bottom to the top. The overall understanding of the main concepts and principles related to the support vector machine was significantly higher in fifth-grade learners than in third-grade learners. In particular, in the 5th-grade class, many learners intuitively guessed the principle of decision boundary even before hearing the instructor's explanation. It could also be inferred that the prior knowledge of mathematics, such as the vertical and vertical lines, and the distance between parallel and parallel lines, affects the learner's understanding.

However, the degree of understanding of the SVM felt by learners themselves was rather higher in third-grade learners. The cause was found in the difference in the affective aspect. The unfamiliar and challenging learning elements of the SVM highlighted the pride of new learning for middle-grade students. In fact, as an extension, higher-grade learners made much more meaningful inquiries directly related to the learning content after the classes.

Based on these results, the proposals for the development direction of AI convergence education for elementary school students are as follows. First, various AI education topics can be applied to many grades by adjusting the approach and educational goals. For example, as in this paper, learners in the upper grades of elementary school and above can focus on concepts and principles, and learners in the lower middle grades can focus on inducing interest and interest. Second, it is necessary to enhance the educational effect by actively and reasonably linking with other subject achievement standards when designing education. In particular, consideration of the applied grade is essential. Third, it is desirable to include not only the concepts and principles of education on AI algorithms but also the origin and real-life usage content elements. As a result, it will be possible to satisfy the intellectual curiosity of learners and demonstrate the value of convergence education.

5.1. Limitations and Further Study

This research was only for few elementary students, so it is hard to generalize the results. Additionally, due to the characteristics of the applied school, there is a limitation that there were only female students. Therefore, it is necessary to increase the number and diversity of students and further verify the educational effect. Additionally, the completeness of the program should be improved by reflecting on the learner's responses and teaching and learning needs in the field class. In the future, we hope for various educational programs to be actively studied that allow elementary school learners to learn AI algorithms interestingly and effectively.

Acknowledgments

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