

RESEARCH ARTICLE

Development of an App Inventor-based AI-PBL Program for the “Sustainable Convergent Engineering” Content Area in the 2022 Revised High School Technology and Home Economics Curriculum

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ABSTRACT

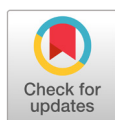
The purpose of this study is to develop a Project-Based Learning (PBL) program aligned with the “Sustainable Convergent Engineering” content area of the 2022 revised high school Technology and Home Economics curriculum. To achieve this purpose, the PDI (Preparation–Development–Implementation) instructional design model was applied, and the study was conducted through three stages: preparation, development, and implementation.

In the preparation stage, the “Sustainable Convergent Engineering” content area of the 2022 revised Technology and Home Economics curriculum and relevant sections of high school Technology and Home Economics textbooks were analyzed. In addition, App Inventor was selected as an instructional tool for artificial intelligence (AI) education to support project implementation.

In the development stage, based on the analysis results, a PBL topic centered on a hyper-connected society, information and communication engineering, and engineering ethics was established. As a result, an eight-session PBL program was developed in which students created an assistive object-recognition application using App Inventor. Furthermore, content validity was examined by experts in technology education and AI education to verify the appropriateness and classroom applicability of the program.

In the implementation stage, a pilot test was conducted with 60 second-year high school students at a high school in Seoul, and student satisfaction survey data were collected and analyzed. The results indicated a generally high level of satisfaction, with an overall mean score of 4.36 out of 5. In particular, students reported a strong sense of achievement and interest while directly designing and implementing applications and verifying the outcomes on actual devices. In addition, students demonstrated high levels of interest and active participation regarding the practical application of AI technologies in real-life contexts. Based on these findings, the program was revised and refined to finalize the PBL program.

Keywords: Technology-Home Economics, App Inventor, Project Based Learning (PBL), Artificial Intelligence (AI)



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Introduction

Recent advances in artificial intelligence (AI) technologies have rapidly expanded across various industrial sectors, including communications, transportation, logistics, and media, driving structural changes throughout society. These changes have affected not only industrial structures but also labor markets, methods of information production and consumption, and decision-making systems across society as a whole. Accordingly, the ability to understand and effectively utilize AI technologies has emerged as a key competency in future society, and the field of education is also being required to respond in a systematic and proactive manner. Kim and Yoo (2016) predicted that the demand for AI-related professionals would continue to increase and emphasized the need to expand AI and programming education at the school level. This suggests that AI education should not be limited to elective courses or specialized areas, but rather should be addressed as an essential component of the general school curriculum. Therefore, AI education should move beyond simple technical skill acquisition and foster integrated competencies, including problem-solving ability, critical thinking, and ethical judgment.

In Korea, technology education at the high school level is undergoing substantial changes following the implementation of the 2022 Revised National Curriculum, which emphasizes engineering design, digital transformation, and AI literacy as essential competencies for future society (Ministry of Education, 2022). The newly introduced content area, Sustainable Convergent Engineering, reflects these educational goals by encouraging students to understand emerging technologies and apply them to authentic engineering problems. However, despite these curricular changes, relatively few instructional models have been developed that systematically integrate AI technologies, engineering design, and project-based learning within the formal Technology and Home Economics curriculum. Consequently, there is a growing need for curriculum-based instructional programs that enable students to apply AI technologies while engaging in authentic engineering problem-solving in school settings (Yoon, 2022).

Meanwhile, the technology domain of the high school Technology and Home Economics curriculum has educational significance in that it enables students to experience technological thinking and engineering problem-solving processes through real-life problem situations. In particular, one of the content areas presented in the 2022 revised high school Technology and Home Economics curriculum, “Sustainable Convergent Engineering,” emphasizes fostering learners’ abilities to apply advanced technologies, such as information and communication engineering, artificial intelligence, and the Internet of Things (IoT), to authentic problem situations. In addition, this content area aims to help learners understand the principles and applications of technologies utilized in a hyper-connected society and to cultivate attitudes toward the ethical use of technology. Furthermore, the curriculum emphasizes the application of Project-Based Learning (PBL) to solve real-life problems, thereby promoting students’ active participation and practical performance competencies (Ministry of Education, 2022).

However, AI- and information and communication engineering-related instruction in actual school settings is still often conducted in a theory-centered manner, resulting in learning that remains at the level of abstract conceptual understanding. Kim (2024) pointed out that high school AI education tends to focus heavily on explaining concepts and principles, thereby limiting students’ opportunities to apply technologies to real-world problem situations or to experientially understand how such technologies operate. Such limitations not only reduce students’ interest in and

understanding of AI and engineering technologies but also hinder the development of the practical problem-solving competencies emphasized in the curriculum. Therefore, AI education needs to move beyond simple knowledge delivery toward practice-oriented learning experiences in which students directly design and implement technologies themselves.

In response to these concerns, PBL-based teaching and learning approaches have recently received increasing attention. PBL involves a series of processes in which learners establish goals based on authentic and contextualized problems, design and carry out solution processes, and collaboratively produce outcomes. Such processes are regarded as effective approaches for supporting practical AI learning because they encourage learners’ active participation and help them concretely recognize the practical applicability of technology (Kim, 2024). In particular, PBL centered on engineering design processes has the advantage of integrating theoretical understanding with practical implementation.

Although the spread of generative AI technologies has increased the possibility of automating programming processes, school education continues to emphasize the importance of learners directly experiencing algorithmic thinking and procedural problem-solving processes. In particular, technology education at the high school level requires learning experiences that go beyond merely utilizing AI technologies to understanding and structuring the operating principles of technology and the processes involved in problem-solving. From this perspective, block-based programming can serve as an effective educational tool because it reduces the burden associated with complex syntax and enables learners to understand and implement engineering problem-solving processes step by step. In particular, MIT App Inventor provides a block-based programming environment and AI extension functions that allow learners with limited programming experience to participate more easily in application development activities.

Previous studies have shown that App Inventor is a highly accessible educational tool with strong potential for practical product-oriented learning, while PBL in AI education effectively promotes learners’ active participation and real-world problem-solving competencies (Ahn & Lee, 2014; Choi & Heo, 2024; Choi & Kim, 2016; Jeong et al., 2022). However, relatively few studies have systematically designed and applied App Inventor-based PBL programs incorporating AI extension functions within the “Sustainable Convergent Engineering” content area of the high school Technology and Home Economics curriculum.

The purpose of this study was to analyze AI-related learning contents required in the “Sustainable Convergent Engineering” content area of the 2022 revised high school Technology and Home Economics curriculum and to design and develop an App Inventor-based PBL program accordingly. Furthermore, this study sought to explore the educational significance and classroom applicability of the “Sustainable Convergent Engineering” content area through the developed PBL program.

To achieve these purposes, this study first analyzed the “Sustainable Convergent Engineering” content area of the 2022 revised high school Technology and Home Economics curriculum and related contents in high school Technology and Home Economics textbooks in order to derive learning elements related to information and communication engineering and AI. Second, based on these learning elements, an App Inventor-based PBL program including learning objectives, instructional contents, lesson structures, teaching and learning methods, assessment elements, instructional materials, and student worksheets was developed. In addition, content validity was examined by experts in Technology and Home Economics education and AI education, and the program was revised and refined based on the results. Third,

the developed PBL program was pilot-tested in high school Technology and Home Economics classes, and the program was further revised and finalized by reflecting feedback obtained during the implementation process.

Literature Review

Technology Education in the 2022 Revised Curriculum

According to the 2022 Revised National Curriculum, the technology domain of the high school Technology and Home Economics curriculum emphasizes the development of learners' engineering and technological competencies through creative problem-solving activities based on real-life experiences related to technology and engineering. In particular, the curriculum aims to provide practice-oriented learning experiences in which learners solve real-world problems by integratively applying technological knowledge, thinking skills, and attitudes (Ministry of Education, 2022). Table 1 presents the content elements and achievement standards related to information and communication engineering, including AI technologies, within the "Sustainable Convergent Engineering" content area of the curriculum. This content area integratively presents knowledge, skills, and attitudes centered on information and communication engineering and AI technologies, while emphasizing the understanding of advanced technologies, ethical use of technology, and the cultivation of engineering problem-solving competencies. In addition, the curriculum highlights learning activities in which students understand the principles and applications of information and communication engineering technologies, including AI, and apply them to real-life problem-solving situations. In this regard, the content area demonstrates strong alignment with Project-Based Learning (PBL), as it enables learners to develop engineering thinking and practical competencies through the processes of exploring authentic problems and designing and implementing solutions.

Analysis of AI Instructional Tools

With the growing expansion of AI education both domestically and internationally, various online-based instructional tools have been developed and distributed to support learners' understanding and utilization of AI technologies. These tools contribute to the development of learners' computational thinking and digital competencies by supporting the understanding of AI principles, data-based problem solving, and experiences in algorithm design and implementation.

Among the domestic and international AI instructional tools presented in Ahn (2023), AI Cody, Brightics Studio, Dialogflow, App Inventor, Orange3, Teachable Machine, and Colab were identified as appropriate tools in consideration of the educational purposes of this study and their applicability to high school students. Based on an examination of the educational suitability of each tool in relation to the objectives of the PBL program developed in this study, App Inventor, Teachable Machine, and Colab were initially selected as suitable tools for helping students understand the basic principles of computer vision and machine learning and connect them to product-oriented learning activities.

Colab provides a cloud-based environment built on Jupyter Notebook, enabling users to implement and experiment with various machine learning models. However, because it requires a basic understanding of Python syntax and text-based coding, it may present an initial barrier for learners with limited programming experience.

Teachable Machine is an intuitive tool that enables learners to easily create computer vision-based models such as image classification and pose recognition, making it effective for experiential understanding of AI concepts. However,

the range and types of data that can be utilized are relatively limited, and the learning process is presented in a simplified form. Consequently, learning activities may remain focused on procedural execution or imitation, which limits opportunities for deeper understanding of AI principles and creative problem-solving activities.

In contrast, App Inventor is an educational tool that supports mobile application development through a visual block-based programming environment, allowing learners with little programming experience to use it relatively easily. In particular, App Inventor provides AI extension functions that enable the implementation of various smart technologies, including image recognition and machine learning model integration. Furthermore, learners can immediately execute and verify the functions they design on smartphones. These features can support learners in understanding the operational principles and application processes of AI technologies while engaging in PBL activities involving the creation of actual products. Therefore, App Inventor was considered an appropriate tool for supporting practical engineering problem-solving experiences and conducting AI-based PBL activities.

Table 1. Content Framework and Achievement Standards Related to Information and Communication Engineering in the 2022 Revised High School Technology and Home Economics Curriculum

Core Idea	• Information and communication engineering contributes to the advancement of AI technologies through connections and information exchange among people, objects, and systems. • Advanced convergent engineering contributes to solving engineering problems by integrating knowledge from various domains centered on information and communication technologies.
Domain Category	Content elements
Knowledge & Understanding	• Hyper-connected society and information and communication engineering
Processes & Skills	• Solving convergent problems • Utilizing AI technologies • Recording engineering problem-solving processes • Evaluating and sharing engineering outcomes
Values & Attitudes	• Convergent thinking and critical attitudes • Recognition of the value of engineering • Practice of engineering ethics • Challenging attitudes toward engineering • Recognition of the importance of communication • Cooperative and positive attitudes
Achievement Standards	[12TH06-01] Students understand information and communication engineering through advanced technologies such as big data, the Internet of Things (IoT), and AI, explore cases of information and communication engineering applications, and develop attitudes toward the ethical use of information and communication technologies. [12TH06-02] Students solve engineering problems related to the hyper-connected society and information and communication technologies through engineering problem-solving processes and recognize the importance of engineering communication through the evaluation of outcomes.

Source: Reconstructed from Ministry of Education (2022), Technology and Home Economics / Informatics Curriculum, p. 49.

Analysis of Previous Studies

An analysis of previous studies on App Inventor-based instruction and PBL in AI education revealed that both areas commonly emphasize the importance of practice-oriented learning experiences and learner-centered instructional design.

First, studies related to App Inventor-based instruction reported that the block-based programming environment enhances learner accessibility and that the structure allowing immediate verification of outputs positively influences learning motivation and interest. Ahn and Lee (2014) suggested that App Inventor is an appropriate educational tool for middle and high school students because it reduces the psychological burden associated with coding and provides

opportunities to implement applications on actual devices. Choi and Kim (2016) and Park (2021) reported that App Inventor-based instruction positively affects not only creativity, convergent thinking, and computational thinking, but also affective outcomes such as interest and engagement. However, many previous studies focused on elementary school students or pre-service teachers, or were limited to basic application development activities. Consequently, research on systematic instructional programs integrating AI extension functions for high school students remains limited.

Meanwhile, studies on PBL in AI education have reported that practice-oriented project activities positively influence learners' self-efficacy, learning motivation, problem-solving abilities, and creative attitudes. Choi and Heo (2024) found that participation in AI convergence projects significantly improved both individual and collective efficacy among learners, while Jun (2024) reported that activity-centered project instruction positively contributed to the development of self-efficacy and value awareness related to AI and software education. In addition, Kim (2024) and Jeong et al. (2022) emphasized that AI education should move beyond simple conceptual understanding toward the design and implementation of real-world problem-solving models. These studies suggest that experiences involving the application of AI technologies in authentic contexts can positively influence both learners' cognitive understanding and affective development.

Taken together, previous studies indicate that App Inventor is a highly accessible educational tool with strong potential for practical product-oriented learning, while PBL in AI education serves as an effective instructional strategy for promoting learners' active participation and real-world problem-solving competencies. However, relatively few studies have systematically designed and implemented App Inventor-based PBL programs incorporating AI extension functions within the "Sustainable Convergent Engineering" content area of the high school Technology and Home Economics curriculum. Therefore, this study aimed to develop an App Inventor-based PBL program that connects information and communication engineering and AI technologies to authentic problem-solving activities grounded in the "Sustainable Convergent Engineering" content area of the curriculum and to examine its applicability in educational settings. This study is meaningful in that it addresses gaps in previous research and proposes an AI-based instructional approach appropriate for the high school level.

Research Methods

Preparation

This study adopted a developmental research approach to design and refine an AI-integrated Project-Based Learning (PBL) program based on the Sustainable Convergent Engineering content area of the 2022 Revised High School Technology and Home Economics Curriculum. The program was developed following the Preparation–Development–Implementation (PDI) instructional design model. Throughout the preparation stage, curriculum documents, high school Technology and Home Economics textbooks, previous studies, and AI instructional tools were analyzed to establish the instructional framework. Data collected during the expert validation and the pilot implementation were used to revise and refine the program. Quantitative data from the expert validation and student satisfaction surveys were analyzed using descriptive statistics (means), while qualitative responses to open-ended questions were analyzed through content

analysis to identify areas for program improvement.

In the preparation stage, a foundational analysis was conducted for the design of the PBL program. Specifically, the following procedures were conducted.

First, the 2022 revised Technology and Home Economics curriculum and the content elements and achievement standards of the “Sustainable Convergent Engineering” content area were analyzed.

Second, learning contents and activity tasks related to information and communication engineering and AI presented in relevant units of high school Technology and Home Economics textbooks were examined.

Third, domestic and international AI instructional tools were compared and reviewed in order to select tools appropriate for PBL instruction at the high school level.

Fourth, previous studies related to AI education and PBL were analyzed to establish the theoretical foundation for instructional design.

Fifth, the learning environment was analyzed, including the availability of digital devices in the target school and the characteristics of the learners.

Following the development stage, the instructional program underwent two stages of evaluation. First, content validity was examined by six in-service teachers with expertise in Technology and Home Economics or AI-related education. Subsequently, the revised program was pilot-tested with 60 second-year students at a high school in Seoul. Data were collected through expert validation questionnaires and student satisfaction surveys. Quantitative responses were analyzed using descriptive statistics (mean scores), whereas qualitative responses to open-ended questions were analyzed to identify major themes for program improvement.

Development

In the development stage, a PBL topic was established and lesson-specific learning objectives and learning activities were designed based on the results of the preparation stage. Based on these results, instructional plans, teacher instructional materials, and student activity worksheets were developed.

Subsequently, content validity was examined by experts in Technology and Home Economics education and AI education. The instructional materials were then revised and refined by reflecting the results of the validity review.

Implementation

In the implementation stage, the revised PBL program was pilot-tested with 60 second-year students at a high school in Seoul over five class sessions. The pilot implementation was conducted to examine the classroom applicability of the developed program and to collect students' perceptions of the learning experience. After the completion of the instruction, a student satisfaction survey was conducted to analyze the appropriateness of the program and identify areas requiring improvement. Based on the survey results, the instructional materials were revised for a second time, and the program was finalized.

Stage	Research Contents
Preparation (P)	- Analysis of the 2022 revised Technology and Home Economics curriculum - Analysis of the content elements and achievement standards of the “Sustainable Convergent Engineering” content area in the 2022 revised high school Technology and Home Economics curriculum - Analysis of learning contents and activity tasks related to information and communication engineering in units associated with the “Sustainable Convergent Engineering” content area in the 2022 revised high school Technology and Home Economics textbooks - Analysis of AI instructional tools - Analysis of previous studies - Analysis of the learning environment
Development (D)	- Establishment of the topic - Organization of lesson structure and derivation of learning objectives - Establishment of lesson-specific learning contents and activities - Development of draft instructional materials (lesson plans, teacher instructional materials, and student activity worksheets) - Expert validity review - Revision and refinement of instructional materials
Implementation (I)	- Student pilot test - Student satisfaction survey - Second revision and finalization of instructional materials

Fig. 1. Procedure for developing the PBL program based on the PDI model

Results

Preparation

Analysis of the Technology Domain in the 2022 Revised High School Technology and Home Economics Curriculum

An analysis of the technology domain in the 2022 revised high school Technology and Home Economics curriculum revealed that the curriculum strongly emphasizes practice-oriented learning centered on real-world problems related to technology and engineering, as well as the development of engineering problem-solving competencies. The curriculum is designed to include the entire process from problem recognition and design to production and evaluation as part of the learning experience, while encouraging learners to integratively apply technological knowledge, skills, and attitudes.

In particular, the “Sustainable Convergent Engineering” content area emphasizes both the ability to solve problems by integrating knowledge from various domains centered on information and communication engineering and the cultivation of ethical attitudes toward technology use. This content area demonstrates strong alignment with PBL, which enables learners to experience the entire engineering problem-solving process, and it was found to provide an appropriate curricular foundation for designing AI-based project instruction.

Analysis of the Content Elements and Achievement Standards of the “Sustainable Convergent Engineering” Content Area

An analysis centered on achievement standards [12TH06-01] and [12TH06-02] revealed that understanding information and communication engineering and AI technologies, exploring application cases, cultivating ethical attitudes toward technology use, documenting engineering problem-solving processes, and sharing outcomes were presented as core elements. This indicates that the curriculum integratively requires learners to understand the principles of advanced technologies, apply them to real-life problems, recognize ethical responsibilities, and develop engineering communication competencies.

Accordingly, it was determined that a PBL program enabling learners to experience the entire process of problem definition, design, implementation, and sharing through the development of AI-based applications would serve as an appropriate instructional approach for practically implementing the achievement standards.

Analysis of Learning Contents and Activity Tasks Related to Information and Communication Engineering in Textbooks

An analysis of relevant units in high school Technology and Home Economics textbooks showed that basic conceptual explanations and simple inquiry activities related to information and communication engineering and AI were relatively well presented. However, integrated project activities in which learners independently define problems, design and create products, and share and evaluate results were found to be limited.

In other words, while concept-oriented activities were sufficiently provided, practice-oriented activities allowing learners to experience the entire engineering problem-solving process were lacking. These findings suggest that PBL-based instructional materials are needed to more effectively realize the intent of the curriculum.

Analysis of AI Instructional Tools

AI instructional tools were compared and analyzed in terms of functionality, learner accessibility, expandability, and educational suitability. The analysis showed that Colab is appropriate for implementing machine learning models but requires prior understanding of text-based coding. Teachable Machine provides an intuitive user environment but has limitations in expandability and advanced learning activities. In contrast, App Inventor offers both a block-based

programming environment and AI extension functions, thereby providing advantages in terms of both accessibility and expandability.

In particular, App Inventor enables learners to immediately execute and verify the functions they design on smartphones, making it an appropriate tool for strengthening practical experiences in engineering problem-solving. Therefore, App Inventor was selected as the final instructional tool in this study.

Analysis of AI Previous Studies

A comprehensive review of previous studies related to App Inventor-based instruction and the application of PBL revealed that these instructional approaches positively influence learners’ motivation and problem-solving experiences. In addition, such approaches have been reported to strengthen convergent thinking competencies and foster positive perceptions toward coding (Hwang, 2023; Lee, 2008; Moon, 2014; Oh, 2002).

However, many previous studies focused primarily on implementing specific functions or producing outcomes, while relatively few studies systematically structured the entire engineering problem-solving process within instructional design. Accordingly, this study aimed to design a PBL framework structured around the full process of problem definition, design, implementation, evaluation, and sharing. Table 2 summarizes previous studies related to App Inventor-based instruction, PBL in technology education, and PBL in AI education.

Table 2. Analysis of Previous Studies

Previous Studies	Content
App Inventor Utilization	- Positively influences learners’ interest and confidence in programming compared to text-based programming languages (Ahn & Lee, 2014)
PBL in Technology Education	- Demonstrates positive effects on increasing learners’ interest (Moon, 2014) - Shows various educational effects, including strengthening problem-solving experiences, providing opportunities for diverse inquiry and expression activities, enhancing flexibility of thinking, and offering experiential learning opportunities (Oh, 2002)
PBL in AI Education	- Effective in enhancing learners’ learning motivation (Jun, 2024) - Positively influences the development of active and creative learning attitudes and the ability to explore solutions to real-life problems (Kim, 2024)

Analysis of the Learning Environment

The target school environment allowed students to use personal smartphones, and stable wireless internet access was available in classrooms. This indicated that the school possessed appropriate conditions for implementing mobile application-based PBL instruction.

Furthermore, the environment in which learners could immediately verify results on actual devices was expected to positively influence learning motivation and the development of a sense of achievement.

Development

Establishment of the PBL Topic

In this study, a PBL topic was designed based on the achievement standards and core ideas of the “Sustainable Convergent Engineering” content area so that learners could apply information and communication engineering

technologies to solving real-world social problems. In particular, the study sought a topic that reflected the curriculum’s emphasis on a hyper-connected society and the utilization of AI technologies while also enabling practical problem-solving activities appropriate for high school students.

Accordingly, this study focused on the social issue of supporting the daily lives of individuals with visual impairments. Individuals with visual impairments may experience difficulties in immediately recognizing information about various objects in everyday life, and the need for information and communication technology–based support has continuously been emphasized. This issue was considered to have educational value because possibilities for problem-solving could be explored through AI-based image recognition technologies and mobile applications.

In addition, this study utilized App Inventor to provide high school students with opportunities to directly design and implement applications incorporating AI functions. App Inventor offers a block-based programming environment, allowing learners with limited programming experience to access programming relatively easily. Furthermore, by utilizing AI extension functions, learners can implement functions such as image recognition in actual applications.

Based on these considerations, this study established the PBL topic as the “Development of an Assistive Application for Individuals with Visual Impairments Using AI-Based Object Recognition Functions.” This topic was designed to enable learners to apply the principles of information and communication engineering and AI technologies to authentic problem-solving processes while experiencing the entire engineering problem-solving process in a practice-oriented manner.

Establishment of Lesson-Specific Learning Objectives

Table 3. Lesson Structure and Core Learning Objectives of the Program

Lessons	Core Learning Objectives
1, 2	Students can understand the concepts of information and communication engineering and related technologies, explain the characteristics of a hyper-connected society, and propose practical strategies for the ethical use of AI technologies.
3-5	Students can understand the basic structure of App Inventor and implement simple applications using block-based coding.
6	Students can design and implement applications using various App Inventor components and AI extension functions.
7, 8	Students can complete an application incorporating object-recognition functions and practice engineering problem-solving processes while considering the ethical use of information and communication engineering technologies.

Table 3 presents the lesson structure and core learning objectives of the program.

The program was organized into a total of eight lessons. Lessons 1 and 2 focused on understanding the concepts of information and communication engineering and AI, as well as exploring the ethical use of AI technologies. Lessons 3 through 5 addressed understanding the basic functions of App Inventor and implementing basic applications. Lesson 6 focused on the use of AI extension functions, while Lessons 7 and 8 involved completing the object-recognition application and engaging in sharing and reflection activities.

Rather than treating each lesson as an independent coding activity, the program was intentionally designed as a continuous engineering design project. Students first explored a real-world problem experienced by individuals with visual impairments, identified user needs, and discussed possible engineering solutions. They then progressively designed, implemented, tested, and refined an AI-based object-recognition application using MIT App Inventor. Throughout the instructional sequence, learners repeatedly documented their engineering problem-solving processes,

collaborated with peers, and evaluated and improved their products based on feedback. This organization enabled students to experience the complete engineering design process while applying AI technologies to an authentic problem within the Technology and Home Economics curriculum.

Each lesson was designed to integratively reflect the domains of knowledge, skills, and attitudes.

Establishment of Lesson-Specific Learning Contents and Activities

Table 4. Lesson-Specific Learning Contents

Lessons	Learning Topics	Main Content
1, 2	- Information and communication engineering and the hyper-connected society - Ethics of information and communication engineering	- Understanding information and communication engineering and the hyper-connected society - Principles and application cases of information and communication engineering technologies in the hyper-connected society - Ethics of information and communication engineering
3-5	- Introduction to App Inventor and use of basic functions - Implementing applications with App Inventor	- Introduction to App Inventor - Accessing App Inventor and understanding its basic structure - Demonstration of simple application examples - Free practice activities
6-8	- Developing an object-guidance application for individuals with visual impairments using App Inventor	- Computer vision and application cases - Utilization of App Inventor extension functions - Presentation of the project task (problem definition–design–implementation–improvement–sharing) - Project implementation activities

Table 4 presents the lesson-specific learning contents of the program.

Based on the directions established during the preparation stage for developing PBL-based instructional materials, lesson-specific learning contents were systematically organized. Learning activities were designed in accordance with the principles of PBL so that learners could actively participate in collaborative problem-solving processes. In this process, the teacher was expected to perform not only the role of a knowledge provider, but also that of a facilitator, guide, and feedback provider throughout the learning process.

The instructional materials were designed to enable learners to utilize AI technologies within convergent problem-solving processes based on an understanding of the characteristics of the hyper-connected society and the fundamental concepts of information and communication engineering. In particular, learning activities were organized so that the engineering problem-solving procedures of problem definition, idea generation, design and implementation, and result sharing and reflection could be carried out in a step-by-step manner. In addition, learners were encouraged to document the engineering problem-solving process in order to clarify their thinking processes, while product development and sharing activities were intended to support the expansion and reconstruction of learning outcomes.

Furthermore, in terms of values and attitudes, the instructional materials emphasized recognition of the social value of engineering and the ethical use of technology, while also fostering responsibility and communication attitudes required in collaborative problem-solving processes. Through these instructional materials, learners are expected to understand the principles of information and communication engineering and AI technologies and to experience PBL by applying such technologies to convergent problem-solving processes and producing and sharing actual outcomes.

Development of the Draft Instructional Materials

The instructional program developed in this study consisted of lesson plans, teacher instructional materials, and student activity worksheets. The lesson plans were systematically organized by lesson and specifically presented the instructional procedures, teaching contents, instructional considerations, and student activities. Through this structure, the instructional procedures and activity flow were clearly organized to support teachers in effectively implementing PBL instruction.

In addition, instructional presentation materials (PPT slides) were developed for teachers to use in actual classroom settings in accordance with the instructional flow of the lesson plans. These materials included explanations of key concepts, problem presentation materials, activity guidelines, and stages for summarization and reflection, thereby ensuring consistency and efficiency in instructional implementation.

Student activity worksheets were designed in alignment with the learning objectives and activities of each lesson so that the organization of key concepts, documentation of engineering problem-solving processes, and product design and implementation activities could be organically connected. In particular, the worksheets included self-assessment and peer-assessment components to encourage learners to reflect on their own learning processes and expand learning through collaborative interaction. Through these features, the instructional materials were designed to support PBL classes that reflected self-directed, collaborative, and reflective learning characteristics.

Expert Validation

The questionnaire developed by Kim (2024) for evaluating the field applicability of experiential learning activities was revised and reconstructed to fit the purpose and characteristics of this study. A survey was conducted to improve the developed instructional program and to verify its content validity. The survey consisted of objective items using a five-point Likert scale, along with open-ended questions that allowed respondents to freely provide suggestions for improvement and additional comments (Nam, 2026, pp. 87–88).

A total of six in-service teachers, including Technology and Home Economics teachers and information teachers with experience teaching technology- or AI-related courses and more than six years of teaching experience in educational settings, participated in the survey. Through this process, the appropriateness of the program content, the systematic organization of the program, the feasibility of classroom implementation, and the validity of the assessment components were comprehensively reviewed. The survey results are presented in Tables 5 and 6.

A comprehensive analysis of the expert feedback indicated that the major areas requiring improvement included adjusting the difficulty level of variable settings, improving the balance between activity quantity and instructional time allocation, and clarifying the structure of collaborative group activities.

Table 5. Results of Objective Responses from the Expert Validation Survey

Domain	Survey Item	M
Appropriateness of Learning Objectives and Contents	The instructional materials appropriately reflect the characteristics and objectives of the “Sustainable Convergent Engineering” content area in the Technology and Home Economics curriculum.	5.00
	The learning elements included in the instructional materials effectively demonstrate how computer vision and deep learning technologies can be utilized in practice.	4.67
	The computer vision–related contents included in the instructional materials are appropriate for the high school level.	4.50
	The difficulty level of the instructional materials is appropriate for high school students.	4.50
Appropriateness of the Lesson-Specific Instructional Model	The learning objectives and contents are appropriately distributed across lessons.	5.00
Appropriateness of Applying the PBL Model	Applying PBL to these learning contents is more appropriate than lecture-based instruction in terms of learning effectiveness.	5.00
	The instructional materials are appropriately designed according to the PBL model.	4.67
	The instructional materials can encourage learners’ self-directed inquiry, idea generation, and problem-solving.	4.67
Appropriateness for Student Interest	The instructional materials can induce learner interest and participation.	4.83
Appropriateness for Real-Life Application	The instructional materials are educationally meaningful because they are connected to real-life contexts.	5.00
Applicability in Educational Settings	The instructional materials can be sufficiently applied across diverse schools and classroom environments.	4.00
Appropriateness of Learning Tools	App Inventor and computer vision–related extension functions are appropriate tools for achieving the learning objectives.	4.83
	The process of implementing applications using App Inventor can positively contribute to learners’ sense of achievement.	4.83
Overall Mean		4.73

Table 6. Analysis of Open-Ended Responses from the Expert Validation Survey

Category	Open-Ended Responses
Positive Feedback	- The program was composed around topics capable of stimulating students’ interest. - The overall lesson sequence was systematically connected, resulting in a coherent instructional flow. - The idea of utilizing computer vision technology as an assistive tool for individuals with visual impairments was considered creative and educationally meaningful. - The use of familiar digital media and the design allowing learners to immediately implement ideas through App Inventor were positively evaluated for increasing learning engagement and sense of achievement. - The program was positively evaluated for encouraging students’ creativity and problem-solving abilities by differentiating application functions among groups rather than focusing solely on procedural practice activities.
Suggestions for Improvement	- If the number of variables and situational conditions becomes excessive during the main project process, projects may remain incomplete; therefore, appropriate adjustment of functional scope and difficulty is needed. - The stages and activities of the engineering problem-solving process need to be more precisely adjusted. - In Worksheet 1, the amount of discussion and activity time may exceed class time limitations; therefore, Activities 6 and 8 should be integrated or reorganized. - In Worksheet 2, conducting Activity 3 first and then examining diverse cases through additional questions may be more effective for fostering ethical practice competencies. - During practice activities, teachers should provide guidance on implementation methods while encouraging students to independently lead the idea-generation stage in order to derive more diverse outcomes. - Considering differences in learning pace among students, instructional progress should be flexibly adjusted while checking outputs step by step. - For students unfamiliar with group activities, collaborative learning should be facilitated by clearly assigning and explaining individual group roles.

Revision and Refinement of the PBL Program

The PBL program was revised and refined by comprehensively reflecting the objective survey items that received relatively lower evaluation scores and the suggestions presented in the open-ended responses (Nam, 2026, pp. 65–68). Based on the expert review results, modifications focused primarily on the difficulty level of function implementation, the amount of learning activities, and the structure of collaborative learning.

First, experts pointed out that the complexity of variable settings and conditional statement configurations in the implementation process could pose difficulties for learners. Accordingly, additional guidance on variable-setting methods and block-construction procedures was included in the student activity worksheets in a step-by-step manner to support learners’ understanding of the project implementation process.

Second, concerns were raised that the amount of activities in some lessons was excessive, making it difficult for learners to engage in sufficient inquiry and reflection. To address this issue, the amount of activities was reduced, and similar activities were integrated and reorganized so that lesson activities could be more efficiently arranged and instructional time could be managed more appropriately.

Third, it was suggested that differences in learners’ competency levels could lead to disparities in participation during the project process. Therefore, heterogeneous group formation based on students’ interests and competency levels was adopted as a principle, and the division of roles within groups was explicitly presented. In addition, contribution record sheets for each lesson were included to encourage participation from all learners.

Fourth, concerns were raised regarding the burden of curriculum implementation, including limited instructional hours and the possibility of overlap with contents from other subjects. In response, the amount of activities was adjusted, and some project processes were converted into optional or extended activities so that the program could be flexibly implemented according to school conditions.

Implementation

Student Pilot Test and Feedback

A pilot test was conducted by applying the revised and refined lesson plans, teacher instructional materials, and student activity worksheets to actual high school classes after reflecting the results of the expert validity review. Through this process, the classroom applicability of the App Inventor-based PBL program, the appropriateness of instructional operation, and learners’ responses were comprehensively examined.

The pilot test was conducted over five class sessions with 60 second-year students at ○○ High School located in Seoul. Although the original program consisted of eight lessons, the pilot implementation was partially reduced in consideration of instructional hours and operational conditions in the school setting. The first lesson was organized as a theory-based class addressing the definitions and principles of information and communication engineering and the fundamental concepts of AI. The following four lessons were conducted as practice-oriented sessions focused on designing and implementing applications using App Inventor. The concepts of the hyper-connected society, information and communication engineering, and AI learned during the theory lesson were designed to be applied to authentic problem-solving tasks during the practice lessons.

During the practice sessions, students designed and implemented applications in groups using the basic functions and AI extension functions of App Inventor. The instruction was organized according to the procedures of problem definition, idea development, function implementation, result sharing, and reflection so that the engineering problem-solving process could be systematically experienced.

After the pilot test, a survey was conducted to investigate student satisfaction and perceptions of the instructional experience. Based on the survey results, the appropriateness of the program in terms of difficulty, interest, comprehension, and activity organization was analyzed, and areas requiring improvement were identified and utilized as foundational data for refining the final program.

The pilot implementation was conducted at the school, and the collected data were used solely for research purposes. In addition, care was taken to ensure that participants' personal information was not disclosed during the research process.

Table 7. Student Feedback

Category	Open-Ended Responses
Positive Feedback	- The process of directly creating applications using App Inventor was interesting and enjoyable. (5) - The class was enjoyable overall. (3) - It was helpful to immediately check the execution results and outputs through smartphone applications. (2) - I felt satisfied when the application I created worked properly on my smartphone. - Because the class was participation-oriented, I felt a sense of accomplishment after completing it. (2) - I felt proud of creating my own application, and the process of designing the application was particularly enjoyable. - It was beneficial that applications could be easily created using visual and intuitive blocks. - It was good to be able to utilize various AI programs. - The class reminded me of learning Entry when I was younger, which made it very enjoyable. - The contents were easy to understand. - The detailed explanations made it easy to follow along. - I was able to directly experience coding. - Even students unfamiliar with computer functions could use it effectively. - The class was not boring. - I gained confidence in coding and improved my understanding. - Difficult coding concepts were explained in an easy manner, and we were able to use interesting functions.
Negative Feedback	- Some parts were somewhat difficult to understand. (3) - Once I missed a step, it became difficult to follow the class. (2) - It was disappointing that some codes were difficult to implement within App Inventor itself. - On iPhones, the connection was frequently interrupted or occasional errors occurred.

Following the pilot implementation, a survey was conducted to examine students' satisfaction with the instructional program. The questionnaire consisted of objective items using a five-point Likert scale and open-ended items that allowed students to freely provide suggestions for improvement and additional comments regarding the program (Nam, 2026, pp. 89–90). The objective items focused on students' understanding of instructional contents, interest in activities, appropriateness of difficulty level, satisfaction with collaborative activities, and usefulness of App Inventor.

The collected data were analyzed by examining the means and distributions of the objective items, while the open-ended responses were analyzed through content analysis to derive major themes. The responses and revisions are presented in Tables 8 and 9.

Table 8. Results of the Objective Items in the Student Satisfaction Survey

Survey Item	M
I was able to understand the concept of the hyper-connected society and the core technologies that constitute it through the class.	4.25
I was able to learn with interest by directly experiencing technologies related to information and communication engineering, such as IoT and AI.	4.28
I was able to understand the basic principles and application methods of AI.	4.37
I was able to understand how computer vision technology can be applied to solving real-life problems.	4.43
I came to recognize that computer vision technology can be usefully applied in everyday life.	4.31
I came to understand the factors that should be considered for the ethical use of information and communication engineering technologies.	4.18
The activities involving collecting and analyzing information, exploring solutions, and developing applications to solve problems were interesting.	4.37
My creative thinking expanded through the process of developing and refining ideas for solving real-life problems.	4.33
By implementing applications using App Inventor, I was able to understand the applicability of AI-based image recognition technology.	4.43
I experienced a sense of achievement when obtaining the intended outcomes during the application implementation process.	4.50
I was highly satisfied because I could verify the implemented outcomes on actual devices.	4.48
I became interested in information and communication engineering and AI through the process of implementing applications using App Inventor.	4.35
After the class, I developed a more positive perception toward AI utilization activities.	4.22
I came to understand that AI technologies can be applied in real life.	4.50
Overall Mean	4.36

Table 9. Details of the Second Revision of the Learning Program

Category	Identified Issue	Revision and Improvement
Awareness of Ethical Use	Understanding of the ethical use of information and communication engineering technologies appeared relatively low.	Ethical considerations were more explicitly presented as conditions in the problem-solving process, and the purpose of supporting individuals with visual impairments was continuously emphasized throughout the instruction.
Difficulty of Block Coding	Some learners reported that the block-coding process was somewhat difficult.	Step-by-step examples of block construction and visual materials were added to the teacher materials, and stages for comprehension checks and supplementary explanations were reinforced in the lesson plans.
Instructional Pace and Learner Differences	Some students experienced difficulty keeping up due to differences in prior competency levels.	The core implementation process was subdivided, and guidelines for step-by-step result checking and flexible pacing adjustment were added.
Device Environment Issues	Connection instability occurred on some iOS devices when using App Inventor.	Android smartphones were prepared as backup devices to support implementation and result verification.

The results presented in Tables 7-9 indicated that students showed generally high levels of satisfaction with the App Inventor-based PBL instruction.

First, the results of the objective items in Table 8 showed an overall mean score of 4.36, indicating that students were generally highly satisfied with the instruction. In particular, the highest mean scores were found for the items “I experienced a sense of achievement when obtaining the intended outcomes during the application implementation process” ($M = 4.50$), “I came to understand that AI technologies can be applied in real life” ($M = 4.50$), and “I was highly satisfied because I could verify the implemented outcomes on actual devices” ($M = 4.48$).

In addition, relatively high scores were observed for the items “I was able to understand how computer vision technology can be applied to solving real-life problems” ($M = 4.43$) and “By implementing applications using App Inventor, I was able to understand the applicability of AI-based image recognition technology” ($M = 4.43$). These

findings indicate that the students developed a positive understanding of the real-life applicability of AI technologies. On the other hand, the item “I came to understand the factors that should be considered for the ethical use of information and communication engineering technologies” ($M = 4.18$) showed a relatively lower mean compared with other items.

Second, the results of the open-ended responses in Table 7 indicated that many students provided positive feedback such as “The process of directly creating applications was interesting and enjoyable,” “It was good to immediately verify the results on smartphones,” and “Because the class was participation-oriented, I felt a sense of achievement.” Students positively responded to the block-based coding activities and smartphone-based implementation experiences.

However, some students reported that “Some parts were difficult to understand,” “Once I missed a step, it became difficult to follow,” and “The connection was unstable on iPhones.” Some students reported difficulties related to instructional pace, coding complexity, and device connectivity.

Second Revision and Finalization of the Learning Program

Based on the results of the student satisfaction survey, areas requiring improvement in the instructional materials were identified, and the PBL program was finalized by reflecting these findings to provide a more stable instructional program that considered learners’ competency levels and actual classroom environments (Nam, 2026, pp. 91–133). The major improvements can be summarized into three areas.

First, students’ awareness of the ethical use of information and communication engineering technologies appeared relatively low. Accordingly, the instructional flow was revised so that the problem-solving conditions in the project process were presented more explicitly, and the purpose of the developed application as a support tool for individuals with visual impairments was continuously emphasized throughout the instruction.

Second, some learners experienced difficulties related to the complexity of block coding and the pace of instruction. To address differences in learners’ prior competency levels, additional visual materials supporting comprehension were included in the teacher instructional materials, and the lesson plans were revised so that teachers could monitor learners’ understanding and learning progress more effectively.

Third, App Inventor connections were found to be unstable in some iOS device environments. Therefore, Android smartphones were prepared as backup devices so that learners could verify the application implementation process and outcomes without interruption.

Discussion

The findings of this study suggest that the App Inventor-based AI-PBL program can support practice-oriented problem-solving experiences aligned with the goals of the “Sustainable Convergent Engineering” content area in the 2022 revised curriculum. In particular, this study attempted to connect AI education with engineering problem-solving processes within the formal Technology and Home Economics curriculum rather than treating AI learning as a separate coding activity.

Unlike many previous studies that primarily focused on programming instruction or the use of AI tools, this study reconstructed the curriculum content itself into a coherent AI-integrated PBL program. By systematically linking

curriculum achievement standards, engineering design processes, instructional activities, and assessment, the study presents a practical curriculum implementation model that can support teachers in translating the intentions of the 2022 revised curriculum into classroom practice.

First, the PBL program developed in this study is meaningful in that it systematically incorporated the engineering problem-solving process into actual classroom activities. Previous studies have pointed out that AI education in school settings has often focused on conceptual and theoretical understanding, thereby limiting opportunities for learners to apply technologies to authentic problem-solving situations (Kim, 2024). In contrast, this study structured instructional activities around the processes of problem definition, design, implementation, sharing, and reflection so that learners could experience not only the use of AI functions but also the engineering thinking process itself. This approach aligns with the direction of practice-oriented competency-based education emphasized in the 2022 revised curriculum.

Second, App Inventor was found to be an accessible and appropriate tool for implementing AI-based project activities at the high school level. This finding is consistent with previous studies reporting that App Inventor reduces learners' programming burden while promoting interest, creativity, and computational thinking through block-based programming activities (Ahn & Lee, 2014; Choi & Kim, 2016; Park, 2021). In particular, the block-based programming environment appears to reduce learners' cognitive burden related to syntax while allowing them to focus more on problem-solving processes and application design.

Third, the findings of this study suggest that PBL-based AI instruction can promote learners' active engagement in engineering problem-solving experiences. This result is also consistent with previous studies showing that project-based AI learning enhances learners' motivation, self-efficacy, collaborative learning, and authentic problem-solving experiences (Choi & Heo, 2024; Jun, 2024). In addition, collaborative activities enabled learners to share ideas and collaboratively refine their outcomes, thereby fostering communication and collaboration experiences. These findings support previous studies emphasizing that AI education should move beyond simple technology acquisition and be connected to authentic problem-solving experiences (Jeong et al., 2022; Kim, 2024).

At the same time, several aspects requiring improvement were also identified during the implementation process. Some learners experienced difficulties related to the block-coding process and instructional pace, and differences in learners' prior competency levels resulted in varying degrees of participation during project activities. In addition, technical limitations were observed, including unstable App Inventor connections in certain iOS environments. These findings suggest that, for AI-based PBL instruction to be implemented effectively in school settings, differentiated support materials, step-by-step instructional guidance, and stable technological environments should be provided together.

Furthermore, the findings suggest that learners were more strongly engaged in functional implementation activities than in ethical reflection regarding AI technologies. This finding supports previous arguments that AI education should address not only technological implementation but also ethical awareness and responsible decision-making in authentic contexts (Jeong et al., 2022; Kim, 2024). Therefore, future AI education should address not only technical implementation competencies but also opportunities for learners to critically reflect on the social responsibility and ethical implications of AI technologies.

Taken together, the findings demonstrate the applicability of an App Inventor-based AI-PBL program within the “Sustainable Convergent Engineering” content area and the potential for expanding practice-oriented AI education in high school technology education.

From the perspective of technology education, this study also contributes by presenting a curriculum-based instructional design process that systematically connects curriculum achievement standards, engineering design processes, AI technologies, and project-based learning. Rather than treating AI as an independent programming topic, the program demonstrates how AI can be integrated into the existing Technology and Home Economics curriculum to promote engineering thinking, technological problem solving, and ethical decision-making. This approach may provide practical guidance for teachers seeking to implement the 2022 revised curriculum in authentic classroom settings.

Conclusions and Implications

Conclusions

The purpose of this study was to develop an AI-based PBL program utilizing MIT App Inventor based on the “Sustainable Convergent Engineering” content area of the 2022 revised high school Technology and Home Economics curriculum and to explore its applicability in educational settings. To achieve this purpose, the program was designed based on analyses of the curriculum, textbooks, AI instructional tools, and previous studies, and was revised and refined through expert validity review and a pilot implementation with high school students.

The findings indicate that the developed PBL program promoted learners’ interest and participation while connecting information and communication engineering and AI technologies to real-life problem-solving activities. In addition, the findings suggest that App Inventor can serve as an accessible instructional tool for AI education at the high school level.

Therefore, this study demonstrates a practical approach to implementing AI-integrated PBL within the framework of the 2022 revised Technology and Home Economics curriculum. By systematically connecting curriculum achievement standards, engineering design processes, AI technologies, and project-based learning, the developed program provides a practical instructional model that teachers can adapt to classroom practice. The findings are also expected to serve as foundational data for the future development of AI-integrated instructional materials and curriculum implementation strategies in technology education.

Implications

The findings of this study suggest that AI-based PBL using App Inventor can be meaningfully integrated into the “Sustainable Convergent Engineering” content area of high school technology education. By connecting AI technologies with engineering problem-solving activities, the program provides a practical example of how the goals of the 2022 revised curriculum can be implemented in classroom practice.

The results also indicate that successful implementation requires consideration of learners’ prior competency levels, instructional pace, and device and network environments. Therefore, differentiated learning materials, step-by-step

instructional support, and detailed teacher guidance are needed. In addition, ethical issues and social responsibility related to AI should be more explicitly incorporated into the problem-solving process.

Finally, because this study was conducted with second-year students at a single high school and focused mainly on expert validation and student satisfaction, the findings should be interpreted with caution. Future studies should examine the program across diverse school contexts and grade levels and investigate learning outcomes through pre/post-tests, performance assessments, and analyses of student products.

Conflicts of Interest

The authors declared no conflicts of interest.

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