Development and Application of Elementary School AI Education Program Using the International Baccalaureate (IB) Primary Years Programme (PYP) Approach

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Abstract

The objective of this study is to enhance elementary school students' foundational understanding of artificial intelligence (AI) and to foster their Computational thinking. This goal was realized through the creation of an AI education program integrating the ADDIE model and the International Baccalaureate (IB) Primary Years Programme (PYP) teaching methodology. Before developing the educational program, we conducted a preliminary needs analysis with 60 fifth-grade students from IB World School P Elementary and 36 staff members, aligning with the stages of the ADDIE model. Drawing from the outcomes of this preliminary needs analysis, we opted for the transdisciplinary theme 'How the world works,' as it resonated most aptly with AI-related content, as determined by participating educators. Real-life AI-based concepts were seamlessly woven into the educational material. Throughout the program, students actively engaged in exploratory activities centered on the chosen transdisciplinary theme and central concept. Collaborating on team projects, they collectively tackled problem-solving processes, completing activities and assignments aimed at fostering self-directed learning. To assess the effectiveness of the developed educational program on students' computational thinking, pre- and post-tests were administered. Validation results underscored that the program made a significant contribution to the enhancement of Computational Thinking among the participating students.

Keywords: IB PYP education, AI education, computational thinking, entry, elementary software education

1. Introduction

The rapid advancement of artificial intelligence (AI) has resulted in significant changes across various sectors of society, particularly in education (Byeon, 2022; Moon et al., 2021). It is crucial for students to recognize the importance of AI consistently and acquire the essential skills to adapt and thrive in this evolving landscape. (Moon et al., 2021). Previously, having in-depth knowledge was enough to achieve excellence in various fields (Androutsos et al., (2020). However, the advent of modern AI services such as ChatGPT has shifted the emphasis from mere memorization to the utilization of AI for situational problem-solving, accompanied by creative and analytical thinking. Consequently, computational thinking has emerged as a pivotal component of contemporary education. Moreover, the proliferation of big data has prompted society to transcend rote learning-based educational approaches, necessitating the development of new methodologies that prioritize inclusive and creative thinking. To address this need, the 2022 educational curriculum reform strives to nurture proactive talent, emphasizing inclusivity and creativity. This curriculum is designed to emphasize competencies that foster holistic development in learners and enhance their quality of life. (Moon et al., 2021). Against this backdrop, this study delves into various considerations when harnessing AI in conjunction with societal changes, advocating for the development of an education program grounded in AI principles.

The International Baccalaureate (IB) Primary Years Programme (PYP) is a globally recognized educational program that aims to augment students' critical thinking and academic prowess through inquiry-based learning (International Baccalaureate Organization, 2017). This program has garnered international acclaim in the educational community for its effectiveness and educational excellence. Numerous schools in South Korea have embraced the IB PYP, resulting in active research into its significance and application strategies (Hong, 2021).

Previous studies have unequivocally demonstrated that the IB PYP has a substantial impact on students’ academic abilities, critical thinking, and collaborative learning (Lim, 2022; Lee, J. Y., Kim, & Lee, 2020). Preliminary research has also indicated that the characteristics of the IB PYP align harmoniously with the requisites of AI education, allowing for the integration of philosophical inquiries concerning AI and traditional AI learning principles.

The primary objective of this study is to develop an educational program that combines IB PYP educational tenets with AI education, thereby enhancing students' Computational Thinking. To achieve this goal, we collaborated with IB PYP experts during the program development phase to evaluate the suitability of its principles. Additionally, to identify appropriate themes and central ideas for AI-related education, we conducted a survey among elementary school teachers currently implementing the IB PYP. Finally, this study proposes an education program that melds philosophical questions pertaining to AI and conventional AI principles with the educational philosophy of the IB PYP. This program has the potential to significantly improve students' critical thinking, creativity, and problem-solving abilities. It is likely to play a pivotal role in nurturing flexible thinking skills capable of adapting to the social transformations driven by AI advancement.

Furthermore, this study explores the potential for integrating the educational principles of the IB PYP into the domestic educational landscape. Simultaneously, it emphasizes the importance and necessity of AI education. Based on the official guide for the IB PYP curriculum, we have provided specific learning materials and processes, enabling educators unfamiliar with the IB PYP to easily implement them in real educational settings.

2. Theoretical Background

2.1 IB PYP Education Program

The International Baccalaureate (IB) Primary Years Programme (PYP) forms the elementary education curriculum within the International Baccalaureate educational system. The primary objective of this program is to nurture students who can adeptly respond to the complexities of a changing global society and actively engage in responsible actions to ensure a sustainable future (International Baccalaureate Organization, 2017). In contrast to traditional subject-based education, the PYP places the learner at the center of its instructional design, exploring content that transcends disciplinary boundaries and focuses on intricate real-world social issues (Ribble & Bailey, 2007). Throughout this process, students gain firsthand experience in applying their acquired knowledge and skills meaningfully in real-life scenarios.

IB PYP education targets the holistic development of students, encompassing their knowledge, abilities, attitudes, and values. This is achieved through the structuring of education around six transdisciplinary themes that unfold over the year: "Who we are," "Where we are in place and time," "How we express ourselves," "How the world works," "How we organize ourselves," and "Sharing the planet" (Resnick et al., 2009). These themes integrate various subject matters, providing a comprehensive learning experience that goes beyond individual subjects (Sullivan & Bers, 2016).

Furthermore, the program emphasizes enhancing computational thinking. For example, within the "Code" theme, students explore fundamental programming principles such as algorithms, conditional statements, loops, variables, and functions (Lee et al., 2011). By using block-based programming languages like "Scratch," they create their own digital content, delving into computer science principles and fostering creative thinking (Resnick, 2007). This approach effectively cultivates key competencies, including collaboration, communication, and critical thinking (Brennan & Resnick, 2012).

The IB PYP does not only aim to transcend the boundaries of individual subjects but also elevate learning and computational thinking. In this study, we developed an education program aligned with current AI trends, rooted in the educational philosophy and methodology of the PYP. Conventional software education primarily focused on mastering fundamental block coding concepts for software development, and educational programs were developed around the implementation of programs based on these concepts.

However, our method diverged from tradition. The aim of the study was to facilitate a deeper level of learning by exploring the far-reaching societal impacts and ethical dilemmas associated with AI, rather than solely imparting AI-related skills and concepts. Using this method, learners engage in contemplation of the various issues that may arise from the utilization of AI, even from a philosophical perspective, as active members of society. The program was meticulously designed to seamlessly link the transdisciplinary themes of IB PYP education with AI education.

While adhering to the official guidelines of the IB PYP education program, it also delved into the societal phenomena and challenges emerging from the relentless advancement of AI.

2.2 AI Education

AI is a technology that endows computer systems with intelligent functions such as learning, inference, perception, and natural language processing. It encompasses subfields such as machine learning, deep learning, natural language processing, and computer vision (Russell & Norvig, 2016). In the 21st-century information society, AI plays a pivotal role across various fields, underscoring the growing necessity for AI education (Lee, J. H., 2019). Especially in the field of education, AI exerts significant influence, highlighting skills such as creativity, collaboration, critical thinking, and communication among students (Merryfield, 1997). Additionally, project-based learning stands out as an effective educational strategy where students acquire knowledge and skills through real-world problem-solving (Bell, 2010).

The objective of this study is to design an education program that comprehensively explores the principles of AI, its societal impacts, and considerations for its proper use, using the project-based learning methodology in alignment with the educational principles of the IB PYP. Using this method, we anticipate that students will enhance their real-world problem-solving abilities rooted in a profound understanding of AI.

2.3 Computational Thinking

Computational thinking involves using the principles and methodologies of computer science for problem-solving and decision-making. The significance of this capacity has grown alongside the advancement of computer science and has become a core concept in computer education. This form of thinking has particularly been shown to play a crucial role in fostering the ability to solve problems creatively. (Resnick, 2007; Kim, 2020).

Methods for nurturing computational thinking primarily encompass block coding, coding, computer programming, and computer games. Notably, block coding is recognized as a highly effective tool for enhancing computational thinking across all age groups (Lee, Kim, & Lee, 2020). In this context, the concept of "Computational Thinking," initially introduced by Dr. Jeannette Wing in 2006, revolves around applying computer science thinking to education holistically. Computational thinking encompasses fundamental elements such as decomposition, pattern recognition, abstraction, and algorithm design.

Therefore, the field of computer education firmly acknowledges the importance of computational thinking and actively investigates diverse educational strategies and tools to fortify it. Tools like block coding support students in acquiring these thinking skills, empowering them to cultivate the creative and adaptable thinking demanded by future society.

This study explores how to contribute to the augmentation of students' computational thinking through the development of an AI education program founded on the principles of the IB PYP. The program is designed based on the educational methodology of the IB PYP and existing research on AI learning through block coding.

2.4 Entry

"Entry," developed by the Connect Foundation, is a block coding-based programming education tool tailored for elementary school students. This program facilitates students' learning of programming through block coding and has been substantiated in multiple studies as enhancing students' creativity and problem-solving skills. Specifically, the educational utilization of Entry has demonstrated a positive impact on students' creative problem-solving skills (Lee, 2020) and also proves beneficial for language acquisition (Hong, 2021). Entry not only serves as a programming learning tool but also contributes to the enhancement of programming education quality through the provision of educational content and community features. As the significance of digitalization escalates in the field of education, the utilization of educational tools, such as Entry, is projected to make a substantial contribution to nurturing future talent.

In this study, students learned and practiced the principles of AI using Entry, a tool with which they were already familiar. As part of the IB PYP, we conducted a course that allowed students to learn the principles of AI and programming through Entry. We designed activities that enabled students to directly code and express their own AI concepts, along with opportunities for presenting the programs they had developed to others.

2.5 Analysis of Prior Research

This study was conducted based on various prior studies that delve into theories and practical examples concerning AI and curricula. Lim Yuna (2022) analyzed the features of the PYP framework designed to support curriculum and unit development, based on the interdisciplinary and conceptual approach of IB schools. Hong Sunjoo (Hong, S. J.,

2018) explored avenues for school curriculum innovation through a case study of IB PYP. These studies facilitated an understanding of the structure and innovation of educational curricula.

Meanwhile, Byun Jeongho (2022) researched the impact of an AI-enabled coastal plant exploration program on the definitional domain of elementary students gifted in science. This study offers insights into how AI technology can aid learning. The Ministry of Education's 2015 revised curriculum (Ministry of Education, 2015) outlines the current educational standards and served as a crucial reference for curriculum analysis in this study.

Yang Changmo (Yang, 2022) examined the effects of an AI education program on improving the attitudes and competencies in AI for gifted elementary students. These research findings provide insights into how AI education positively influences elementary students' learning.

Moon Woojong et al. (Moon, et al., 2021) conducted research on the effects of machine learning education centered on data labeling on elementary students' computational thinking, while Kim Bongcheol et al. (2021) developed a machine learning education program for elementary students based on localized public data. These studies offer practical examples and methodologies in machine learning and AI education.

Kim Byungjo and Kim Hyunbae (2022) conducted studies on developing elementary AI education content using the Entry text model learning. This study provides vital guidelines for creating AI educational materials suitable for elementary students.

Son Wonsung (2020) concentrated on the development of software education lesson plans using an AI education platform, specifically targeting upper elementary grades. This study presents specific plans on how AI-based education can be integrated into software education for elementary students.

Based on previous research, this study developed an AI education program within the IB PYP framework. We combined AI education program features that augment computational thinking derived from previous research, with the curriculum provided by the IB PYP to enhance computational thinking. Based on this foundation, the AI education program developed in this study proceeded as team projects. Students autonomously selected topics, collaboratively organized, and presented content as team assignments. The learning process was designed to enable students to grasp more advanced concepts as they advanced through the sessions, building upon content from earlier sessions.

3. Development of AI Education Program Based on IB PYP

3.1 Research Procedure

Table 1. Stages of Development of Education Programs

Research Phases	Methodology
Analysis	· Prerequisite Analysis IB PYP students and teachers · Pre-test: Computational thinking Test (Computational Thinking Based Inspection Paper Developed by the KERIS 2017)
Design	· Specification of performance objectives - Development of AI education programs for elementary school students applying IB PYP · Evaluation tool design
Development	· Development of Unit of Inquiry - 30-hour plan - Teaching Materials
Implementation	·Application of AI education programs for elementary school students
Evaluation	·Post-test: Computational thinking Test (Computational Thinking Based Inspection Paper Developed by the KERIS 2017) · Analysis of training program application results

Drawing on prior research, this study developed an AI education program within the IB PYP framework It was developed by combining features of AI education programs that enhance computational thinking from previous studies with the curriculum provided in the IB PYP to improve computational thinking. To create an education program that meets real-world needs, the ADDIE model was used for the program design, as listed in Table 1.

3.2 Design and Development of Education Program

3.2.1 Needs Analysis

We conducted a preliminary needs analysis using the ADDIE model with 60 fifth-grade students at an IB World School and 36 teachers from IB schools. The preliminary needs analysis was first conducted with the students. For the students, the preliminary needs analysis assessed the need for AI education, its content, and the required educational learning tools.

Table 2. The Necessity of Artificial Intelligence Education in Elementary Schools

Necessity	Response
Very necessary	21(35%)
Necessary	17(28.3%)
Moderately Necessary	16(26.7%)
Not Necessary	4(6.7%)
Not Necessary At All	2(3.3%)

Discription: Table 2 lists the students' responses regarding the necessity of AI education. 90% of the students indicated that AI education is necessary, while only 3.3% responded that it is not necessary at all.

Table 3. Preferred AI education content

Education content	Response
Acquiring coding skills through software development.	23(38.3%)
Exploration of artificial intelligence related to real-world applications.	22(36.7%)
Investigation of the principles of artificial intelligence.	15(25%)

Discription: Table 3 lists the responses concerning the preferred AI education content. The most preferred AI education content among the students was acquiring coding skills through software development, accounting for 38.3%.

The preliminary needs analysis was also conducted with teachers who have experience with the IB PYP. For the teachers, the analysis explored the limitations of existing AI education, the advantages of the IB PYP, and the need for AI educational materials that can be implemented through the IB PYP.

Table 4. Limitations of Existing AI Education

Education content	Response
Education content biased towards skill acquisition.	17(48%)
Course content that feels disconnected from real-life applications.	11(30%)
Decrease in student interest owing to simplistic educational content structure.	5(14%)
others	3(8%)

Discription: Table 4 lists the responses regarding the limitations of existing AI education. 48% of elementary school teachers identified 'education content biased towards skill acquisition' as the most significant limitation of current AI classes.

According to the preliminary needs analysis, there is a preference for education programs that surpass mere skill acquisition and are linked to real life through program development. Based on this, our study aims to develop a learner-centered AI education program where students can explore AI concepts and enhance their Computational Thinking through the creation of real-world programs.

Table 5. Necessity of Artificial Intelligence Education Program Using IB PYP

Education content	Response
Very necessary	21(58.3%)
Necessary	7(19.4%)
Moderately Necessary	5(13.8%)
Not Necessary	3(8.3%)
Not Necessary At All	0(0%)

Discription: Table 5 lists the responses regarding the necessity of an AI education program using the IB PYP. 91.5% of elementary school teachers responded that AI education is necessary.

3.3 Design of AI Education Program Based on IB PYP

Based on the preliminary needs analysis with students and teachers experienced in the IB PYP, we designed the education program by selecting learning topics that consider the AI-related content of the 2015 revised curriculum and applying them to IB PYP education, as listed in Table 6. When designing the program, we consulted IB PYP education experts to ensure that the topics and core concepts, as well as the content presented at each educational stage, adhere to IB PYP teaching methods.

Table 6. Design of Educational Programs

Transdisciplinary theme	How the world works
Grade	5th grade
Central Idea	AI technology can help in everyday life
Key concepts/ Related concepts	Connection, Function, Change/ AI, programming
Approaching to Learning (ATL)	Research skills, Thinking skills, Communication skills
Line of Inquiry (LOI)	Explore AI Explore the programming process Create an AI program
Action	Discover examples of AI applied in real life Utilize and apply AI technology to solve the inconveniences of one’s life. Know the right awareness that AI technology developers should have for a better life.
Assessment	Planning and producing AI programs that provide convenience in daily life

First, we selected 'How the world works' as the most appropriate transdisciplinary theme for content related to AI. Reflecting the needs analysis results that called for a program related to real life, we set the central concept to 'AI technologies can aid in daily life,' and oriented the educational activities and assessment towards designing and developing AI programs that enhance everyday convenience.

LOI 1, 'Exploring AI,' focuses on the key concept of 'Connection,' emphasizing how closely AI is related to daily life. LOI 2, 'Exploring the Programming Process,' focuses on the key concept of 'Function,' exploring the basic functions of Entry and the operating principles of AI. LOI 3, 'Creating an AI Program,' is designed based on the concept of 'Change,' encouraging students to identify inconveniences in their real lives and develop simple programs using the skills they have learned, which they then share with each other.

3.4 Development of AI Education Program

The content of the entire 30-lesson program, developed based on the program design, is outlined in Table 7.

Table 7. Lecture Plan for AI Education Program

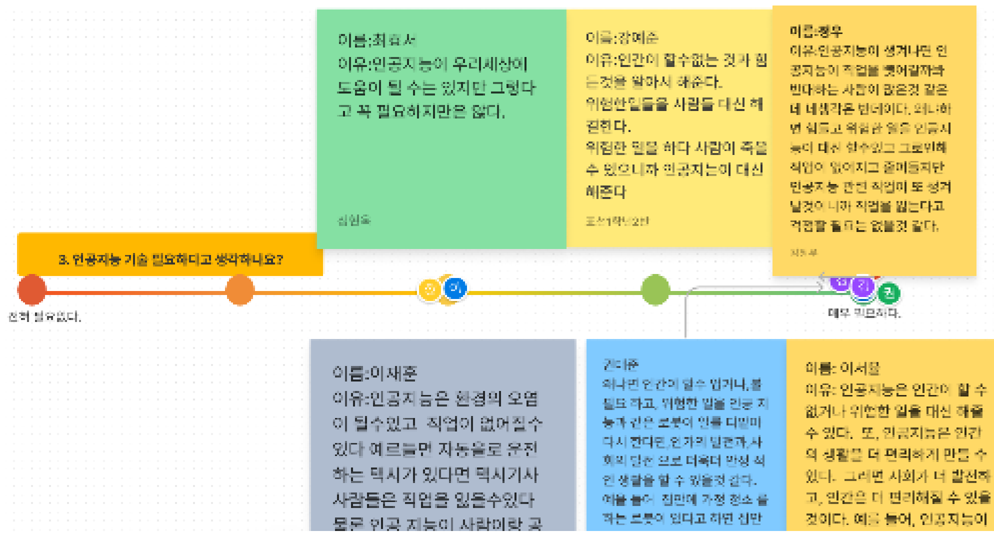
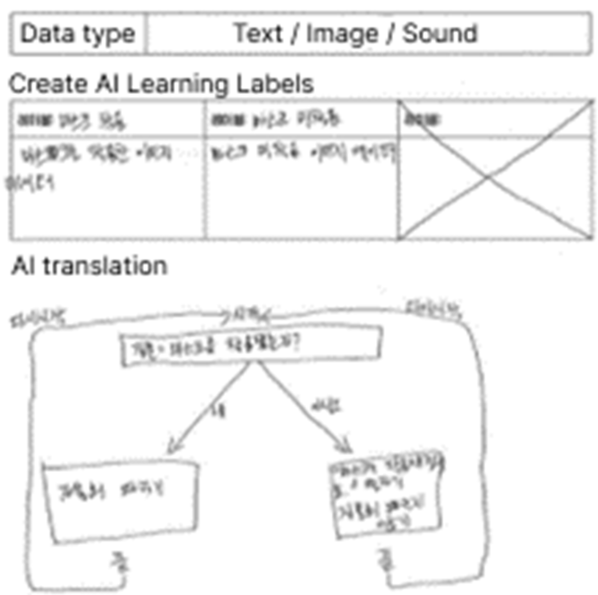
Lines of inquiry	Inquiry cycle	Learning experiences
Explore AI	Tuning in (1–3rd)	·Investigate students' prior background knowledge ·Present examples of application of AI that provides convenience in daily life ·Present other AI cases (e.g., ‘Deepfake’) ·Student discussion progress (Forward function vs. reverse function) ·Create ‘Developer’s profile’ ·Creating principles to be followed when developing an artificial intelligence program
Explore the programming process	Finding out (4–11th)	·Learn the basic principles of AI ·Explore AI applied cases ·Defining the concept of artificial intelligence ·Learning the basic functions of AI educational programs 1 ·Learning the basic functions of AI educational programs 2 ·Create students' own programs by applying basic functions
Create an AI program	Sorting out & Going further (12–19th)	·Have problem awareness for program development ·Planning an AI program for each team ·Create students' own AI program
	Making conclusions (20–25th)	·Midterm presentation ·Give and receive feedback ·Modify the program by reflecting feedback
	Taking action (26–30th)	·Presentation of the final program ·Reflection

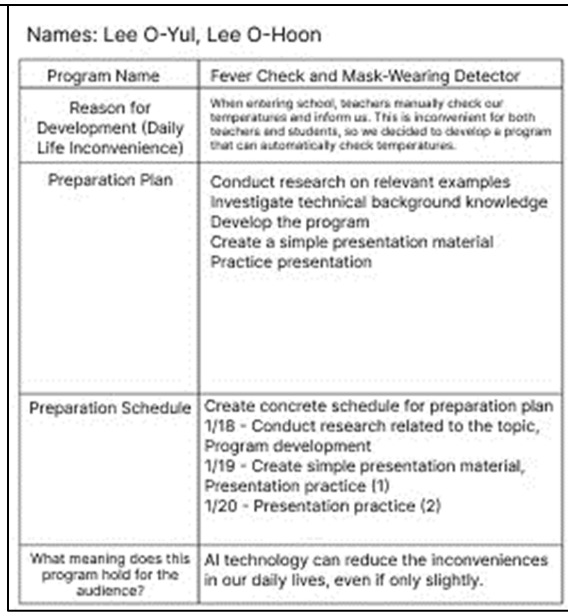
The education program was developed following the design procedures of the IB PYP and Kath Murdoch's Inquiry Cycle. When planning the inquiry program, we extended it to 30 lessons based on the input of experts (IB coordinators) who proposed that considering all stages of the inquiry cycle would benefit students' conceptual understanding. In the 'Starting the Inquiry' stage, students are guided to fill out a KWL chart, recording what they already know and what they are curious about concerning AI to explore their prior knowledge. We also introduced readily accessible AI services from daily life to instill awareness of the necessity of learning about AI technology. Alongside services that provide convenience through AI, we included cases related to deepfakes and Amazon's cashier-less stores, encouraging students to share their thoughts and consider the principles and attitudes required before developing any program. In the 'Discovery' stage, based on expert suggestions, we designed the program to allow students to explore how AI operates and its real-world applications rather than merely lecturing them. Aligned with the characteristics of IB education, the educational activities are structured so that students can research and share what they have learned to form their own concepts, rather than receiving knowledge from the teacher. Considering expert recommendations that various 'thinking routines' should be incorporated, we arranged for the use of tools such as Jamboard and Figma. We also structured the program to enable students to become familiar with the basic features of Entry, which they can use for future programming.

During the 'Explain’ and ‘Further Inquire' stages, the program is designed for students to consider real-life inconveniences and brainstorm how AI technology can improve them, results in hands-on planning and programming activities. For the 'Conclusion' stage, we planned to hold an interim presentation session where students could share their initial project results and receive peer feedback, providing an opportunity for revisions and improvements.

Finally, in the 'Taking Action' stage, students presented the final completed program and reflected on its execution, reinforcing the central concept of AI. Examples of educational activities used in the training are listed in Table 8.

Table 8. Activity in the Exploration Cycle

LOI	Learning process
Tuning in	 Articulating thoughts on artificial intelligence. Do you think AI technology is necessary?
Finding out	 Exploring the principles of artificial intelligence through the creation of example programs.
Sorting out & Going further	Creating software that provides convenience in everyday life.

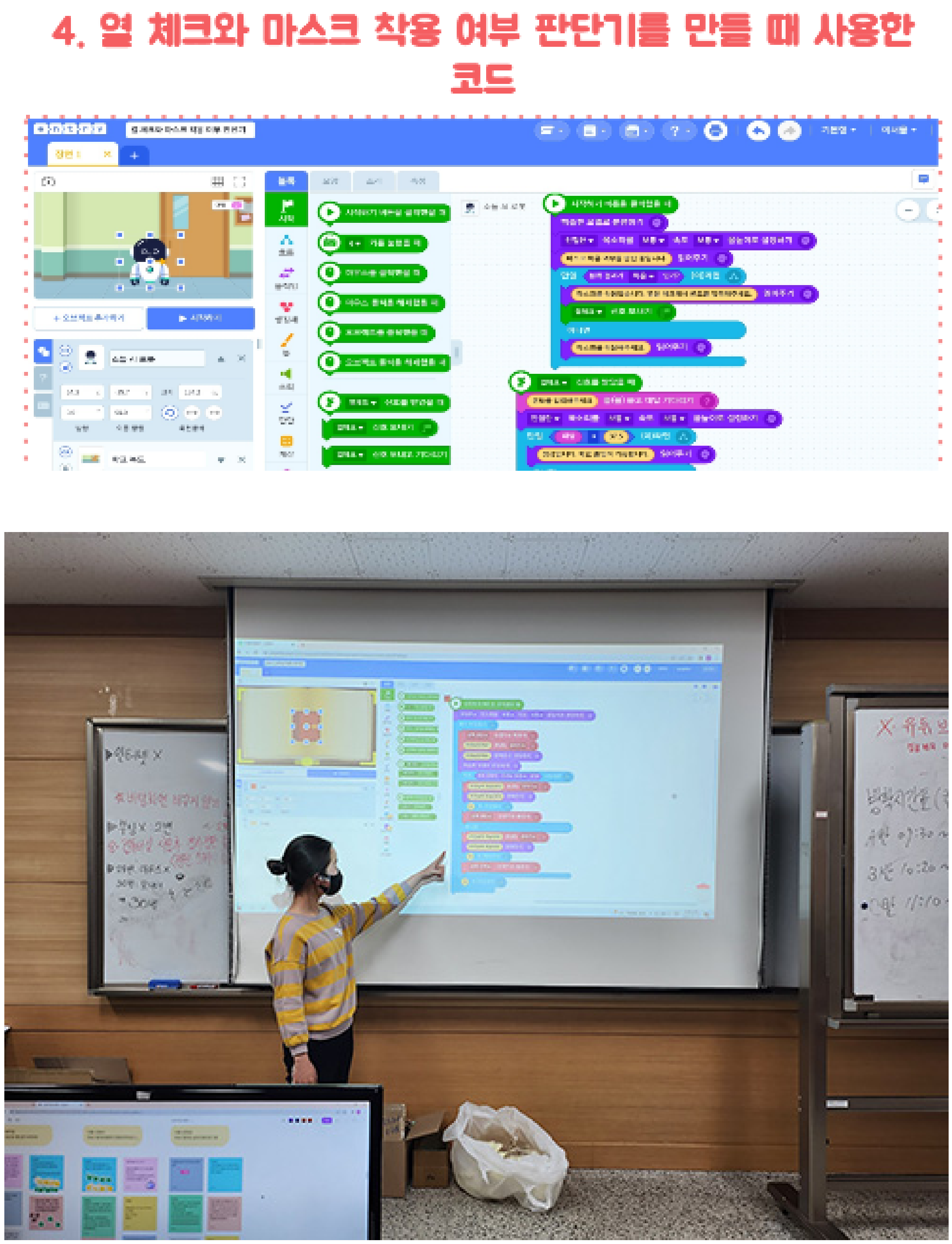


Names: Lee O-Yul, Lee O-Hoon

Program Name	Fever Check and Mask-Wearing Detector
Reason for Development (Daily Life Inconvenience)	When entering school, teachers manually check our temperatures and inform us. This is inconvenient for both teachers and students, so we decided to develop a program that can automatically check temperatures.
Preparation Plan	Conduct research on relevant examples Investigate technical background knowledge Develop the program Create a simple presentation material Practice presentation
Preparation Schedule	Create concrete schedule for preparation plan 1/18 - Conduct research related to the topic, Program development 1/19 - Create simple presentation material, Presentation practice (1) 1/20 - Presentation practice (2)
What meaning does this program hold for the audience?	AI technology can reduce the inconveniences in our daily lives, even if only slightly.

Making conclusions	Exchanging feedback on software.

Taking action	Presenting the final software.



4. Research Methods and Procedures

4.1 Research Participants

This study involved 15 fifth-grade students currently enrolled at IB World School P Elementary. While the students who participated in this study have experience learning core subjects through the IB PYP, they were encountering the concept of AI for the first time. Although they have experience coding with Entry, the participants had no prior experience in using Entry's AI blocks for learning.

4.2 Research Tools

In this study, we used a computational thinking-based test included in the 2017 research report titled "Development of Software (SW) Education Effectiveness Measurement Tools," published by the Korea Education and Research Information Service.

4.3 Research Design and Setup

As listed in Table 9, before applying the elementary school AI education program based on the IB PYP, we administered a pre-test from the computational thinking-based test developed by the Korea Education and Research Information Service. The education program was conducted over two weeks, totaling 30 sessions, in an immersive learning format. After completing the education program, a post-test was administered using the same computational thinking-based test from the Korea Education and Research Information Service to measure any changes in the Computational Thinking of the participating students.

Table 9. Experimental Design

	Pre-test	Treatment	Post-test
G	O1	X	O2

G: Experimental group (N = 15)

O1, O2: Computational thinking Test (Computational thinking based inspection paper written by the KERIS 2017) (Figure A, B style)

X: Machine learning education program using data labeling

5. Research Results

5.1 Verification of the Education Program's Effectiveness

To assess the impact of the IB PYP-based AI education program on enhancing elementary school students' computational thinking, we conducted a detailed analysis.

5.1.1 Normality Test of Computational Thinking

With 15 students participating in the program, we initially conducted a Shapiro-Wilks normality test to ensure the statistical validity of our analyses. The test results confirmed the normal distribution of both pre- and post-test scores, facilitating further statistical examination.

Table 10. Normality Test Results

Subscales	Descriptive Statistics(N=15)				stat	p
	M	SD	Max	Min		
Pre-test	7.733	3.261	13.00	2.000	.955	.606
Post-test	9.266	3.0814	13.00	3.00	.963	.069

5.1.2 Comparison of Pre-Test and Post-Test in Computational Thinking

Following the confirmation of data normality, we applied a paired samples t-test to examine the pre- and post-intervention changes in computational thinking. The test indicated a significant increase in students' scores, from an average of 7.733 to 9.266, marking a substantial improvement in Computational thinking with a p-value of .002.

Table 11. Computational Thinking Scores Comparison

Subscales	N	Pre-Test		Post-Test		t	p
		M	SD	M	SD		
CT	15	7.733	3.261	9.266	3.081	-3.440	.002*

5.2 Analysis of Research Results

The analysis of pre- and post-test results highlights the IB PYP-based AI education program's effectiveness in enhancing computational thinking among elementary students. The statistical significance of the score improvement, underpinned by rigorous normality testing and paired samples t-test, illustrates not only the program's efficacy but also its potential to significantly influence Computational thinking development in the educational field. This study's findings suggest that integrating AI education within the IB PYP framework can substantially benefit students' computational and critical thinking abilities, marking a significant step forward in educational methodologies aimed at preparing students for a technology-driven future.

6. Conclusion and Recommendations

The advent of the Fourth Industrial Revolution has underscored the critical need for educational systems to embed foundational competencies such as Artificial Intelligence (AI) within their curricula. This imperative is driven by the evolving technological landscape that demands not only theoretical knowledge of AI but also practical skills for navigating a digital world. Our research, set against this backdrop, initiated the development and critical evaluation of an AI education program rooted in the International Baccalaureate (IB) Primary Years Programme (PYP) framework, utilizing the ADDIE instructional design model. Specifically targeting elementary school students, this program was strategically crafted to promote computational thinking through dynamic programming activities over thirty sessions. The significance of this study lies in its direct response to the educational challenge of preparing students for the complexities of the future, providing empirical evidence supporting the integration of AI education at an early stage in child development.

6.1 Theoretical Contributions and Empirical Findings

Empirically, our study demonstrated a statistically significant improvement in computational thinking among participants post-program. This outcome is particularly important as it highlights the program's effectiveness in advancing students' abilities to engage with computational concepts actively. The educational integration of AI, as evidenced by the study, does not merely add to the existing curriculum but enriches it by ensuring that students are not only consumers of digital content but also creators, equipped with the necessary problem-solving skills. Theoretically, the study reaffirms the IB PYP framework's effectiveness as a scaffold for AI education, illustrating how a holistic educational philosophy can be harmonized with the demands for digital competencies.

6.2 Practical Implications and Recommendations for Future Research

The practical implications of our findings are manifold, illuminating a path for educators and curriculum developers to effectively integrate AI education into early learning environments. This study suggests that educational strategies leveraging collaborative online tools and project-based learning can significantly foster computational thinking. However, it also identifies the necessity for improvements, particularly in providing comprehensive guidance on digital tools and developing resources for students new to digital learning.

Future research should focus on exploring the scalability of the AI education program across varied educational contexts and assessing the long-term effects of early AI education on students' academic and career prospects. The development and evaluation of specialized tools to accommodate diverse learning needs in both online and blended environments emerge as essential for advancing this educational field.

6.3 Limitations and Future Directions

This study, while yielding valuable insights into the integration of AI education within the IB PYP framework, presents several limitations that necessitate careful consideration:

- **Sample Size and Generalizability**: The study's relatively small sample size (N=15) may limit the findings' generalizability to a broader population. Future research should aim to include a larger cohort to enhance the robustness and applicability of the results across diverse educational settings.
- **Program Duration**: The intervention's duration, encompassing 30 sessions, may not sufficiently capture the long-term effects of AI education on the development of Computational thinking. A more extended period of study could provide deeper insights into the sustained impacts of AI education, offering a clearer understanding of its benefits over time.
- **Educational Framework and Methodology**: The study's focus on the IB PYP framework and the ADDIE instructional design model, while providing a structured approach to AI education, may not encompass the full spectrum of methodologies available in this rapidly evolving field. Future investigations could benefit from exploring a variety of educational frameworks and instructional designs to uncover potentially more effective approaches for integrating AI education.

Given these considerations, it is imperative for subsequent research to address these limitations by expanding the sample size, extending the duration of the intervention, and exploring a broader range of educational methodologies. Such efforts will be crucial in validating and extending the current study's findings, ultimately contributing to a more comprehensive understanding of how AI education can be most effectively integrated into early learning environments.

Furthermore, this call for expanded research underscores the need for a multidisciplinary approach, incorporating insights from educational technology, cognitive science, and curriculum development. By doing so, future studies can offer more nuanced recommendations for educators and policymakers aiming to prepare students for the complexities of the digital age, ensuring that AI education is both accessible and impactful for all learners.

6.4 Concluding Remarks on Research Impact

In conclusion, this research significantly contributes to the discourse on educational innovation, advocating for the early integration of AI and computational thinking into elementary education. By demonstrating the positive outcomes of a well-structured AI education program, this study not only underscores the importance of preparing students for the digital age but also emphasizes the need for ongoing research and development in this area. As technological advancements continue to reshape our world, it is crucial that educational interventions evolve accordingly, empowering students to not just navigate but actively shape the technological landscape.

References

Androutsos, A., & Souma, P. (2020). Developing an 'Out of the School Doors' Approach for Teaching Innovation Based on Design Thinking: Focus on Gamified Mobile Applications. *Journal of Education and Teaching Methodology, 1*(1), 31-40.

Barron, B. (2003). When smart groups fail. *The Journal of the Learning Sciences, 12*(3), 307-359. https://doi.org/10.1207/S15327809JLS1203_1

Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 83*(2), 39-43. https://doi.org/10.1080/00098650903505415

Brennan, K., & Resnick, M. (2012). *New frameworks for studying and assessing the development of computational thinking*. In Proceedings of the 2012 Annual Meeting of the American Educational Research Association, Vancouver, Canada.

Byeon, J. H. (2022). The effects of a coastal sand dune plant exploration program utilizing artificial intelligence on the definitional domain of elementary science talented students. *Journal of Science Education Research, 46*(1), 53-65.

Hong, S. J. (2021). Exploring school curriculum innovation through IB PYP case studies. *Journal of Education and Culture Studies, 27*(5), 49-74.

International Baccalaureate Organization. (2017). *Primary Years Programme: From principles into practice*. International Baccalaureate Organization.

Kim, B. C., Kim, B. S., Ko, E. J., Moon, W. J., Oh, J. C., & Kim, J. H. (2021). Development of elementary school machine learning education program based on localized public data. *Journal of Information Education, 25*(5), 751-759. https://doi.org/10.14352/jkaie.2021.25.5.751

Kim, B. J., & Kim, H. B. (2022). Development of elementary AI education content using Entry text model learning. *Journal of Information Education, 26*(1), 065-073. https://doi.org/10.14352/jkaie.2022.26.1.65

Kim, C. (2020). Effects of creative convergence class of design thinking on improving university students' creativity confluence competency and problem solving ability. *Asia-Pacific Journal of Educational Management Research, 5*(3), 33-40. https://doi.org/10.21742/AJEMR.2020.5.3.03

Kim, N. R., Yoon, S. Y., & Kang, H. Y. (2018). Development and application of a convergence education program using Entry education contents. *Humanities and Social Sciences*, 21.

Lee, I., Martin, F., Denner, J., Coulter, B., Allan, W., Erickson, J., ... & Werner, L. (2011). Computational thinking for youth in practice. *ACM Inroads, 2*(1), 32-37. https://doi.org/10.1145/1929887.1929902

Lee, J. H. (2019). Analysis of the relationship between computational thinking and programming education. *Journal of Korean Association of Computer Education, 22*(1), 17-25.

Lee, J. Y., Kim, J. M., & Lee, S. W. (2020). The effect of elementary students' block coding learning activities on creative problem-solving abilities. *Journal of Computer Education, 23*(4), 41-50.

Lim, Y. N. (2022). Analysis of the International Baccalaureate educational content framework: Focusing on IB PYP. *Journal of Curriculum and Evaluation Research, 25*(2), 59-87. https://doi.org/10.29221/jce.2022.25.2.59

Merryfield, M. M. (1997). A framework for teacher education in global perspectives. *Theory & Research in Social Education, 25*(3), 333-348.

Ministry of Education. (2015). 2015 Revised Curriculum.

Moon, W. J., Kim, B. S., Kim, J. A., Kim, B. C., Seo, Y. H., Oh, J. C., Kim, Y. M., & Kim, J. H. (2021). The effect of machine learning education focused on data labeling on elementary students' Computational Thinking. *Journal of Information Education, 25*(2), 327-335. https://doi.org/10.14352/jkaie.2021.25.2.327

Resnick, M. (2007). All I really need to know (about creative thinking) I learned (by studying how children learn) in kindergarten. *ACM Creativity & Cognition Conference Proceedings*, 1-6. https://doi.org/10.1145/1254960.1254961

Resnick, M., Maloney, J., Monroy-Hernández, A., Rusk, N., Eastmond, E., Brennan, K., ... & Kafai, Y. (2009). Scratch: Programming for all. *Communications of the ACM, 52*(11), 60-67. https://doi.org/10.1145/1592761.1592779

Ribble, M., & Bailey, G. D. (2007). Digital citizenship in schools. International Society for Technology in Education.

Russell, S. J., & Norvig, P. (2016). Artificial intelligence: A modern approach. Retrieved from https://aima.cs.berkeley.edu/

Son, W. S. (2020). Development of SW education lesson plans using artificial intelligence (AI) education platform: Focusing on upper elementary school. *Journal of Information Education, 24*(5), 453-462. https://doi.org/10.14352/jkaie.2020.24.5.453

Sullivan, A., & Bers, M. U. (2016). Robotics in the early childhood classroom: Learning outcomes from an 8-week robotics curriculum in pre-kindergarten through second grade. *International Journal of Technology and Design Education, 26*(1), 3-20. https://doi.org/10.1007/s10798-015-9304-5

Yang, C. M. (2022). The effects of artificial intelligence education programs on the improvement of elementary gifted children's attitude and literacy in artificial intelligence. *Journal of Information Education, 26*(1), 35-44.

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