2025 Project Albus Final Report

A Study Analyzing Changes in Learning Experiences and Teaching Effectiveness Through the Use of AI and Digital Tools

Principal Investigator: SooJin Jeon

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I. Introduction

1 Research Necessity

Recent advances in artificial intelligence (AI) and cloud-based digital technologies have brought structural changes to the overall school education environment. In particular, with the spread of the 1:1 device policy, digital learning tools such as Google Chromebook and Google Workspace are gaining attention as a major technological foundation for instructional management and learning support in school education. These digital environments enable the sharing and management of learning materials, the recording and accumulation of task performance processes, and the expansion of interactions between teachers and students, possessing the potential to reconstruct overall instructional management methods. However, the introduction of digital tools to date has mainly focused on environment construction and usage expansion, and empirical verification of what educational changes such tool usage brings to students' learning experiences and teachers' instructional management methods in actual classroom contexts has not been sufficiently conducted.

This problematic awareness aligns with the direction of future education emphasized by the OECD's Learning Compass 2030 and Teaching Compass. The OECD presents the strengthening of student agency as a core principle for developing competencies required in future society, where learners actively participate in their own learning, set goals, reflect on and adjust their learning processes. This presupposes the need for an educational environment where students can recognize and regulate their learning status as subjects of the learning process, not merely as knowledge recipients. However, in actual school settings, despite increasingly distinct individual differences among learners, structural limitations exist in sufficiently reflecting individual students' learning levels and pace due to limited class time and teachers' work conditions.

Along with this, the role of teachers is also changing. The OECD Teaching

Compass defines teachers not as knowledge transmitters but as agents of educational change and designers of learning environments, emphasizing the importance of teacher agency. Teachers' roles are expanding as professionals who interpret learning data, design instruction, and make professional judgments that facilitate student growth. However, in real school settings, as various work burdens accumulate—including lesson preparation, assignment evaluation, feedback provision, attendance and classroom management—constraints arise in teachers devoting sufficient time and energy to qualitative improvement of instruction and individual student support.

In this context, Google has promoted the Albus Project centered on Google for Education, so that digital tools can be utilized not merely as technology introduction but in ways that substantially support teachers' instructional design and students' learning experiences. The Albus Project aims to support teachers' lesson preparation and feedback writing, students' learning process recording and reflection using Google Workspace and generative AI, and to explore instructional environments where digital tools can simultaneously strengthen both student agency and teacher agency. However, despite the purpose and potential of such projects, empirical analysis of what changes this environment brings to students' and teachers' educational experiences in actual classroom contexts has not been sufficiently accumulated.

Therefore, this study intentionally introduced an instructional environment based on Google Workspace and the use of generative AI such as Gemini into the research context, constructing an instructional environment that enables the accumulation and management of learning records, the visualization of task performance processes, and support for instructional material production and feedback writing. Using Google Classroom, Docs, Slides, Forms, etc., students' assignment submission history, learning products, and participation processes were systematically recorded and managed, and generative AI was utilized to assist in drafting materials, constructing items, organizing feedback sentences, and reconstructing learning materials during teachers' lesson preparation processes. This environment was designed to function as a tool supporting rather than replacing teachers' professional judgment and instructional design.

This study was conducted through Project Albus under this background. Project Albus is an international research project that empirically analyzes what changes the introduction of Google for Education's educational tools (Chromebooks, Google Workspace) and generative AI Gemini brings to teachers' work methods and students' personalized learning in school settings. This project has been expanded and operated as 42 projects in 19 countries worldwide from 2021 to present, accumulating application cases in various educational environments including Asia-Pacific (APAC), Europe, and the Middle East-Africa. Through this, Project Albus aims to systematically verify the impact of digital tools and AI beyond simple technology introduction on instructional design, learning experiences, and overall educational effectiveness, and to explore the possibility of actual change in school education.

The instructional environment attempted in this study can be said to be a research attempt to concretize the direction of digital tool usage that the Google Albus Project aims for in school classroom contexts and to empirically verify its educational effectiveness. Therefore, this study aimed to analyze what changes the use of such digital tools brings to students' learning experiences and teachers' instructional management methods in actual classroom contexts, focusing on Google Workspace-based instructional environments and the use of generative AI such as Gemini. Rather than aiming to verify the effects of digital technology itself, this study seeks to provide empirical evidence for how the future education direction presented by the OECD can be implemented in school settings by clarifying how teachers and students were designed to use digital tools and generative AI, and how such usage environments connect to the strengthening of student agency and teacher agency.

2 Research Purpose

The purpose of this study is to empirically analyze the educational effectiveness of the Albus Project, which applies Google Workspace-based instructional environments and the use of generative AI such as Gemini to school classroom contexts, with the future education direction of strengthening student agency and teacher agency presented by the OECD Learning Compass 2030 and Teaching Compass as the theoretical and policy background. In particular, this study aimed to explore the possibility of an instructional environment where both teachers and students can grow together by examining together how digital tool usage affects not only changes in students' learning experiences but also teachers' instructional design methods, instructional management efficiency, repetitive work burden, and teacher self-efficacy perception. This study set the overall school-level instructional environment covering elementary, middle, and high school students as the research subject, not limited to specific grades or subjects.

Specific research purposes are as follows.

First, from the student perspective, we aimed to verify through pre-post surveys what changes Google Workspace-based instructional environments bring to elementary, middle, and high school students' learning experiences centered on learning engagement and interest, self-directed learning attitudes, and self-efficacy. Through this, we aimed to analyze how the use of learning records and the visualization of task performance processes affect students' perception that they can perform their own learning and the formation of confidence in learning.

Second, from the teacher perspective, we aimed to verify through pre-post surveys what changes the support for instructional material production and feedback writing using generative AI such as Gemini brings to teachers' instructional design burden, instructional management efficiency, reduction of repetitive work, and teacher self-efficacy. In particular, we aimed to analyze how generative AI usage operates not to replace but to assist teachers' professional judgment and instructional design, and what impact it has on confidence in instructional management and efficacy perception as teachers.

Third, from a comprehensive perspective, we aimed to comprehensively verify through qualitative analysis of lesson observations, teacher-student interviews, and best practice analysis how changes in teachers' instructional design and management methods in classes where Google Workspace-based instructional environments and generative AI usage are applied connect to changes in students' learning engagement, self-direction, and self-efficacy. Through this, this study aimed to clarify whether digital tool usage can form an educational environment that operates as interconnected changes within the same instructional design context, not limited to changes in teachers and students respectively.

Through this research purpose setting, this study aimed to comprehensively understand not only how digital tool and generative AI usage affects changes in students and teachers respectively, but also how these changes appear interconnectedly within the context of actual educational practice of instructional design and management. This can be said to be an attempt to empirically explain the structure in which teachers' professional practice and students' learning experiences interact and change, beyond simple usage status or satisfaction, in the process of introducing digital technology to educational settings. Based on this analysis, this study ultimately aims to provide practical implications necessary for designing and operating instructional environments using AI and digital tools in school settings in the future, and to present evidence data for educational policy and field application.

II. Theoretical Background

1 Teacher and Student Agency in the AI Era

1) Teacher Agency

Teacher agency in the AI era refers to the capacity of teachers to function as professional agents who autonomously design and make judgments about teaching and learning based on educational purposes and values, rather than being passive entities moved by external directives or algorithms amid technological environmental changes. The OECD Teaching Compass defines teachers not as implementers of educational change but as designers and decision-making agents of change, specifying that teacher agency is a key element determining the quality and sustainability of education (OECD, 2025).

The core foundation of teacher agency lies in self-efficacy. Bandura defines self-efficacy as an individual's belief that their actions can create meaningful change, which enables sustained practice and reflection even in new challenging situations (Bandura, 1997). In an environment where AI technology deeply intervenes in the teaching-learning process, teachers' self-efficacy acts as a psychological foundation that prevents the weakening of professionalism due to technology dependence and positions AI as a tool assisting educational judgment.

Furthermore, teacher agency is not simply an individual characteristic but possesses contextual and procedural nature. Priestley, Biesta, and Robinson explain teacher agency as an ecological concept formed through the interaction of past experiences, present institutional and cultural conditions, and prospects for the future (Priestley et al., 2015). This suggests that whether and how AI is introduced is not determined solely by teachers' autonomous choices, but that teacher agency is manifested within the interaction with school culture, policy environment, and technology design.

In the AI era, teachers' continuous professional development also becomes an important component of agency. Knowles argued that when adult learners diagnose their own learning needs, set goals, and select learning strategies, the effectiveness and sustainability of learning are strengthened (Knowles, 1975). In a rapidly changing AI environment, professional development centered only on external training has limitations, and teachers need to become self-directed professional learners who set their own learning goals and explore new technologies and teaching strategies.

Ethical judgment is also a core element of teacher agency in the AI era. AI-based recommendations and data analysis can support educational decision-making, but they can accompany problems such as algorithmic bias, privacy protection, and stigma effects on learners. The OECD emphasizes that the ultimate responsibility for AI utilization lies with teachers, not technology, and that teachers must judge the use of technology based on human values in education and students' long-term growth (OECD, 2025). Therefore, teacher agency in the AI era is defined as educational subjectivity that integrates professional judgment, continuous learning, and ethical responsibility.

2) Student Agency

Student agency in the AI era refers to the capacity for students to set their own learning goals, regulate the learning process, and take responsibility for the results even in an environment rich with information and automated learning support. The OECD Learning Compass 2030 presents student agency as a core educational goal, defining the ability to choose, act, and reflect based on a sense of purpose as an essential competency for future society (OECD, 2019).

Student agency is understood as both an outcome and a process of learning. The OECD explains that when students participate as agents of learning, motivation and engagement are strengthened, which in turn forms a cyclical structure leading to learning outcomes (OECD, 2019). In AI-based learning environments, personalized learning paths and immediate feedback are provided, but for this support to connect to learning, students need the ability to monitor their learning status and adjust their strategies.

In this regard, Zimmerman's self-regulated learning theory can be utilized to explain student agency from a process dimension. Zimmerman explains that learners regulate their own learning through a cyclical process of goal setting, execution, and reflection, which is a concept focused on learning process management (Zimmerman, 2002). In AI environments, students must not simply accept automatically provided feedback and recommendation results, but interpret them and adjust their own learning strategies, where self-regulation ability operates as a core mechanism of student agency.

However, student agency is not an isolated ability of individuals but develops within social interaction. Vygotsky viewed learning and development as occurring through social interaction, explaining that learners gradually internalize self-regulation abilities within the support of adults and peers (Vygotsky, 1978). Even in the AI era, student agency is strengthened through teachers' structured support and gradual transfer of responsibility, and unconditional granting of autonomy carries the risk of deepening learning gaps.

Additionally, student agency is also connected to responsible technology use. The OECD emphasizes that even if not all students design AI, they should be able to critically understand and ethically judge the results of AI systems (OECD, 2019). This means that students must grow as moral agents who consider not only their own learning outcomes but also the impact of technology use on others and society.

Consequently, student agency in the AI era is understood not as freedom of choice itself, but as a combination of cognitive, affective, and ethical competencies that enable purposeful choice. This is strengthened through interaction with teacher agency, and school education must establish a systematic support structure so that students can grow as agents of learning even within AI environments.

2 AI and Digital Learning Environments for Teaching and Learning Support

1) AI and Digital Teaching-Learning Support Environment

Recent educational environments are transitioning beyond simple utilization of digital tools to platform-centered educational environments that comprehensively support the entire teaching-learning process (design-operation-evaluation-feedback) (OECD, 2019). This change means that digital technology must function not merely as a tool assisting individual instructional activities but as a teaching-learning support system that connects teachers' instructional design and operation with students' learning process management and reflection as one flow (Mishra & Koehler, 2006). In this context, the OECD emphasizes through Learning Compass 2030 and Teaching Compass that in future education, both student learner agency and teacher professional agency must be strengthened simultaneously (OECD, 2019, 2025).

A representative teaching-learning support environment that aligns with this policy and theoretical direction is Google Workspace for Education. Google Workspace supports the implementation of the cyclical structure of teaching-learning within a digital environment by linking material production and sharing in the teacher's instructional design stage, task management and interaction in the instructional operation stage, and accumulation of learning records and feedback provision in the evaluation and feedback stage, based on a cloud-based collaborative environment. This is consistent with instructional design theory that understands teaching-learning not as a collection of disconnected activities but as a continuous and adjustable process (Liu, G.Z., 2010; Branch, 2009).

For such platform-centered teaching-learning environments to function effectively, learning device infrastructure that can implement them stably is essential, and in this process, Chromebook functions as a key mediator. Chromebook provides a structure that enables continuous accumulation and management of learning materials and performance history through cloud environments based on student accounts, allowing adjustment of learning experiences according to students' learning levels and pace. This connects with self-regulated learning theory and the concept of self-efficacy that support learners in recognizing and regulating their own learning processes (Bandura, 1997; Zimmerman, 2000). In particular, the visualization of learning records and tracking of task performance processes play important roles in strengthening learners' self-monitoring and sense of control over performance, forming students' perception that they can perform their own learning and enhancing learning engagement and confidence in learning (Zimmerman & Schunk, 2011).

From the teacher perspective as well, Google Workspace and Chromebook-based environments operate as teaching-learning support tools that enhance the efficiency of instructional design and operation. Through real-time sharing and collaborative work functions, teachers can immediately grasp students' learning processes and provide feedback, reducing repetitive management tasks and creating conditions to focus more on instructional design and learning support. This aligns with teacher agency theory that views teachers not as simple tool users but as instructional designers and learning environment coordinators (Priestley, Biesta, & Robinson, 2015; OECD, 2025), and is closely connected to strengthening teacher self-efficacy through teachers' perception of instructional control and professional judgment (Tschannen-Moran & Hoy, 2001).

Furthermore, Chromebook-based environments play roles in mitigating learning environment gaps between schools and homes and enhancing digital learning accessibility through low-cost, high-security structures and cloud operation methods based on central management. These characteristics act as important environmental premises and institutional conditions for securing equity and fairness of educational opportunities in the digital transformation process, providing a foundation for stable operation of digital-based teaching-learning environments in school settings. Moreover, such environments, in conjunction with the spread of collaboration-centered teaching-learning paradigms, prepare conditions for actually implementing learning experiences that strengthen students' collaborative problem-solving and communication competencies.

To understand such teaching-learning support environments more concretely, this study aims to systematically present the functions and educational utilization possibilities of the main tools constituting Google Workspace by area. In particular, by systematically organizing the roles each tool performs in the entire teaching-learning process, including class management, communication and interaction, collaboration-based content creation, and creative output management, we aimed to reveal that digital tool utilization is not a listing of individual functions but a platform-level environment that comprehensively supports instructional design and operation. The table below is presented as reference material to overview the main functions and educational utilization directions of Google tools used in this study.

Table 2-1. System and Educational Applications of Google Tools for Teaching-Learning Support

Area	Tool	Tool Description	Educational Application
Classroom Management	Google Classroom	Learning management system (LMS) that serves as the hub of instruction, integrating material distribution, assignment collection, grading, and feedback management on a single platform	Real-time communication through announcements, customized task assignment to individual students, systematic grade management and process-based assessment through rubric-based evaluation
	Practice Sets	Automated practice problem and immediate feedback provision tool	Providing repeated practice suited to individual student levels, strengthening basic learning through automatic grading and immediate feedback, supporting teachers' formative assessment and individual remedial instruction

Area	Tool	Tool Description	Educational Application
Communicati on & Engage ment	Google Meet	High-definition video conf erencing tool providing br eakout rooms, polls, and real-time caption function s	Operating remote video classes, inviting external expert mentoring, supporting s mall group discussion activities
	Gmail / Goo gle Chat	Official email service and real-time messaging platf orm	Official communication channel betwee n teachers and students, real-time Q& A and idea sharing space (spaces) utiliz ation during team project performance
	Google Calen dar	Personal and shared sche dule management tool	Sharing class operation schedules, assig nment deadline reminders, cultivating s tudent self-management abilities throug h counseling appointments (Appointme nt slots)
	Read Along	AI voice recognition-base d reading support tool th at analyzes learners' readi ng performance in real-ti me	Improving reading fluency and pronunc iation accuracy in literacy learning, prov iding individual feedback, supporting te achers' basic learning diagnosis and cu stomized instruction
Content Cre ation & Coll aboration	Google Docs	Web-based word process or supporting real-time s imultaneous editing by multiple people	Collaborative writing, group discussion recording, identifying contribution lev els and individual feedback using vers ion history
	Google Slides	Visual presentation mater ial production tool	Joint presentation material production, participatory classes using Q&A functi on, multimedia portfolio composition
	Google Sheets	Spreadsheet tool for dat a collection, organization, and analysis	Experimental data analysis, class statis tical surveys, strengthening data litera cy through social phenomenon analys is
	Google Forms	Survey and quiz creation tool	Checking learning comprehension thr ough formative assessment, self and peer assessment, instructional redesig n based on results
	Google Sites	Tool for creating website s without coding	Building project result archives, stude nt digital portfolio creation, operating class websites

Area	Tool	Tool Description	Educational Application
Creativity & Organization	Google Drive	Cloud-based file storage and sharing system	Systematic preservation of learning materials, learning history management based on student individual folders
	Google Keep / Google Tasks	Note-taking and to-do list management tools	Recording inquiry topic brainstorming, writing project step-by-step checklists, and other self-regulated learning support
	NotebookLM	Artificial intelligence-based information summarization and inquiry assistance tool	Summarizing key points of learning materials, context-based question generation, supporting critical reading and in-depth inquiry
	Gemini	Google's generative AI-based multimodal learning and work support tool	Generating drafts of instructional materials, proposing discussion questions and assignment ideas, assisting in learning concept explanations, expanding students' brainstorming and problem-solving thinking, streamlining teachers' instructional design
	Google Vids	AI-based video production tool	Creating learning content summary videos, cultivating creative expression competencies through storytelling and campaign video production

2) Prior Research on AI and Digital Teaching-Learning Environments

Prior studies commonly report that digital tools centered on Google Workspace can facilitate learners' active participation throughout the teaching-learning process and efficiently support teachers' instructional operation and evaluation. In particular, research centered on Google Classroom emphasizes that the platform provides an effective environment for implementing active learning and process-based assessment by comprehensively supporting task management, learning material distribution, feedback provision, and learning record accumulation. Mohd Shaharanee et al. (2016) applied the Technology Acceptance Model (TAM) to analyze the effects of using Google Classroom in data mining classes, confirming significant positive effects in terms of accessibility, perceived usefulness, communication, and learner satisfaction. In domestic research, Kwon and Kang (2019) reported through a case of process-based assessment using Google Classroom in high school English classes that the expansion of individual feedback opportunities and automatic accumulation of online portfolios improve the efficiency of learning process management. Additionally, Noh (2019) presented interest level, media utilization efficacy, and learning motivation as major factors affecting learner satisfaction, analyzing that Google Classroom increases learner satisfaction by providing flexible learning environments without spatiotemporal constraints. Recently, Simeonova-Ingilizova (2025) presented that self-directed learning competency and cognitive achievement of learners can be simultaneously improved through instructional design combining flipped learning and Google Classroom in an engineering education context, showing the scalability of platform-based instructional design.

Meanwhile, research utilizing Google Meet in remote learning environments is discussed centering on the impact of real-time interaction on learning engagement and achievement. Purwoko et al. (2022) revealed through a vocational high school case study that instructional operation using Google Meet's breakout room function is effective in maintaining learners' concentration and inducing participation. Khalili et al. (2024) also confirmed in research targeting online university learners that Google Meet is perceived as a beneficial tool that improves academic achievement and learning engagement. On the other hand, Benaissa and Yassine (2025) pointed out that while learners' emotional engagement appeared positive in real-time video classes, limitations still exist in maintaining concentration and long-term memory of learning content in online environments, proposing the necessity of combining short session composition and interactive elements such as quizzes. These studies suggest that the educational effectiveness of video class tools is maximized when combined with instructors' instructional design strategies rather than technology itself.

Recently, discussions on the educational application potential of generative AI tools are also expanding. Chang (2025) analyzed classes utilizing generative AI tools in programming-related courses and reported that not only learning outcomes and learning motivation but also team-based collaborative task performance abilities improved significantly. Particularly noteworthy is the observation that learners strengthened collaborative learning by utilizing generative AI as a brainstorming partner or assistant in the problem-solving process. Imran and Almusharraf (2024) defined Google Gemini as a next-generation AI education tool and evaluated that its multimodal function of simultaneously processing text, images, audio, and video has high potential for building personalized learning experiences and intelligent tutoring systems.

Additionally, web-based collaboration tools such as Google Sites, Google Docs, and Google Chat are being utilized as media that strengthen learners' digital literacy and collaboration competencies. According to Halim's (2024) systematic review, Google Sites is evaluated as an effective tool for realizing digital pedagogy by enabling teachers to easily create websites with structured learning materials and supporting students' digital portfolio construction. Furthermore, Andrade and Roshay (2023) reported that real-time collaborative writing activities using Google Docs improve ESL learners' writing fluency and immediacy of peer feedback, while Besser (2024) connected Google Chat with the Community of Inquiry (CoI) framework and analyzed that real-time messaging contributes to strengthening social, teaching, and cognitive presence and mitigating feelings of isolation in online learning environments.

Finally, class cases that comprehensively applied various digital tools without being limited to specific platforms also report positive educational effects. Kim Seong-rim and Kwon Jun-hee (2023) analyzed a case of applying QuizN, Mentimeter, and Google Forms in parallel in university classes and reported that over 85% of learners showed high satisfaction. These tools were found to contribute to enhancing the efficiency of the teaching-learning process by creating learner-centered interactive environments, visualizing abstract concepts, and providing immediate feedback to learners.

These theoretical discussions and prior studies suggest that digital-based teaching-learning environments have positive potential for strengthening learner agency and teacher professionalism. However, existing studies are often limited to specific subjects or short-term application cases, or analyze changes in only one subject, either students or teachers, thus having limitations in comprehensively verifying how changes in teachers' instructional design and operation and changes in students' learning experiences appear connected within the same instructional context.

Therefore, this study (Albus Project) sought to empirically analyze how Google Workspace-based instructional environments and generative AI utilization are applied and operate in actual school instruction across elementary, middle, and high school levels. Specifically, through pre- and post-surveys of teachers and students, we quantitatively analyzed changes in digital tool utilization experience and perception, self-efficacy, and class and learning engagement, and qualitatively analyzed the context and operating process of changes through class observations and teacher/student interviews. Furthermore, by deriving best practices based on these analysis results, we sought to present the conditions and possibilities for digital tool utilization to operate as interconnected changes within the same educational practice context of instructional design and operation, rather than being limited to separate changes in teachers and students respectively.

III. Research Methods

1 Research Procedures and Methods

This study was conducted following the procedures of research design and participant recruitment → pre-survey → teacher training and instructional design mentoring → teacher-led instructional design and application/operation → class observation and interviews → post-survey → data analysis and result integration, in order to analyze how instructional environments utilizing AI and digital tools are designed and operated in school settings and what changes appear in students and teachers as a result.

1) Research Design and Pre-preparation

The research team constructed a mixed research design that collects and analyzes both quantitative and qualitative data based on research objectives and analysis variables. From the student perspective, learning engagement, self-directedness, and self-efficacy were set as main analysis variables, and from the teacher perspective, an analysis framework was prepared centering on instructional design and operational efficiency, work burden perception, and teacher self-efficacy. Based on this, pre- and post-survey questionnaires for students and teachers, class observation recording framework, and teacher and student interview questions were developed.

2) Research Participant Recruitment and Pre-survey Implementation

Research participants consisted of teachers and students from elementary, middle, and high school levels. Through guidance on research participation, the research purpose, participation methods, and data collection content were shared, and research was conducted only for participants who completed the consent procedure. Before instructional application, pre-surveys were conducted for teachers and students to identify digital tool utilization experience, learning and instruction-related perceptions, and self-efficacy levels. The pre-survey was conducted online while maintaining the same question structure to enable comparison with the post-survey.

3) AI and Digital Tool Utilization Training and Instructional Design Mentoring for Teachers

After the pre-survey, AI and digital tool utilization training and instructional design mentoring were conducted for participating teachers. The training focused on educational utilization methods of main Google Workspace tools and cases of instructional material production and feedback support using generative AI, guiding directions applicable to actual instructional design.

Along with this, instructional design mentoring was conducted in parallel to reflect teacher-specific and school-level instructional contexts. During the mentoring process, support was provided for teachers to specify how to integrate digital tools into the instructional flow according to their subject and class characteristics, including task operation, collaborative activity composition, and feedback methods. Through this, teachers were induced to select, adjust, and utilize tools from the perspective of designing their own instruction, rather than passively using digital tools.

4) Teacher-led AI and Digital Tool Utilization Instructional Design and Application/Operation

After training and mentoring, participating teachers directly designed instruction utilizing AI and digital tools according to their subject and instructional context and applied and operated this in actual classes. Teachers shared instructional materials and operated tasks centered on Google Classroom, and composed learning activities and collaborative tasks utilizing Docs, Slides, Sheets, Forms, etc.

Students experienced accessing learning materials using Chromebooks, performing tasks and collaborative activities, and sharing results and feedback processes. In some classes, generative AI was applied to support teachers' instructional material production, assist in feedback sentence composition, and derive learning activity ideas, serving as assistance for teacher work and class operation. This stage focused on actual instructional practice processes where teachers designed and operated digital tools as subjects of instruction, rather than the research team controlling or directly intervening in classes.

5) Class Observation and Teacher/Student Interviews

During the instructional application period, the research team conducted class observations and systematically recorded digital tool utilization methods, student participation and collaborative activity patterns, and changes in teachers' instructional operation strategies. Observation content was organized centering on tool utilization scenes, teacher-student interaction, student participation levels, and facilitating and constraining factors in class operation.

During or after the instructional application process, interviews were conducted with teachers and students. Teacher interviews focused on identifying changes in instructional design and operation, changes in work burden perception, perceptions of digital tool and generative AI utilization, and difficulties and improvement needs during the application process. Student interviews collected data centering on learning participation experience, task performance and collaboration experience, and the impact of learning process visualization on learning attitudes and confidence. Collected data were analyzed according to the Thematic Analysis procedure presented by Braun and Clarke (2006). Through this, core patterns inherent in the data were identified and their meanings systematically interpreted.

6) Post-survey Implementation

After the completion of instructional application, a post-survey with the same structure as the pre-survey was conducted. Through this, changes before and after instructional application (students: learning engagement, self-directedness, self-efficacy; teachers: instructional operation efficiency, work burden, self-efficacy, etc.) could be quantitatively compared and analyzed.

7) Data Analysis and Result Integration

Collected quantitative data were analyzed through descriptive statistics and pre-post comparison analysis to confirm change patterns. Qualitative data including class observation records and interview transcripts were analyzed thematically to derive core experiences and change factors, constraining factors, and characteristics of best practices that appeared repeatedly. Finally, quantitative analysis results and qualitative analysis results were integrated to comprehensively interpret the impact of instructional environments utilizing AI and digital tools on teachers and students and their operating context.

Through these research procedures, this study sought to comprehensively analyze how AI and digital tool utilization is implemented within the actual educational practice flow of teacher training-mentoring-instructional design-application, and what changes appear as a result in students' learning experiences and teachers' instructional operation. Particularly, by centering on teacher-led instructional design and application processes rather than direct intervention by the research team, and combining pre-post surveys, class observations, and teacher/student interviews, we sought to capture both quantitative changes and qualitative context. These procedures are an important characteristic of this study in that they provide a foundation for understanding how changes are formed and operate within the actual context of instructional design and operation in school settings, rather than merely judging the effects of digital tool utilization as fragmentary outcomes.

2 Research Participants and Instruments

1) Research Participants

This study was conducted targeting teachers and students at various school levels to verify the effectiveness of digital-based education models. The number of research participants was 26 teachers in total, and for students, it consisted of 490 elementary students, 90 middle school students, and 514 high school students. Thus, a total of 1,047 students spanning all elementary, middle, and high school stages were included in the research subjects to secure data diversity.

2) Research Instruments for Teachers

The teacher questionnaire used in this study was employed to comprehensively identify teachers' background variables, perceptions and experiences regarding technology and AI utilization, difficulties and support needs when utilizing them, and perceptions of the effects of AI-based instruction. Survey questions were reconstructed to fit the research purpose by referring to teacher survey questions developed by Google, and some questions were modified and supplemented to reflect the teaching and learning utilization context of Google AI tools (Gemini, NotebookLM). The survey was composed of the same questions pre and post to enable comparative analysis of teachers' perception changes and instructional application experiences before and after project participation.

Table 3-1. Measurement Content and Response Methods of Research Instruments

Items	Category	Measurement Content	Response Method
1~3	Respondent Characteristics	Gender, school level, teaching experience	Multiple choice
4	AI Tool Utilization Experience	Types of AI tools used during instruction (auto grading, personalized learning, chatbots, etc.)	Multiple response

Items	Category	Measurement Content	Response Method
1	Technology/AI Utilization Perception	Overall perception of computer and AI utilization in schools	Likert 5-point
2	Device Suitability in Instructional Environment	Main devices used in instruction (laptops, Chromebooks, tablets, etc.)	Multiple choice
3	Technology/AI Usage Frequency	Weekly technology/AI utilization time in instruction	Multiple choice
4	Google Tools Proficiency	Google educational tools and AI tool utilization proficiency	Likert 5-point
5/6	Technology/AI Usage Difficulties	Difficulties related to perception, access, and support when using technology/AI	Multiple response
8	Needed Resources and Support	Resource and support needs for AI utilization	Multiple response
10/11	Class Engagement and Interest	Student engagement and interest levels perceived by teachers during instruction	Likert 5-point
12	Changes in Working Hours for Teacher Instruction Preparation and Class Operation	Weekly work time allocation for instruction, administration, counseling, etc.	Hours/wee k
14	Strengthening Self-directed Learning Competency	Impact on students' self-directed learning competency strengthening and administrative efficiency	Likert 5-point
15	Instructional Operation Administrative Efficiency	Impact on teachers' instructional operation and administrative efficiency	Likert 5-point
17~18	Recommendation Intention	Intention to recommend Google Workspace and Chromebook to colleague teachers	Likert 5-point/Op en-ended
19~25	Google AI Tools Perception	Teaching and learning effects, ease of use, etc. of Gemini, NotebookLM	Likert 5-point

Teacher interviews were composed of semi-structured questions to explore in-depth the instructional experience utilizing Chromebooks and Google tools. Interview questions were designed centering on learning effects and engagement, instructional operation and collaboration strategies, AI function utilization experience, technical and ethical issues, changes in assessment methods, and future development directions, with the purpose of qualitatively collecting teachers' actual instructional cases and perceptions.

Table 3-2. Main Question Content of Teacher Interviews

No.	Area	Main Question Content
1, 6	Learning Effects and Engagement	Learning efficiency, engagement, learning attitude changes in Chromebook and Google tools-utilizing instruction
2	Google Classroom Utilization	Convenient and inconvenient factors of Google Classroom usage
3	Collaboration Tools Utilization	Effects and difficulties of Docs, Sheets, Slides collaboration instruction
4	Instructional Differentiation	Google tools-based instructional cases considering student level differences
5	AI Function Utilization Experience	Gemini, Practice Sets and other AI function utilization experience and student responses
7	Ethical Issues	Experience with and responses to ethical issues such as copyright, plagiarism, bias
8	Technical/Management Issues	Technical and managerial difficulties during Chromebook use and support needs
9	Assessment and Feedback	Effects of Google tools-utilizing assessment and feedback
10	Future Development Directions	Items to maintain/improve and future development directions

2) Research Instruments for Students

The student questionnaire used in this study was developed to identify changes in attitudes toward technology through project participation, proficiency in device and Google tools utilization, and perception of instructional effects utilizing generative AI (Gemini). Survey questions were reconstructed to fit students' eye level, and were designed to measure not only simple tool usage but also the resolution of psychological barriers to technology and the impact of AI on actual learning processes (problem-solving, etc.). The survey conducted pre- and post-surveys using the same questions (or corresponding questions) before and after project participation, enabling comparative analysis of students' perception changes and learning growth following the application of digital-based education models.

Table 3-3. Specific Content and Response Methods of Student Research Instruments

Items	Category	Measurement Content	Response Method
1~4	Respondent Characteristics	Name, school name, gender, grade	Short answer/Multiple choice
5	Technology Attitude Changes	Perception shift and psychological attitude changes regarding technology use	Multiple choice
6	Device Suitability Perception	Perception of the most suitable device for learning (Chromebook, laptop, etc.)	Likert 5-point
7	Tools Used in Class	Smartphones, tablets, computers, etc.	Multiple choice
8	Technology Utilization Frequency	Weekly utilization time of technology and digital tools in the classroom	Multiple choice
9	Google Tools Proficiency	Ability to use and familiarity with major apps such as Gemini, Classroom, Drive, etc.	Likert 5-point
10~11	Usage Difficulties	Difficulties related to perception, infrastructure, and support when utilizing technology and AI tools	Multiple response
12	Problem Experience and Support	Types of technical problems occurring during class and support needs for AI utilization	Multiple response

Items	Category	Measurement Content	Response Method
13~14	Class Engagement and Interest	Engagement and interest levels felt by students in existing classes	Likert 5-point
15~19	Gemini Tool Effectiveness	Comprehensive evaluation of learning comprehension using Gemini, self-directed problem-solving ability, activity interest, ease of use, and intention to continue using in the future	Likert 5-point

To supplement survey data and identify actual changes experienced by students using Chromebooks, Google tools, and AI (Gemini), in-depth interviews were conducted. Interview questions were designed considering students' developmental stages, with particular emphasis on confirming specific activity experiences and basic digital literacy formation for elementary school students.

표3-4. Main Questions for Student Interviews

No.	Area	Main Question Content
1	Main Activity Experience	Identify the most memorable experience among Chromebook activities and the reasons
2	Task Performance and Resolution	Identify difficulties encountered during Google Classroom task performance and the process of self-resolution
3,4	Outputs and Sharing	Identify types of works created with Google Docs/Slides and experience sharing materials through Google Drive
5	Information Search Experience	Explore specific topics researched using Google Search or YouTube
6	Changes in Learning Methods	Identify changes in study methods or learning speed before and after Chromebook use
7	Technical Difficulties	Identify actual inconveniences experienced during Chromebook use such as login, internet connection, etc.
8	AI Tool Experience	Explore impressions and responses from directly using Practice Sets or Gemini
9	Safety and Ethical Rules	Confirm awareness of safety rules to follow when using Chromebooks, such as personal information protection
10	Future Expected Activities	Collect activities students want to newly challenge with Chromebooks in the next class

3 Teacher Training and Mentoring

1) Teacher Training and Mentoring Operations

This training was operated in a blended format combining in-person and online training, and was planned and operated in collaboration with Google Korea and Poin2, an educational professional partner company. The training was designed with a 4-stage structure of introduction-deepening-expansion-settlement to share project goals and systematically strengthen field application competencies. The teacher training process was conducted for a total of 29 sessions online and offline, and teacher mentoring was conducted for a total of 81 sessions.

In-person training was placed at the starting point and mid-checkpoint of the entire training process. In the introduction stage, through Kick-off and lesson design-centered in-person training (6 sessions), research purposes and operational directions were shared, and basic competencies were strengthened focusing on Google Workspace basic tools and Chromebook utilization. In the mid-checkpoint stage, through Google Korea visit training (3 sessions), project operation status was reviewed, and teachers' learning motivation and lesson design expansion possibilities were enhanced by encountering digital collaboration and AI utilization cases in actual corporate environments.

Online training consisted of a total of 11 sessions, 2 sessions per session, and was operated in the form of theme-specific deepening training centered on actual class application, including Google Workspace basic tools, Google Classroom operation, Gemini and NotebookLM, Google Vids, Google Sites, Apps Script and AppSheet, Gemini-based vibe coding, and Gemini utilization within Classroom. Each session was designed with a Q&A-centered structure, allowing teachers to immediately explore and apply utilization plans suited to their lesson contexts. Additionally, in the middle stage, a separate case-sharing time was arranged for participating teachers to mutually share lesson application results and problem-solving experiences.

In particular, this study implemented individualized customized mentoring that designated a dedicated 1:1 mentor for each teacher in parallel with training. Mentors provided a total of 81 individual guidance sessions on lesson design, tool selection, AI utilization methods, and assessment and feedback structures, considering each teacher's lesson context and digital utilization level. Mentoring was operated in parallel through online and asynchronous feedback methods, and consisted of a structure that continuously supported lesson design draft review, lesson application process monitoring, and post-lesson reflection and improvement direction discussion.

This training and mentoring system aimed to support teachers in educationally meaningfully utilizing Google Workspace and generative AI tools in actual classes, beyond simple tool function delivery. Through this, teachers were able to strengthen their role as designers integrating digital tools into lessons and learning environment coordinators, forming a cyclical professional development structure leading from training-mentoring-lesson application-reflection.

Table 3-5. Teacher Training and Mentoring Topics and Schedule

Training Type	Topic	Schedule	Hours
In-person Training	Kick-off and Lesson Design	8/30(Sat)	6
	Mid-Project @Google Korea	10/25(Sat)	3
Online Training	Q&A + Google Workspace Basic Tools	9/15(Mon)	2
	Q&A + Google Classroom Operation	9/24(Wed)	2
	Q&A + Chromebook and Instructional Tools	9/25(Thu)	2
	Q&A + Gemini & Notebook LM	10/1(Wed)	2
	Q&A + Google Vids(Gemini Canvas+Google Sites)	10/2(Thu)	2
	Q&A + Exploring Google Workspace EDU Plus	10/13(Mon)	2
	Mid-term Case Sharing Session	11/6(Thu)	2
	Q&A + Gemini vibe coding	11/17(Mon)	2
	Q&A + Apps Script w/ Gemini & AppSheet	11/24(Mon)	2
	Q&A + Using Gemini within Google Classroom	12/1(Mon)	2
Total			29
Teacher Mentoring	20 coaches, 26 coaching participants	9/15~12/29	81 sessions

2) Teacher Mentoring Satisfaction

Table 3-6. Average Scores by Teacher Mentoring Satisfaction Item

No.	Item	Average
1	Do you think the matching with the assigned coach (school level, subject, region, etc.) was appropriate?	4.47
2	What is your overall satisfaction with the assigned coach?	4.74
3	How do you evaluate the coach's 'expertise'? (Evaluation by item) [Knowledge of Google tool utilization (Gemini, Chromebook, etc.)]	4.05
4	How do you evaluate the coach's 'expertise'? (Evaluation by item) [Instructional application and educational guidance ability]	4.05
5	How do you evaluate the coach's 'expertise'? (Evaluation by item) [Listening and empathetic attitude (rapport formation)]	4.05
6	Compared to before receiving coaching, have there been positive changes in your confidence in digital tool utilization or teaching methods?	4.32
7	Do you think you would have had difficulties proceeding with the Albus Project (training, device utilization, etc.) without this 1:1 coaching?	3.84
Average		**4.22**

- (Open-ended question) If a similar coaching program is conducted in the future, what would you like to suggest for better operation?

Open-ended responses showed that 1:1 customized coaching was very helpful for instructional application and digital utilization, with high satisfaction regarding coach expertise. Additionally, pre-project coach assignment, operational monitoring and lesson plan standardization, expansion of Chromebook practical tips, and securing offline networking and time were suggested as improvement tasks.

"1:1 coaching was very useful and helpful. The coach's instructional cases and digital utilization coaching were very helpful," "If coaches are assigned, it will be more helpful for lesson planning," "Need for operational team-level process progress confirmation for coaching activities," "Expansion of offline meeting opportunities, securing stable time," "Need for operational team-level process progress confirmation for coaching activities"

(Interim Conclusion)

According to this mentor satisfaction survey, the 1:1 customized coaching program showed overall high satisfaction and made substantial contributions to actual classroom improvement and strengthening of digital tool utilization competency of field teachers. The analysis shows that the overall average score across all items was 4.22 out of 5, confirming that participating teachers had a positive perception of the necessity and effectiveness of coaching.

In particular, "overall satisfaction with the assigned coach (4.74)" and "appropriateness of coach-teacher matching (4.47)" scored highly, suggesting that the coach assignment method and personnel support system aligned well with field needs. Additionally, items related to coach expertise—including Google tools utilization competency, instructional application and educational guidance ability, and listening and empathy attitudes—all scored above 4 points, demonstrating that coaches' professional competence and field support capabilities were well-balanced.

Furthermore, in the pre-post coaching comparison items, "positive changes in confidence in digital tool utilization and teaching methods (4.32)" were confirmed, indicating that this coaching went beyond simple information delivery to induce actual changes in teaching practice. Meanwhile, the item "difficulty in proceeding with the Albus Project without coaching" showed a relatively lower score (3.84), suggesting that some teachers perceived they could carry out the project based on existing capabilities. However, this should be interpreted not as coaching being unnecessary, but rather as indicating that when support is available, the quality and stability of instruction are significantly enhanced.

Analysis of open-ended responses revealed that while teachers highly valued the usefulness and satisfaction of 1:1 customized coaching, they proposed future improvements including systematization of pre-assigned coach allocation, strengthened operational monitoring and process management, standardization of lesson plans, expanded sharing of Chromebook practical tips, offline networking opportunities, and securing sufficient coaching time. This should be interpreted not as dissatisfaction with coaching quality itself, but rather as a demand for sophistication of operational structure and support methods.

In summary, this 1:1 coaching program is evaluated as a successful support model that achieved substantial effects in strengthening teachers' digital instruction capabilities and classroom application. It is judged that educational effectiveness can be further maximized in the future through refinement of operational systems and continuous, expansive support.

3) Operations Team and Coach Performance Satisfaction Results

Table 3-7. Average Scores by Operations Team and Coach Performance Satisfaction Item

No.	Item	Average
1	Were the coaching session operation sheets and kickoff meetings provided at the project start sufficiently helpful in performing the coach role?	4.54
2	During the coaching period, were the operations team (PM) announcements, schedule guidance, and inquiry responses smooth?	4.85
3	How was the coaching participation willingness and activeness of your assigned teachers (mentees)?	4.38
4	Compared to when you first met, do you judge that there was significant change in the assigned teacher's digital tool utilization competency?	4.77

- (Open-ended question) Please provide one improvement suggestion for the operations team or recommendation for the next cohort from your experience with this project.

Open-ended responses proposed expanding program opportunities along with pre-survey of mentee participation willingness and expectation levels (focusing on voluntary participation), adjusting coach assignment scale (maintaining 1:1 or team operation for multiple mentees), and strengthening networking through mid-term sharing sessions as key improvement tasks.

"It would be good to expand such good opportunities widely." "It would be helpful to survey mentees' desired level of coaching participation in advance. If we could identify in advance the range from completely passive to completely active levels they expect, mentors could adjust accordingly." "I wish there was time to gather and talk together during the coaching process ^^"

(Interim Conclusion)

According to the coaching performance satisfaction survey results, the coaching operational system and outcomes of this project received very high overall evaluation. Average scores for all items were above 4.38, with particularly outstanding results in the operations team (PM) management and communication capabilities and perception of teacher competency changes.

First, the smoothness of operations team (PM) announcements, schedule guidance, and inquiry responses (4.85) recorded the highest score, demonstrating that the administrative and operational support system for the overall project was stably established and operated. This is evaluated as an important achievement in that it created an environment where coaches could focus on their essential roles of field support and teaching-learning improvement. Additionally, the coaching session operation sheets and kickoff meetings provided at the project's beginning (4.54) were found to provide practical help in coaches' role understanding and activity preparation.

The coaching participation willingness and activeness of assigned teachers (mentees) (4.38) was also evaluated at a high level, confirming that this coaching program was perceived by teachers as a meaningful and acceptable support method. Furthermore, the evaluation of changes in teachers' digital tool utilization competency before and after coaching (4.77) appeared very positive, suggesting that coaching did not stop at short-term support but led to actual improvement in teachers' capabilities and instructional changes.

Analysis of open-ended responses proposed future improvement directions including expanding coaching opportunities, pre-surveying mentee participation willingness and expectation levels, flexible adjustment of coach assignment scale (maintaining 1:1 or team operation for multiple mentees), and strengthening mid-term sharing and networking. In particular, the need to adjust coaching methods and intensity according to mentee participation types (voluntary participation status, expectation levels) was raised, which is interpreted as a demand for operational sophistication to more precisely enhance coaching effectiveness.

In summary, this coaching project is evaluated as having achieved clear results in improving teachers' digital instruction capabilities through systematic operational support and effective coaching design. It is judged that in the future, by strengthening customized operational strategies that more precisely reflect participating teachers' characteristics and expectations, along with teacher sharing and connection structures, the scalability and sustainability of coaching can be further enhanced.

4 Teaching and Learning Design and Educational Case Studies

1) Class-by-Class Instructional Operation Plan

This study involved 26 teachers from various school levels—elementary through high school—operating student-focused instruction. Participating teachers mostly designed and operated approximately 10 class sessions per school, with some schools adjusting sessions according to academic schedules and instructional contexts. The total number of class sessions conducted by the 26 teachers with students reached 271.

By school level, at elementary schools, 25 classes from 10 schools participated with instruction operated for a total of 490 students. Middle schools had 8 classes from 3 schools with 90 students participating. High schools had 26 classes from 6 schools with instruction conducted for a total of 514 students. The total number of participating students was 1,047, and in that this represents large-scale instructional application encompassing all elementary, middle, and high school levels, this study possesses the character of empirical research based on actual school settings.

In this way, this study was not limited to specific school levels or subjects, but rather sought to analyze changes in teachers' instructional design and operation along with changes in students' learning experiences within the same educational practice context, by applying Google Workspace-based digital tools and generative AI-utilizing instruction across diverse instructional contexts spanning elementary, middle, and high schools.

Table 3-8. Student Instruction Operation Status by School Level

Category	Number of Schools	Number of Classes	Total Class Sessions	Number of Participating Students
Elementary School	10	25	141	490
Middle School	3	8	40	90
High School	6	26	90	514
Total	19	59	271	1,047

Table 3-9. Status of Participating Schools

No.	School	Teacher	Sessions	Participants
1	Asan Elementary School	Lim*Sol	10	24
2	Asan Elementary School	Baek*Cheol	10	23
3	CheonanYongam Elementary School	Ah*Hoon	10	24
4	Seongyeon Elementary School	Park*Ho	10	22
5	Sucheong Elementary School	Noh*Geun	10	22
6	Sucheong Elementary School	Lim*Min	10	22
7	Eomsa Elementary School	Kim*Hee	11	17
8	OnyangOncheon Elementary School	Min*Beom	10	20
9	CheonanYongso Elementary School	Jung*Gi	10	24
10	Handeulmulbit Elementary School	Shin*Jung	10	29
11	Handeulmulbit Elementary School	Lee*Hyung	10	27
12	Handeulmulbit Elementary School	Shin*Jin	10	30
13	OnyangDongsin Elementary School	Jung*Jin	10	189
14	NonsanBuchang Elementary School	Cheon*Ryun	10	17
15	CheonanGyegwang Middle School	Kim*Jin	10	20
16	AsanTechno Middle School	Park*Hye	10	26
17	Hongbuk Middle School	Kim*Tae	10	20
18	Hongbuk Middle School	Jung*Ra	10	24
19	Hanil High School	Kim*Ae	10	60
20	Hanil High School	Lee*Woo	10	60
21	Daecheon High School	Kim*Sol	10	136
22	BokjaGirls' High School	Na*Young	10	40
23	BokjaGirls' High School	Seo*In	10	28
24	YesanGirls' High School	Kim*Kyung	10	70
25	Hoseo High School	Lim*Geun	20	100
26	Cheongyang High School	Kim*Hoon	10	20
Total			**271**	**1,047**

2) Handeulmulbit Elementary School Instructional Operation Case

Author	Lee Won-hyung	Affiliation	Handeulmulbit Elementary School

1. Background and Necessity of Instruction

- Teachers should be able to monitor and manage students' academic performance situations, converting them into data for use in parent consultations.
- Students should be able to enhance their information technology device literacy through edutech-based instruction and self-evaluate their activity status to improve academic ability and develop metacognition.

2. Basic Overview

School Level	Elementary	Grade	2	교과	Mathematics, Integrated
Unit	I Want to Master the Computer				
Lesson Topic	Developing Research and Collaboration Skills Using Chromebook				
Achievement Standards	"2Sl03-02" Explore the relationship between seasons and daily life. "2Jl03-02" Play while feeling changes in nature. "2Ba03-03" Develop community spirit through the lives of various figures. "2Sl03-03" Examine the past and present of objects of interest and imagine the future. "2Jl03-03" Express traditional culture in new ways. "2Sl04-01" Explore and modify the shape or function of everyday tools.				
Learning Objectives	Can research various topics using computers. Can collaborate based on content researched using computers. Can develop basic computer usage skills and produce outputs useful to all.				
Google Edutech Tools Utilization Plan	1. Tools Utilized (check all) ☐ ① Calendar ☑ ② Chromebook ☑ ③ Gemini ☐ ④ Gmail ☑ ⑤ Google Classroom ☑ ⑥ Google Documents ☑ ⑦ Google Drive ☑ ⑧ Google Forms	☐ ⑨ Google Maps ☑ ⑩ Google Search ☐ ⑪ Google Sheets ☑ ⑫ Google Slides ☐ ⑬ Practice Sets ☐ ⑭ Read Along ☐ ⑮ YouTube Interactive Questions ☑ ⑯ Notebook LM			

	2. Specific Utilization Methods 1) Material provision and collaboration activities: Provide materials reorganized with Gemini and Notebook LM, conduct collaboration activities using Google Sheets and Google Slides 2) Feedback, etc.: Provide feedback using comments 3) Other: Conduct presentation activities if time permits
Chromebook, Digital Device Utilization	1. Device utilization method in student activities: Direct participation type 2. Device usage plan for individual vs. collaborative learning: Focus on functional improvement education for students during individual learning, focus on research and utilization education during collaborative learning 3. Precautions (network, accounts, accessibility, etc.): Difficulties due to network and accounts are anticipated, so secure 2 or more networks for network issues, and prepare backup accounts for account problems
Basic Environment and Materials	Chromebook, smart pen, wireless mouse, router, smartphone
Evaluation Methods and Elements	Process-based assessment

3. Session-by-Session Instructional Structure

Session	Teaching-Learning Content (Main Activity or Topic per Session)	Tools and Devices Utilized	Grade	Subject	Instruction Implementation Date
1	Discuss reasons for liking this season while thinking about the four seasons	Google sheets	2	Integrated	9.9.
2	Learn about animals and plants that indicate the four seasons	Google Search	2	Integrated	9.11.
3	Film playing with various natural objects while experiencing the seasons	Google Slides	2	Integrated	9.16.
4	Take a 24 solar terms journey and learn about the term I'm curious about	Google Documents	2	Integrated	9.23.

Session	Teaching-Learning Content (Main Activity or Topic per Session)	Tools and Devices Utilized	Grade	Subject	Instruction Implementation Date
5	Think about and research foods suitable for each season	Google Slides	2	Integrated	9.25.
6	Observe fruits that can be seen in each season	Gemini, Quiznne	2	Integrated	9.30.
7	Experience seasons through pictures	Google Slides	2	Integrated	10.14.
8	Search for and research great figures using digital devices	Notebook LM	2	Integrated	10.16.
9	Learn about the past and present appearance of objects I'm interested in	Google Search	2	Integrated	10.21.
10	Examine what figures said to us and conduct virtual interviews by inviting figures	Gemini, Google Sheets	2	Integrated	10.28.

4. Expected Effects and Reflection

1) Expected Instructional Effects

Can develop competency in utilizing information technology devices that enable learning areas that may be difficult in reality.

2) Anticipated Difficulties and Response Plans

For students experiencing difficulty using devices, assign typing practice, drawing, and research activity tasks during lunch and morning hours to develop basic functional usage abilities. If network problems occur and are not resolved within 15 minutes, suspend class and adopt a form of instruction excluding devices, and request help from the education office finance department after a 1-week interval.

3) Post-Instruction Reflection Plan

Conduct self-evaluation while reviewing instructional outputs, provide students with opportunities for reflection, have them present their thoughts, and upgrade improvement ideas and next session application plans.

5. Public Lesson Monitoring Results

1) Google Tools Application Method by Instructional Flow

Stage	Tools Utilized	Application Method
Introduction	Google Slides	Topic recognition through presentation of season-related photos and materials
Exploration	Google Search	Explore necessary information through keyword searches
Expression	Google Slides	Post and share presentation materials using pictures, photos, and sentences
Enrichment	Gemini, Notebook LM	Generate examples and provide quizzes using AI
Collaboration	Google Slides	Collaborative learning through real-time co-editing
Feedback	Google Classroom, Comment function	Provide feedback between teachers and students
Extension	Google Search, Gemini	Generate additional questions and explore materials

2) Application Method of Google Tools and Generative AI in Instruction

This instruction was designed as digital-based instruction that considers the developmental level of 2nd grade elementary students, utilizing Chromebook and Google tools as learning tools centered on research, organization, and expression. Students explored information related to seasons and daily life, natural environment, food, and flora and fauna using Google Search, and organized researched content into pictures and short sentences using Google Slides. Google Classroom was utilized as a learning management tool for providing learning materials, task guidance and submission, and feedback. Generative AI (Gemini) was applied as a supplementary tool to enhance learning interest and support thinking expansion, being utilized for presenting season-related examples, generating questions, and quiz activities. Meanwhile, Notebook LM was utilized by teachers to organize instructional materials and structure reference materials. Instructional outputs were organized and shared in student portfolio format on Google Sites, enabling cumulative recording of the learning process and confirmation of growth.

3) Actual Utilization and Effects in Instruction

During class time, students used Chromebooks to research natural environments and daily life related to seasons, and organized researched content into presentation materials using Google Slides. Through visualization activities using Google Slides, students were able to structure their thoughts while expressing researched content in pictures and text.

Example presentation and quiz activities using Gemini increased student participation, showing the effect of expanding beyond simple information searches to learning that understands and applies concepts. Additionally, by uploading student-produced outputs to Google Sites and sharing them in portfolio format, students were able to cumulatively manage learning results and feel a sense of achievement. This instructional method contributed to enhancing learning interest and concentration by having students independently explore topics closely related to daily life.

4) Changes in Students and Teachers

As students became accustomed to research and presentation activities using digital devices, learning participation increased, and self-directed learning attitudes of independently finding and organizing points of curiosity were strengthened. In particular, through expression activities using Google Slides and portfolio sharing experiences through Google Sites, students were able to accumulate experience in organizing and presenting their learning results. Additionally, during collaborative activities, communication skills and collaborative problem-solving competencies grew together as students asked each other questions and provided help. From the teacher perspective, efficiency in instructional material preparation and instruction operation increased through utilizing Google tools and generative AI, and an environment was created where teachers could understand students' learning processes step-by-step and implement process-based assessment. In particular, material organization and lesson preparation using Notebook LM reduced teachers' instructional design burden and enabled more systematic instruction operation.

5) Instructional Outputs and Activity Scenes

https://sites.google.com/g.cnees.kr/hme2-2/%ED%99%88

3) Case study of class operation at Sucheong Elementary School

Author	Kangmin Lim	Affiliation	Sucheong Elementary School

1. Background and Necessity of the Class

- Teachers should reflect the digital and AI-based learning environment of the 2022 Revised National Curriculum by linking learning in each subject and creative experiential activities with EdTech to stimulate students' interest and expand their learning experiences. In addition, teachers must foster safe and responsible digital usage habits, playing a role in reducing the learning gap by allowing all students to experience small achievements through the digital and AI tools familiar to the current generation.
- Students should utilize EdTech tools in accordance with the achievement standards of each subject and creative experiential activities to perform various student-centered activities, such as data exploration and collaborative problem-solving. Through this, they construct knowledge and grow into future talents who meet the demands of their generation.

2. Basic Overview

<table>
<tr><th>School level</th><td>elementary school</td><th>Grade</th><td>2nd Grade</td><th>Subject</th><td>All subjects</td></tr>
<tr><th>Unit</th><td colspan="5">All Subjects (Refer to the lesson plan by session)</td></tr>
<tr><th>Lesson Topic</th><td colspan="5">All Subjects (Refer to the lesson plan by session)</td></tr>
<tr><th>Achievement Standards</th><td colspan="5">All Subjects (Refer to the lesson plan by session)</td></tr>
<tr><th>Learning Objectives</th><td colspan="5">All Subjects (Refer to the lesson plan by session)</td></tr>
<tr><th>Google EdTech Tool Utilization Plan</th><td colspan="3">1. Utilized Tools (All checked)
① Calendar
② Chromebook
③ Gemini
④ Gmail
⑤ Google Classroom
⑥ Google Documents
⑦ Google Drive
⑧ Google Forms</td><td colspan="2">⑨ Google Maps
⑩ Google Search
⑪ Google Sheets
⑫ Google Slides
⑬ Practice Sets
⑭ Read Along
⑮ YouTube Interactive Questions
⑯ Notebook LM</td></tr>
</table>

	2. Specific Utilization Methods 1) Material Provision and Collaborative Activities: Chromebook familiarization activities, research activities using materials provided by the teacher (for lower grades), virtual figure interview activities using Gemini, and unit wrap-up game activities using Chromebooks. 2) Feedback, etc.: Since lower-grade students are inexperienced in using Chromebooks, preliminary lessons on Chromebook utilization and individual feedback are provided. Differentiated feedback is provided based on EdTech utilization capabilities and the level of achievement of learning objectives. 3) Others: Demand for valid curriculum reconstruction for EdTech utilization.
Chromebook, Digital Device Utilization	1. Device Utilization Method in Student Activities: Direct participation type 2. Device Usage Plan for Individual vs. Collaborative Learning: Individual Learning) Organize student-centered activities through the 1-to-1 Chromebook initiative. Collaborative Learning) Create collaborative outputs, such as making card news by having each student create one slide. 3. Precautions (Network, Accounts, Accessibility, etc.): Since the school only has 29 Chromebooks, the usage schedule must be appropriately coordinated with other grades. Networks and accounts for Chromebook usage must be checked in advance to ensure no disruptions to the class.
Basic Environment and Materials	Establishment of an environment for Chromebook utilization, including a 1-to-1 Chromebook setup, and preliminary training on Chromebook usage.
Evaluation Methods and Elements	Observational evaluation and teacher evaluation regarding EdTech utilization capabilities and the achievement of learning objectives and standards.

3. Lesson Plan by Session

Session	Teaching and Learning Content by Session (Main Activities or Topics)	Utilized Tools and Devices	Grade	Subject	Class Execution Date
1	<AI and Software Education> Familiarization with Chromebook Usage	Chromebook	2	Creative Experiential Activities	10/17

2	<Ecological Transition Environmental Education> Reading Environmental Storybooks and Understanding the Value of Nature and Life via Environmental Quizzes	Gemini and Chromebook	2	Creative Experiential Activities	10/20
3	<Ecological Transition Environmental Education> Creating Environmental Campaign Promotional Videos	Google Slides and Chromebook	2	Creative Experiential Activities	10/20
4	<Seasons> Embarking on a Journey through the 24 Solar Terms ~ Researching the 24 Solar Terms	Chromebook	2	Integrated Subject	10/22
5	<Figures> Who Shall We Learn About ~ Interviewing Historical Figures via AI	Gemini and Chromebook	2	Integrated Subject	10/27
6	Unit 2 (Multiplication Tables) Wrap-up Game	Chromebook	2	Mathematics	10/27
7	<Figures> King Sejong the Great and Jang Yeong-sil ~ Researching King Sejong the Great and Jang Yeong-sil	Chromebook	2	Integrated Subject	11/3
8	<Figures> The King Sejong the Great We Met ~ Wrap-up Quiz on King Sejong the Great	Gemini and Chromebook	2	Integrated Subject	11/4
9	Unit 6 (Experiencing Media) Expressing What We Want to Introduce About Our Class in Text and Drawings	Gemini, Google Slides, Chromebook	2	Korean Language	11/28
10	Unit 8 (I Am a Writer Too) Reading a Story and Imagining the Following Story	Gemini, Google Slides, Chromebook	2	Korean Language	12/10

4. Expected Effects and Reflection

1) Expected Class Effects

Students can develop digital literacy and Self-Directed Learning capabilities by utilizing Chromebooks and Google tools, and experience communication skills and the joy of learning through collaborative activities. Teachers can streamline lesson preparation and data management, and facilitate Process-Based Assessment for individual students.

2) Anticipated Difficulties and Countermeasures

Difficulties such as students' inexperienced device usage and collaborative imbalances are expected. These will be addressed through repetitive instruction on basic functions, the provision of clear role cards, and the offering of highly reliable data links.

3) Post-Class Reflection Plan

Identify areas where students faced difficulties and supplement them with review games. Apply highly engaging activity methods to other subjects to progressively improve the lessons.

5. Open Class Monitoring Results

1) Google Tool Application Methods by Lesson Flow

Category	Utilized Tool	Application Method
Deepening	Gemini(GEMS)	Q&A activity utilizing the 'King Sejong Question Window' created with GEMS
Wrap-up	Chromebook Kahoot	Conducting a whole-class participatory quiz game
Expression	Google Slides	Creating slides through a group collaboration method
Sharing	Google Classroom	Assignment submission and teacher feedback
Expansion	Gemini(Storybook Feature)	Students writing their own prompts to create fairy tales using the storybook feature

2) Application Methods of Google Tools and Generative AI in Class

Considering the developmental level of elementary school students, this class was designed as a digital-based lesson that utilizes Chromebooks, Google tools, and Generative AI as tools centered on learning participation and expression. Google Classroom was utilized as a learning management tool for providing learning materials, guiding and submitting assignments, and offering teacher feedback, while Google Slides was used as an expressive tool for students to visually organize their thoughts and learning content.

Generative AI (Gemini) was utilized to conduct the King Sejong interview activity based on learning content about 'King Sejong the Great' that the teacher had restrictively set in advance using GEMS. Through this, students were guided to utilize AI as a learning tool within a scope relevant to the lesson topic, preventing indiscriminate information exploration.

3) Actual Utilization and Effects in Class

During class, students were able to understand the achievements and significance of the historical figure through the King Sejong interview activity using Gemini, where they asked questions to King Sejong and received answers. This process expanded into learning that reconstructs content through questioning, rather than simple information transmission.

In addition, utilizing Chromebooks for a unit wrap-up activity, a whole-class participatory quiz game was conducted to review learning content and increase interest.

In group activities, a 1-student-1-slide card news creation activity was conducted, having each student take charge of one piece of content related to King Sejong and express it on a slide. This collaborative method was operated under a structure that allowed students to experience both individual responsibility and collaboration simultaneously

The assignment submission and feedback process through Google Classroom played a role in stably managing the learning flow, and activities utilizing digital tools showed the effect of increasing students' class participation and concentration.

4) Changes in Students and Teachers

Students experienced reconstructing and expressing learning content themselves through interview activities utilizing Generative AI and slide creation, which subsequently increased their learning participation and interest. In particular, through quiz games and collaborative activities, they enjoyably reviewed the unit content, and in the process of sharing each other's outputs, their communication skills and collaborative attitudes improved concurrently.

From the teacher's perspective, by setting the learning scope in advance using GEMS and applying Gemini to the lesson based on this, Generative AI could be utilized as a safe and controlled learning tool. Furthermore, utilizing Google Classroom and Google Slides streamlined the management of learning materials and the checking of outputs, creating an environment where the teacher could step-by-step grasp students' learning processes and implement Process-Based Assessment.

5) Class Activity Scenes

3) Case study of class operation at Gyegwang Middle School

Author	Seongjin Kim	Affiliation	Cheonan Gyegwang Middle School

1. Background and Necessity of the Class

- Teacher: The primary goal is to achieve national achievement standards and learning objectives through effective lesson design, and to become proficient in Google EdTech-based lesson design, operation, and evaluation. The teacher strives to develop students' basic literacy and enhance their self-directed learning habits through Google EdTech-based lesson design and material provision. Furthermore, the teacher aims to cultivate digital literacy and reduce the information gap by guiding students to experience various digital tools. - Students: Under the teacher's guidance, students aim to achieve national achievement standards and learning objectives as their primary goal. By faithfully following the teacher's guidance, they seek to improve basic literacy, enhance Self-Directed Learning, boost digital literacy, and increase accessibility to digital tools.

2. Basic Overview

School Level	Middle School	**학년**	3	**교과**	Social Studies
Unit	7. Population Change and Population Problems / 8. Human-made Habitats, Cities / 9. Global Economic Activities and Regional Changes				
Lesson Topic	Regional changes according to population, cities, and globalization				
Achievement Standards	7. Understanding and analyzing population distribution, migration, and population problems caused by population changes. 8. Understanding the conditions for a livable city based on a basic understanding of cities. 9. Understanding agriculture, the service industry, and multinational corporations in the context of globalization.				
Learning Objectives	1. Be able to explain population distribution, migration, and population problems caused by population changes. 2. Be able to explain location, landscape, urbanization, and urban problems based on a basic understanding of cities. 3. Be able to explain the changes and impacts on agriculture, the service industry, and multinational corporations due to globalization.				

<table>
<tr><td rowspan="2">Google EdTech Tool Utilization Plan</td><td>1. Utilized Tools (All checked)
① Calendar
② Chromebook
③ Gemini
④ Gmail
⑤ Google Classroom
⑥ Google Documents
⑦ Google Drive
⑧ Google Forms</td><td>
⑨ Google Maps
⑩ Google Search
⑪ Google Sheets
⑫ Google Slides
⑬ Practice Sets
⑭ Read Along
⑮ YouTube Interactive Questions
⑯ Notebook LM</td></tr>
<tr><td colspan="2">2. Specific Utilization Methods
1) Material Creation
Performance assessment for learning key unit terms (handouts)
: Notebook LM, Google Sheets
Formative assessment quiz on key unit terms : Google Forms and Sheets
Practice worksheet performance assessment by unit : NotebookLM, Forms and Sheets
Audio overview and mind maps by unit : NotebookLM
2) Audiovisual and search materials during class
: Chrome, Gemini, Maps, Earth, Drive, Youtube, etc.
3) Feedback : Utilizing Classroom assignments (auto-grading, comments, returning assignments)
4) Evaluation: Utilizing Classroom assignments (auto-grading)
5) Others: Attempting to use various Google tools depending on the lesson content</td></tr>
<tr><td>Chromebook and Digital Device Utilization</td><td colspan="2">1. Device Utilization Method in Student Activities
Subject Class : Chromebook utilization
Individual Learning outside class : Personal PC and Smartphone utilization
2. Use and management of institutional accounts</td></tr>
<tr><td>Basic Environment and Materials</td><td colspan="2">Textbook, Chromebook, writing utensils</td></tr>
<tr><td>Evaluation Methods and Elements</td><td colspan="2">2 Performance assessments for learning key vocabulary by unit
- Individual handouts
2 Performance assessments for utilizing key terms by unit
- Google Forms class assignment utilization (Auto-grading)</td></tr>
</table>

3. Lesson Plan by Session

Session	Teaching and Learning Content by Session	Utilized Tools and Devices	Grade	Subject	Class Execution Date
1	Population Distribution - Features and factors of world population distribution, features and factors of Korea's population distribution	chromebook Classroom	3	Social Studies	9/4
2	Population Migration (1) - Various types of population migration, population inflow and outflow areas, conflicts due to population migration	chromebook Classroom	3	Social Studies	9/9
3	Population Migration (2) - Conflicts due to population migration, self-directed learning methods using digital devices	chromebook Classroom	3	Social Studies	9/11
4	Population Problems - Population problems in developed and developing countries, Korea's population problems and countermeasures	chromebook Classroom	3	Social Studies	9/16
5	Subject-related autonomous activity - International society and international politics, population change and population problems	Classroom Document Notebook LM	3	Social Studies	9/18
6	Performance assessment utilizing key terms by unit - International society and international politics, population change and population problems	chromebook Classroom	3	Social Studies	9/23
7	Attractive cities of the world - Locations and features of global cities	chromebook Classroom	3	Social Studies	9/25
8	Various landscapes inside the city - City centers and surrounding areas, accessibility and land value differences within the city	chromebook Classroom	3	Social Studies	10/14
9	Urbanization in developed and developing countries - Urbanization and urban problems in developed	chromebook Classroom	3	Social Studies	10/16

	and developing countries				
10	Livable cities - Cities that solved urban problems, conditions for becoming a livable city	chromebook Classroom	3	Social Studies	10/21
11	Globalization of agriculture and regional changes - Corporatization of agricultural production and its impact on the region/consumption areas	chromebook Classroom	3	Social Studies	10/23
12	Multinational corporations and changes in production areas - Spatial division of labor by MNCs, its impact on production areas	chromebook Classroom	3	Social Studies	10/28
13	Changes in the service industry and residents' lives - Globalization of the service industry, changes in residents' lives due to it	chromebook Classroom	3	Social Studies	10/30
14	Subject-related autonomous activity - Human-made cities, global economic activities and regional changes	Classroom Document Notebook LM	3	Social Studies	11/4
15	Performance assessment utilizing key terms by unit 8. Human-made cities, 9. Global economic activities and regional changes	chromebook Classroom	3	Social Studies	11/6

4. Expected Effects and Reflection

1) Expected Class Effects

- Improvement in class fidelity due to reduced lesson preparation and other administrative time (Teacher)
- Enhancement of overall understanding and utilization of Google EdTech (Teacher)
- Enhancement of literacy-centric Self-Directed Learning capabilities (Student)
- Improvement of digital literacy and mitigation of the information gap (Student)

2) Post-Class Reflection Plan

- Reflection through the sharing of research results
- Reflection through internal student surveys
- Frequent consulting with fellow teachers

5. Open Class Monitoring Results

1) Google Tool Application Methods by Lesson Flow

Category	Utilized Tool	Application Method
Class Operation	Chromebook	Conducting all class activities in a digital environment
Class Management	Google Classroom	Application Method: Comprehensively providing and managing performance assessments, quizzes, and learning materials
Performance Assessment	Generative AI (Gemini)	Application Method: Creating performance assessment sheets by uploading key content by unit
Formative Assessment	Google-based Quizzes	Conducting quizzes and checking results immediately
Class Development	Chromebook + Textbook	Proceeding with explanations and activities reflecting the quiz results
Class Wrap-up	Generative AI + veo3	Providing video and audio materials centered on key keywords
Learning Expansion	Generative AI (Gemini)	Providing AI utilization experiences during class

2) Application Methods of Google Tools and Generative AI in Class

In this class, Chromebooks and Google Classroom were utilized not merely as devices but as a learning platform supporting the overall class operation.

By comprehensively providing performance assessment materials, quizzes, and learning guides through Google Classroom, the presentation of materials and assignment management were systematically carried out, allowing the teacher to focus more on class operation and student responses.

The performance assessment sheets were created using Generative AI by uploading the key contents for each unit for the semester. This allowed the creation of performance assessment materials with consistent formats and difficulty levels across units, significantly reducing lesson preparation time.

3) Actual Utilization and Effects in Class

During class, quiz activities using Chromebooks allowed students to immediately check their scores and self-recognize parts they misunderstood or concepts they lacked. This process served to induce students to check and supplement their own learning status, rather than relying on one-way explanations from the teacher.

Furthermore, guiding students to accurately understand the meaning of key keywords presented in the textbook through performance assessment activities had a positive impact on improving literacy in social studies.

The class environment utilizing Chromebooks continuously also contributed to naturally mitigating the gap in digital device utilization among students.

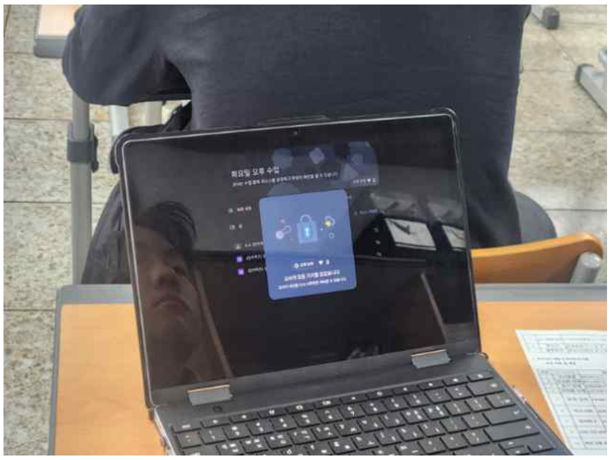
In the wrap-up stage of the class, short video and audio materials centered on keywords created using Generative AI were provided. These overview activities concisely summarized the learning content and repeatedly reminded the students of it, serving as an effective supplementary learning material to aid conceptual understanding.

4) Changes in Students and Teachers

By appropriately utilizing Generative AI during class time, students were able to directly experience AI, and they were observed asking questions and showing interest in it. This expanded beyond a simple technological experience into a natural discussion about AI and social changes, influencing career awareness for some students.

From the teacher's perspective, the burden of creating and managing class materials was reduced, and the efficiency of class operation improved through the utilization of Chromebooks, Google tools, and Generative AI. However, restrictions on app installation on teachers' Chromebooks, difficulties in managing student accounts, and the lack of user manuals were recognized as tasks requiring future improvement.

5) Class Activity Scenes



4) Case study of class operation at Bokja Girls' High School

Author	Ain Seo	Affiliation	Bokja Girls' High School

1. Background and Necessity of the Class

- The Teacher

1) Designs and supports a Google tool and AI-based EdTech environment so students can experience a self-directed inquiry process.
2) Manages the entire learning activity process with digital collaboration tools, monitoring the inquiry progress and providing appropriate feedback.
3) Helps students systematically record, analyze, and present the outputs generated during the inquiry process, thereby reinforcing the fairness and educational significance of evaluations.
4) Acts not merely as a knowledge transmitter but as a learning facilitator and coach, cultivating students' creative thinking and collaborative problem-solving skills.

- The Students

1) Actively utilize Google-based collaboration tools such as Google Classroom, Docs, Sheets, and Slides to conduct creative topic inquiry projects with group members.
2) Develop creative ideation and convergent expression skills through brainstorming, image creation, and report writing activities utilizing AI tools like Gemini and Whisk.
3) Develop the ability to collect, analyze, and interpret data through Google Forms surveys and Sheets data analysis, supporting the inquiry results quantitatively and qualitatively.
4) Visualize and document the inquiry content using Google Docs and Slides, and expand communication competencies through presentation activities.
5) Practice collaboration, critical thinking, and self-reflection throughout the entire class process, cultivating future core competencies including digital literacy.

2. Basic Overview

School Level	High School	Grade	1	Subject	Creative Experiential Activities (Autonomous Activities)
Unit	Autonomous Activities (Creative Topic Inquiry)				
Lesson Topic	Creative topic inquiry project using Google tools and AI				
Achievement	Cultivate self-directedness and collaboration skills through inquiry				

Standards	activities utilizing EdTech tools, and foster a sense of community by sharing the results.
Learning Objectives	Collaboratively conduct inquiries by setting group inquiry topics and dividing roles using collaboration tools such as Google Classroom, Sheets, and Docs. Experience the process of brainstorming, data collection and analysis, visualization, and report writing utilizing EdTech tools. Verify the inquiry hypothesis and propose problem-solving measures based on the collected data and analysis results, and organize the results for logical presentation. Visualize the inquiry process and results, and communicate effectively through presentation and feedback activities.
Google EdTech Tool Utilization Plan	1. Utilized Tools (All checked) ① Calendar ② Chromebook ③ Gemini ④ Gmail ⑤ Google Classroom ⑥ Google Documents ⑦ Google Drive ⑧ Google Forms ⑨ Google Maps ⑩ Google Search ⑪ Google Sheets ⑫ Google Slides ⑬ Practice Sets ⑭ Read Along ⑮ YouTube Interactive Questions ⑯ Notebook LM
	2. Specific Utilization Methods 1) Material Provision and Collaborative Activities: (Teacher) Providing inquiry-related materials using Google Classroom (Students) Collaborating on report creation using Google Docs 2) Feedback, etc.: (Teacher) Submission and feedback using Google Classroom assignment features (Students) Peer evaluation and feedback using Google Docs comment features
Chromebook and Digital Device Utilization	1. Device Utilization Method in Student Activities: Exploring information and creating outputs utilizing Chromebooks. 2. Device Usage Plan for Individual vs. Collaborative Learning: Each student will utilize a 1-to-1 Chromebook to individually explore data and conduct collaborative activities for sharing and creation in the online space. 3. Precautions (Network, Accounts, Accessibility, etc.): A 1-to-1 Chromebook setup is prepared for each classroom, and the

	school's wireless internet is smooth, posing no issues for use.
Basic Environment and Materials	1-to-1 Chromebook per student, wireless internet environment, interactive whiteboard, Google Account (School G-Suite Account).
Evaluation Methods and Elements	• Process Evaluation: Collaborative process utilizing Google tools, data collection and analysis process, reflection of feedback. • Result Evaluation: Creativity, completeness, and logicality of the outputs per group (reports, presentation materials). • Self/Peer Evaluation: Reflection of self-reflection reports and peer feedback results. • Evaluation Elements: Participation, collaboration and communication, inquiry process, output completeness, reflection and growth.

3. Lesson Plan by Session

Session	Teaching and Learning Content by Session	Utilized Tools and Devices	Grade	Subject	Class Execution Date
1	Guide to Creative Topic Inquiry and sharing of expected effects	Google Slides Google classroom	1	Creative Experiential Activities	9/25
2	Group formation and guide to the criteria for selecting inquiry topics	Google classroom Google Sheets	1	Creative Experiential Activities	10/20
3	Brainstorming and topic materialization utilizing Gemini	Gemini Chromebook	1	Creative Experiential Activities	10/24
4	Creating images and mind maps (Topic visualization)	Gemini Whisk Chromebook	1	Creative Experiential Activities	10/27
5	Writing and presenting a research plan	Gemini Chromebook	1	Creative Experiential Activities	10/31
6	Designing and conducting surveys, and collecting data	Google Forms	1	Creative Experiential Activities	11/3
7	Creating research outputs	Gemini	1	Creative	11/6

	utilizing Gemini Canvas	Chromebook		Experiential Activities	
8	Interim check and cross-feedback activities	Google Documents Chromebook	1	Creative Experiential Activities	11/20
9	Drafting the report and reflecting feedback → Completing the final report	Google Documents Chromebook	1	Creative Experiential Activities	11/27
10	Output presentation, sharing, and self/peer reflection activities	Google classroom Google Documents Chromebook	1	Creative Experiential Activities	12/4

4. Expected Effects and Reflection

1) Expected Class Effects

- Enhance self-directed inquiry competencies and digital literacy while utilizing Google EdTech and AI-based tools.
- Develop collaborative problem-solving skills, communication skills, and critical thinking through group activities.
- Develop convergent thinking and creative expression skills through the experience of brainstorming, data analysis, and report writing during the inquiry process.
- Efficiently operate the class by digitally managing and providing feedback on the entire process.

2) Anticipated Difficulties and Countermeasures

- Inexperience in using digital tools: Some students may face difficulties utilizing Google tools or AI → Provide preliminary orientations and simple tutorials.
- Role Imbalances: Possible low participation of some students in group activities → Check individual contributions via Google Docs and Classroom records, and reflect peer evaluations.
- Over-reliance on AI tools: A tendency to use outputs from Gemini, etc.

as they are → Instruct on verifying sources and the critical analysis process.

3) Post-Class Reflection Plan

- Student Feedback Collection: Survey class satisfaction, difficulties, and areas for improvement via Google Forms, and reflect them in class enhancements.
- Output Analysis: Review the completeness of reports and presentation materials to identify additional competencies students need (data analysis, visualization, presentation skills, etc.).
- Teacher Reflection: Check the frequency and effectiveness of tool utilization, and streamline unnecessary or redundant activities to optimize the lesson flow.

5. Open Class Monitoring Results

1) Google Tool Application Methods by Lesson Flow

Category	Utilized Tool	Application Method
Class Operation Foundation	Chromebook	Regular utilization as a personal device in all class activities
Class Management and Communication	Google Classroom	Operating class announcements, assignment presentation/submission, and Q&A
Collaborative Learning	Google Docs	Team-based joint report writing and real-time collaboration
Data Organization and Analysis	Google Sheets	Accumulatively recording semester activity results to build a portfolio
Result Sharing	Google Slides	Visualizing team inquiry results and creating presentation materials
Inquiry Process Support	Gemini	Topic materialization, brainstorming, question generation
AI Utilization Competency Guidance	Gemini	Instructing on AI usage, questioning methods, and source citation at the beginning of the semester
Learning Process Feedback	Google Collaboration Tools in General	Teacher checking the student's work process in real-time
School-Level Support	Google Training Programs	Operating regular training for teachers within the school

2) Application Methods of Google Tools and Generative AI in Class

In this class, Chromebooks and Google tools were utilized not merely as devices, but as a learning environment supporting the overall class operation. Through Google Classroom, class announcements, assignment presentation and submission, and Q&A were systematically operated. Collaboration tools such as Google Docs, Sheets, and Slides were used to allow students to carry out inquiry tasks in teams and collaboratively create outputs.

Furthermore, Generative AI (Gemini) was utilized to support the expansion of thinking, such as materializing inquiry topics, brainstorming, and generating questions. At the beginning of the semester, instructions on source citation, quotation methods, and the proper use of Generative AI laid the foundation for students to utilize AI tools ethically and critically. The teacher continuously participated in school-level Google tool training to strengthen digital and AI utilization competencies.

3) Actual Utilization and Effects in Class

During class time, a collaboration-centric class was held where students utilized Chromebooks to explore data, shared opinions in real-time through Google collaboration tools, and completed their outputs. Google Classroom functioned as a core means to efficiently manage out-of-class announcements and assignment submissions under a joint curriculum operation situation.

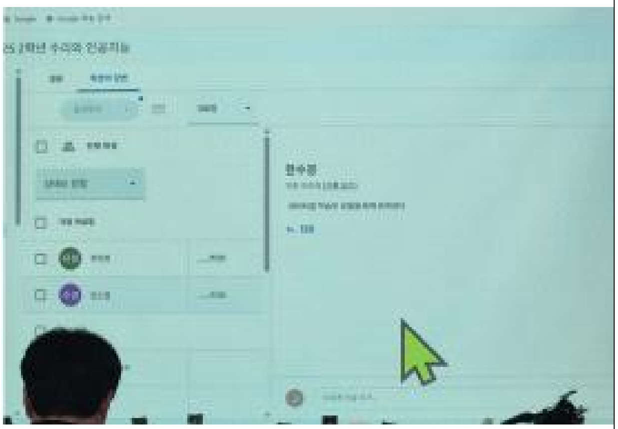
During the brainstorming and Q&A process utilizing Generative AI, students were seen resolving their curiosities and deepening their learning independently. By utilizing tools like Google Sheets, the teacher could accumulatively manage the students' learning process and results, and provide immediate feedback by checking the students' work processes in real-time. This class operation method led to increased student participation and improved the completeness of inquiry activities and learning concentration.

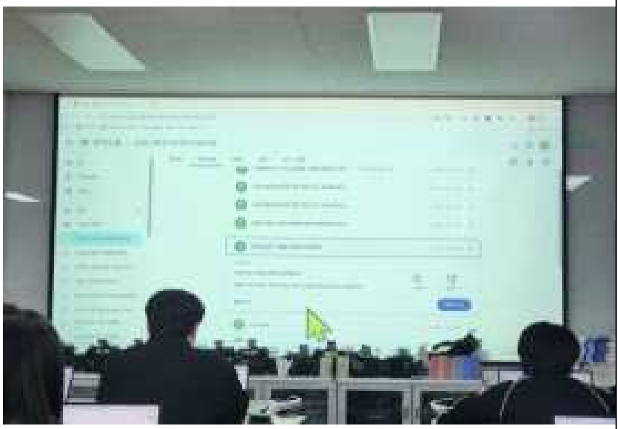
4) Changes in Students and Teachers

Students came to actively participate in collaborative and inquiry activities by freely utilizing Google tools, and their self-directed learning attitude—asking questions and solving problems independently using Generative AI—was reinforced. Additionally, communication and expressive skills were improved concurrently through report writing and presentation activities, and satisfaction with digital-based classes also increased.

From the teacher's perspective, the efficiency of creating class materials and managing learning increased through the utilization of Google tools and Generative AI. An environment was fostered where the teacher could grasp the students' learning processes in real-time and provide individual feedback. Furthermore, during the process of applying Generative AI to the class, awareness of class innovation expanded, and a culture of sharing class cases with fellow teachers was strengthened through school-level training.

5) Class Activity Scenes





Ⅳ. Research Results

1 Pre- and Post-Comparative Analysis Results on Teachers' AI and Digital Teaching Competencies

1) Analysis Methods and Respondent Characteristics

Table 4-1. Status of teacher research participation

School level	Male (persons)	Female (persons)	Subtotal(persons)
Elementary school	8	6	**14**
Middle school	2	2	**4**
High school	5	3	**8**
Total sum	**15**	**11**	**26**

Analysis Methods and Respondent Characteristics

This analysis was conducted using pre- and post-survey data collected from the same participants before and after the implementation of the project. The survey respondents consisted of elementary, middle, and high school teachers who participated in this project, and the response data of a total of 26 teachers were utilized for the analysis. By school level, 14 elementary school teachers, 4 middle school teachers, and 8 high school teachers participated, ensuring that the comparative analysis was not biased toward any specific school level.

The gender distribution was relatively balanced, comprising 15 male teachers and 11 female teachers. This balance contributes to mitigating the possibility that gender-based differences in perception might disproportionately affect the analysis results. All response data utilized in this study selectively included only those from the same respondents who participated in both the pre- and post-surveys. By doing so, the study verified the effectiveness by focusing on intra-individual changes rather than inter-individual differences.

To analyze the changes in perception before and after the project, a paired samples t-test was applied, and the pre- and post-means and standard deviations (SD) were calculated for each item and analysis domain. Based on this, the t-value and significance level (p-value) for the mean differences were calculated to verify the statistical significance of the changes before and after the project implementation. All statistical analyses were based on the pre- and post-response data for the same items, and consistent analytical standards were applied to ensure the reliability and validity of the analysis results. These basic demographics and analysis methods serve as foundational data for interpreting the subsequent perception change analysis results, providing an analytical framework to objectively verify the effectiveness of the project.

2) Current Status of Teachers' AI Tool Utilization (Pre-survey)

Table 4-2. Current Status of Teacher AI Tool Utilization

Division	Equipment	Frequency (%)
1	Content creation and recommendation tools	17(32.1%)
2	Personalized learning platform	12(22.6%)
3	Automatic grading tool	1018.9%)
4	AI-based chatbots or tutors	10(18.9%)
5	Other and unused	4(7.5%)

This analysis was conducted focusing on the pre-survey responses to identify the actual status of teachers' AI tool utilization in the classroom prior to the project implementation. As a result of analyzing the response data of a total of 29 participants (including multiple responses), 17 teachers responded that they utilize "content generation or recommendation tools," accounting for 32.1% of the total and representing the highest proportion. This indicates that many teachers are actively utilizing the generative capabilities of AI during the lesson material creation and curriculum design stages.

Furthermore, "personalized learning platforms" followed with 12 teachers (22.6%), and "automated grading tools" and "AI-based chatbots or tutors" followed with 10 teachers (18.9%) each. This suggests that teachers are attempting to integrate AI into various educational areas, such as individual student learning support and the streamlining of evaluation tasks, rather than limiting its use to simple material creation. Conversely, only 2 teachers (3.8%) responded that they do not use AI tools at all, confirming that the majority of teachers have already entered a practical stage of AI utilization.

In summary, over 90% of the total responses indicated that various forms of AI tools are being utilized in actual lessons and administrative tasks. This translates to an average of 1.8 tools being used in combination per teacher, demonstrating that the foundational technical competencies for adopting EdTech have been sufficiently established. In particular, this pre-utilization status is expected to serve as a crucial foundation that can evolve beyond the simple application of technology into the qualitative advancement of adaptive learning and the establishment of a sophisticated, data-driven feedback system as the project progresses.

3) Frequency and Ratio Analysis on Changes in Attitudes Toward Technology Use in the Classroom

Table 4-3. Perception of Technology and AI Utilization

Division	Response content	Frequency (%)
1	I used to think technology was harmful, but now I see its benefits.	1 (3.8%)
2	I've come to think that technology is useful, but I still find it difficult to use.	2 (7.7%)
3	I've come to understand the benefits of technology and I'm trying to use it as much as possible.	23 (88.5%)

This analysis focused on the post-survey responses to ascertain the changes in teachers' attitudes toward technology use in the classroom after the project implementation. Analyzing the response data of 26 teachers, 23 teachers, accounting for 88.5% of the total, responded, "I have realized the benefits of technology and am trying to use it as much as possible." This signifies that the vast majority of teachers have formed a proactive and practice-oriented attitude toward the utilization of technology.

Additionally, 2 teachers (7.7%) responded, "I have come to think that technology is beneficial, but there are still difficulties in using it," suggesting that while awareness of the educational usefulness of technology has been established, there are still some constraints regarding execution capabilities or environmental factors at the actual stage of classroom application. One teacher (3.8%) responded, "I used to think technology was harmful, but now I know its benefits," confirming a case where a negative perception of technology transitioned to a positive one.

In summary, 96.2% of the total respondents acknowledged the usefulness and positive value of technology, indicating that the project's operation had a practical impact on improving teachers' attitudes toward technology use. Notably, as a result of analyzing the pre- and post-changes of the same participants through a paired samples t-test, the average score for attitudes toward technology use showed a statistically significant improvement ($p < .05$). This implies that beyond a simple change in perception, the experience of participating in the project led to the reinforcement of teachers' technology acceptance and willingness to implement it, further demonstrating its contribution to enhancing Teacher Self-efficacy.

4) Device Suitability in the Class Environment

Table 4-4. Changes in suitability by device used in teacher classes

Rank	Device	Pre-suitability (persons)	Post-suitability (persons)
1	Laptop	12	3
2	Tablet	5	-
3	Chromebook	9	23
Total		26	26

The results of analyzing the changes in suitability by device are as shown in the table below. In the case of laptops, the suitability before the program was 12 persons, but it appeared as 3 persons after the implementation, showing a decrease of 9 persons compared to the pre-survey. This suggests that its suitability or utilization in the actual operation process was evaluated lower compared to initial expectations. On the other hand, Chromebooks recorded a large increase of 14 persons, from 9 persons in pre-suitability to 23 persons in post-suitability. This means that the educational content or learning environment provided by this program has high coherence with the functional characteristics of Chromebooks, showing that Chromebooks are perceived most highly in terms of suitability from both the learners' and operators' perspectives.

5) Frequency of Technology and AI Use in Class

Tabl 4-5. Changes in Teachers' Digital Device Usage Time

Division	Dictionary (SD)	Postmortem (SD)	t	p
Device usage time per week	3.53(0.33)	4.73(.29)	-3.632	0.001***

As a result of the analysis, the weekly digital device usage time increased by approximately 1.20 hours from an average of 3.53 hours (SD=0.33) before the project operation to an average of 4.73 hours (SD=0.29) after the operation, and this change was confirmed at a statistically significant level (t=-3.632, p=0.001). This means that teachers' digital device utilization time practically expanded through this project, demonstrating that it led to behavioral changes in the actual classroom beyond mere awareness improvement.

In particular, the decrease in the post-standard deviation to 0.29 suggests that digital device utilization is not limited to a few active teachers but has settled into a more stable and routine class activity across all participating teachers. In other words, while there were certain individual differences in the level of utilization prior to the project, it can be interpreted that digital device utilization spread more evenly after the program operation.

These results signify that beyond a simple increase in usage time, teachers have come to recognize digital tools as a core element in the class design and operation process. Notably, the systematic support and field-centric execution process mitigated the teachers' psychological burden and contributed to transitioning digital devices from supplementary tools into essential components of the class. In summary, the significant increase in digital device utilization time can be considered a key performance indicator showing that this project led not only to a change in teachers' awareness of digital competencies but also to behavioral changes in actual educational activities, and it is evaluated as an important basis supporting the practical effect of spreading a digital-based class culture.

6) Changes in Utilization Proficiency (Self-Efficacy) by Google Tool

Table 4-6. Changes in Teachers' Proficiency in Using Google Tools

Tool Name	Pre	Post	Change	t	p
Chromebook	3.26	4.23	0.97	-4.721	0.000***
Classroom	3.30	4.38	1.08	-4.865	0.000***
Gemini	3.57	4.38	0.81	-4.600	0.000***
Docs	2.88	3.88	1	-4.655	0.000***
Drive	3.5	4.42	0.92	-4.460	0.000***
Sheets	3.61	4.15	0.54	-2.573	0.000***
Slides	2.92	4.19	1.27	-5.997	0.000***
Gmail	3.3	4.11	0.81	-4.035	0.016*
Practice Sets	2.07	3.42	1.35	-5.729	0.000***
YouTube Interactive Questions	2.4	3.07	0.67	-2.327	0.28
Maps	3.34	3.84	0.5	-2.687	0.013**
Read Along	2.15	2.88	0.73	-2.774	0.010*
Forms	3.61	4.3	0.69	-3.803	0.001**
Search	3.46	4.07	0.61	-3.682	0.001**
Calendar	2.84	3.61	0.77	-3.077	0.005**
Overall	**3.08**	**3.93**	**0.85**	**-4.00**	0.02*

*p < .05, **p < .01, ***p < .001

As a result of the analysis, teachers' utilization proficiency by Google tool was found to have significantly improved overall. The overall average increased by 0.85 points from 3.08 in the pre-survey to 3.93 in the post-survey, and this change was confirmed at a statistically significant level (t=-4.00, p=0.002). This means that teachers' digital tool utilization competencies were strengthened overall through the project operation. Specifically, a statistically significant improvement was observed in most tools (p<.05), including Chromebook, Classroom, Gemini, Docs, Drive, Sheets, Slides, Gmail, Practice Sets, Maps, Read Along, Forms, Search, and Calendar. In particular, Slides (1.27 point increase) and Practice Sets (1.35 point increase) showed large improvement margins, which is interpreted as a marked reinforcement in competencies for creating class materials and utilizing formative assessment and feedback features. This demonstrates that teachers are actively integrating digital tools into the lesson design and evaluation process, beyond mere functional use.

On the other hand, the YouTube Interactive Questions feature increased by 0.67 points from an average of 2.40 to 3.07, but it did not show a statistically significant difference (p=0.28). This suggests the possibility that the utilization context of this feature is more limited compared to other tools, or that there were relatively few actual class application cases. Furthermore, video-based interactive classes may or may not be utilized depending on the subject characteristics or class structure, which is interpreted as making it difficult to show a large change in proficiency within a short period.

Therefore, these results show that proficiency improvements were clearly confirmed in most Google tools, while also suggesting that for certain tools, it is necessary to expand application cases and provide in-depth training. In summary, this project contributed to strengthening teachers' digital class execution competencies overall, and it is judged that a more balanced digital class culture can take root if tailored support for specific functions is provided in the future.

7) Student Class Participation and Interest

Table 4-7. Changes in teacher participation and interest in class

Item	Pre	Post	t	p
Class Participation	4(0.93)	3.73(0.83)	1.318	0.199
Class Interest	4.73(0.45)	4.46(0.70)	2.059	0.05

As a result of the pre- and post-analysis on the changes in teachers' class participation and class interest, no statistically significant changes were observed in either variable. First, class participation decreased slightly from a pre-average of 4.00 (SD=0.93) to a post-average of 3.73 (SD=0.83), but no statistically significant difference was confirmed (t=1.318, p=0.199). Rather than interpreting this as the project's operation having a negative impact on class participation, it suggests the possibility that the room for additional increase was limited because the pre-average was already at a high level.

Meanwhile, class interest slightly decreased from a pre-average of 4.73 (SD=0.45) to a post-average of 4.46 (SD=0.70), and statistically, it was situated on the borderline of the significance level (p=0.05, t=2.059). This shows that a certain level of fluctuation exists, but overall, the average value is maintained at a high level of 4 points or more, confirming that the positive perception of the class itself is being sustained.

In summary, although this project did not lead to a rapid improvement in class participation and interest, it can be interpreted as having contributed to stably maintaining the existing high levels of class satisfaction and immersion. In particular, considering that teachers' digital tool utilization competencies have greatly improved, if the advancement of lesson design and tailored applications are carried out concurrently in the future, the effects of enhancing learner participation and interest may appear more clearly.

8) Changes in Difficulties Experienced When Using Technology/AI

Table 4-8. Changes in Teacher Difficulties When Using Technology/AI

Difficulty Type	Pre (persons)	Post (persons)	Change Pattern
Lack of knowledge (Do not know how to use)	36	19	▽ Large decrease
No difficulty	2	15	▲ Large increase
Access permission/ authorization issues	37	6	▽ Large decrease
Personal information concerns	25	7	▽ Large decrease
Lack of help	16	15	▽ Slight decrease

As a result of analyzing the changes in difficulties experienced by teachers during the technology and AI utilization process, the pre- and post-comparison showed that the overall perception of difficulties was clearly mitigated. In particular, 'Lack of knowledge (Do not know how to use)' decreased significantly from 36 persons in the pre-survey to 19 persons in the post-survey, confirming that basic understanding and practical competencies regarding digital tool and AI utilization practically improved through the project operation. This suggests that beyond simple information provision, coaching and repetitive practice centered on actual class application contributed to increasing teachers' technological acceptance.

Furthermore, 'Access permission/authorization issues' showed the largest decrease margin, dropping sharply from 37 persons to 6 persons. This shows that preliminary guidance and environmental checks on account creation, permission settings, and platform access methods were effectively carried out. In the beginning, administrative and technical constraints acted as major barriers, but as these problems were largely resolved after the project operation, it is interpreted that the possibility of actual class application expanded.

'Personal information concerns' also decreased significantly from 25 persons to 7 persons, showing that psychological anxiety regarding AI and digital tool utilization was mitigated. This can be seen as a result of guidance on security and personal information protection, and the provision of utilization standards having a positive impact on building teachers' trust. The 'Lack of help' item only decreased slightly from 16 to 15 persons, suggesting that there is still a demand among some teachers for an immediate and continuous on-site support system.

Meanwhile, the 'No difficulty' response increased significantly from 2 persons in the pre-survey to 15 persons in the post-survey, showing that technology and AI utilization transitioned from being a challenge for specific teachers to an acceptable level for the majority of teachers. This means that the psychological barrier to digital tool utilization has been lowered, and it is settling in as a part of everyday class activities.

In summary, this project practically contributed to alleviating overall knowledge, institutional, and psychological barriers regarding technology and AI utilization, and it is evaluated to have fostered an environment where teachers can execute digital-based classes more stably. In the future, if a continuous support system and infrastructure improvements are implemented in parallel, it is expected that the settlement and spread of the digital class culture will be further accelerated.

9) Additional Support and Resources Needed for Training

Table 4-9. Additional Support and Resources Required for Training

No.	Item	Frequency
1	Dedicated time to experiment with AI tools	1
2	AI-related training or in-service training workshops	6
3	Technical support for solving AI problems	4
4	Online communities where teachers can share experiences	1
5	Opportunities to collaborate with teachers utilizing AI	6
6	Support for integrating AI-related content into the existing curriculum	7
7	Opportunities to receive continuous feedback	1

As a result of the analysis, the support most requested by teachers was 'Support for integrating AI-related content into the existing curriculum' (7 persons). This shows that beyond simple tool usage, there is a need for specific guides and systematic design support to organically link AI with the formal curriculum.

Next, 'AI-related training or in-service training workshops' (6 persons) and 'Opportunities to collaborate with teachers utilizing AI' (6 persons) showed equally high responses. This means that teachers recognize the importance of systematic training for professional development and a peer-based cooperation system, moving beyond individual utilization. In addition, 'Technical support for solving AI problems' (4 persons) also showed a relatively high frequency, confirming the necessity of establishing a support system that can swiftly resolve technical issues occurring in the actual classroom field.

On the other hand, securing dedicated experimental time (1 person), building online communities (1 person), and providing opportunities for continuous feedback (1 person) showed relatively lower responses. However, this is merely a difference in priority and still needs to be considered as complementary support elements.

10) Changes in Teachers' Working Hours for Class Preparation and Operation

Table 4-10. Analysis of teacher working hours for class preparation and class operation (hours per week)

Category	Pre M(SD)	Post M(SD)	Pre Total Hours	Post Total Hours	Change
Time spent on personal planning and class preparation activities	6.42(2.88)	6.53(3.35)	167	170	+3
Time spent on marking/correcting student assignments	3.80(3.24)	3.3(2.62)	99	86	-13
Time spent on administrative tasks (communication, paperwork)	5.76(4.38)	6.23(7.43)	150	162	+12
Time spent on teamwork and conversation with colleagues	2.96(1.99)	2.73(2.73)	77	71	-6
Time spent on student counseling	3.23(1.8)	4.88(10.01)	84	127	+43
Time spent on extracurricular activities (clubs, etc.)	2.23(1.3)	2.26(1.34)	58	59	+1
Time spent on communication and collaboration with parents/guardians	1.23(0.5)	1.8(2.77)	32	47	+15
Time spent on participation in school operations	2.53(1.73)	1.8(1.77)	66	47	-19
Time spent on others (class time management, mentoring, professional development)	3.73(3.4)	1.3(1.02)	97	34	-63

As a result of analyzing the changes in weekly working hours related to teachers' class preparation and operation, it is analyzed that a structural relocation of tasks occurred, showing increases in some areas and decreases in others. First, the time for 'personal planning and class preparation activities' increased slightly from a pre-average of 6.42 hours to a post-average of 6.53 hours, and the 'total weekly class hours' also slightly increased from 18.73 hours to 18.96 hours. This suggests the possibility that the lesson design process utilizing digital tools and AI initially required a certain level of additional preparation time.

On the other hand, 'Time spent on marking/correcting student assignments' decreased from 3.80 hours to 3.30 hours, showing the possibility that auto-grading, online feedback, and the use of collaborative documents utilizing digital tools improved work efficiency. 'Time spent on teamwork and conversation with colleagues' also slightly decreased from 2.96 hours to 2.73 hours. An interesting point is that the time spent on 'administrative tasks (communication, paperwork) / tutoring/academy record paperwork' increased from 5.76 hours to 6.23 hours, and the 'Time spent on student counseling' also increased relatively significantly from 3.23 hours to 4.88 hours. This suggests the possibility that as digital-based class operations stabilized, more time was invested in administrative and counseling support activities. In particular, the increase in student counseling time can be interpreted as a result reflecting the expansion of individualized classes and learning data-based feedback activities.

'Time spent on extracurricular activities (clubs, etc.)' was maintained without much change, and 'Time spent on communication and collaboration with parents/guardians' increased from 1.23 hours to 1.80 hours, showing the possibility that the spread of a digital-based communication environment contributed to expanding interactions with parents. Conversely, 'Time spent on participation in school operations' decreased from 2.53 hours to 1.80 hours, and 'Time spent on others (class time management, mentoring, professional development, etc.)' also decreased significantly from 3.73 hours to 1.31 hours. This means that the priorities of tasks were reorganized toward more class- and student-centric activities.

Rather than unilaterally increasing the total working hours of teachers, it appears to have acted in the direction of changing the structure of tasks and the method of time allocation. In particular, the decrease in assignment feedback time and the increase in counseling and parent communication time suggest that the utilization of digital tools streamlined repetitive administrative tasks, bringing about the effect of converting that time into student-tailored support activities. This is a result that holds significant meaning in terms of a qualitative restructuring of tasks, rather than a simple reduction in workload.

11) Strengthening Self-Directed Learning Competencies

Table 4-11. Impact on Strengthening Self-Directed Learning Capacity

Category	Post M(SD)
Adaptive learning support	4.03(0.73)
Class immersion	4.5(0.76)
Collaboration frequency	4.57(0.75)
Self-directed learning	4.5(0.7)
Personalized learning	4.38(0.75)
Feedback system	4.5(0.7)
Academic achievement	4.23(0.76)
Creative competencies	4.65(0.63)
Expressing ideas	4.5(0.7)
Task completeness	4.61(0.57)
Concept understanding	4.3(0.73)
Learning ownership	4.57(0.7)
Tool suitability (Student)	4.69(0.54)

As a result of analyzing the teachers' perception levels prior to the study, high average values of 4 points or more were shown overall, confirming that a positive perception of digital-based classes and student-centered learning had already been formed. First, in terms of student learning, most items appeared to be 4 points or higher, such as 'Receiving more help through adaptive learning' (M=4.03), 'Increased interest and immersion through class participation' (M=4.50), 'Increased frequency of collaboration among students' (M=4.57), and 'Improvement in self-directed learning participation' (M=4.50). In particular, 'Showing higher completeness in subject classes' (M=4.61) and 'It was a tool that fit students very well' (M=4.69) showed relatively high averages, suggesting that teachers recognized the effectiveness of digital tool-utilized classes quite positively.

In terms of learning outcomes and competencies, positive perceptions were also high overall, such as 'Improvement in academic achievement' (M=4.23), 'Increase in creative and imaginative task performance' (M=4.65), 'Expressing their thoughts better' (M=4.50), and 'High ownership in the learning process' (M=4.57). This is interpreted as a result reflecting the expectation of enhancing students' higher-order thinking skills and expressiveness, beyond simple tool utilization.

12) Class Operation and Administrative Efficiency

Table 4-12. Impact on Class Operation Administrative Efficiency

Category	Post M(SD)
Improvement in lesson planning and content creation ability	4.5(0.65)
Adjusting the learning environment to fit learning needs	4.54(0.65)
Grasping student levels	4.38(0.69)
Securing time for individual student feedback	442(0.94)
Streamlining administrative tasks	4.46(0.7)
Data insights	4.42(0.7)
Lesson delivery efficiency	4.65(0.48)
External communication/collaboration	4.15(0.88)
Tool suitability (Teacher)	4.42(0.85)

In terms of class operation and administrative efficiency, high averages were shown, such as 'Streamlining assignment management and administrative workflows' (M=4.46), 'Securing student data-based insights' (M=4.42), and 'Improving classroom operation efficiency' (M=4.65). In addition, 'Strengthening communication and collaboration with fellow teachers and guardians' (M=4.15) also maintained a relatively high level, showing that digital tools have a positive effect on fostering a collaborative environment both inside and outside the classroom. However, 'Adjusting lesson content to fit students' comprehension levels' (M=4.38) and 'Securing time for individual student feedback' (M=4.42) were relatively lower compared to other items, but they were still 4 points or higher, judging the overall perception to be at a positive level.

From the pre-study stage, teachers already had high expectations and positive perceptions of the educational value and operational efficiency of digital and AI-based classes, and this can be said to be a baseline level that entails the possibility that the extent of change will appear limited in subsequent post-comparative analyses. In other words, this study can be interpreted as a process of linking already formed positive perceptions to actual execution competencies and structural changes, rather than an improvement from a low starting point.

13) Intention to Recommend Google Workspace and Chromebook

Table 4-13. Changes in Teacher Class Participation and Interest

Item	Average(SD)
Degree of recommendation for Google Workspace for Education	4.73(0.53)
Recommendation for Chromebook	4.57(0.64)

The recommendation level for Google Workspace for Education averaged 4.73 (SD=0.53), and the recommendation level for Chromebooks averaged 4.57 (SD=0.64), showing very high levels of recommendation intention for both items. This means that teachers are building a generally high level of satisfaction and trust in the digital-based class environment.

Reasons for Recommending Google Workspace and Requests for Improvement

As a result of analyzing the descriptive responses, the main reasons for recommending Google Workspace were ▲improvement in the efficiency of classes and evaluations ▲ability to perform integrated work within the Google ecosystem ▲convenience of auto-saving and data storage ▲excellence of collaboration features ▲enhancement of student participation and immersion, etc. In particular, the fact that various tools such as Classroom, Docs, and Drive are organically linked, allowing lesson design, assignment management, and feedback provision all within one platform, was recognized as the greatest strength.

In addition, multiple responses were confirmed stating, "Time saving is possible while maintaining the quality of class and work," and "It is optimized for collaboration between students and teachers, and among teachers," showing that it is perceived as a system supporting the overall class operation structure beyond the dimension of simple tools.

On the other hand, requests for improvement included ▲errors when switching accounts ▲omission issues when distributing assignments ▲ limitations on link sharing and side panel features ▲improvement of screen layout readability ▲configuration of consent forms and surveys tailored to students' eye levels ▲improvement in function response speed. This suggests that while overall satisfaction is high, there is a demand for the stability of detailed functions and user experience (UX) improvements during the actual field application process.

Reasons for Recommending Chromebooks and Requests for Improvement

Major reasons for recommending Chromebooks included ▲fast boot and login speeds ▲auto-saving and cloud-based linkage ▲lightweight and long battery life ▲cost-effectiveness ▲ease of class management ▲security and control functions ▲structure suitable for collaboration and group activities.

Particularly, comments such as "Improvement in students' concentration," "Ease of class management," "Optimization with Google tools," and "Ability to maintain the same environment on any device based on accounts" demonstrate that Chromebooks are recognized as devices optimized for digital-based classes.

However, improvement requests included ▲expanding compatibility with Windows programs ▲restrictions on using KakaoTalk and some general programs ▲advancement of class tool functions (full-screen monitoring, student control features) ▲Wi-Fi speed stability ▲reinforcement of app expandability ▲reduction of device unit prices ▲hardware improvements (pen nibs, charger durability, etc.) ▲whether class management tools can be used with the school's own accounts. This is interpreted as a field demand indicating that while it is optimized for the educational environment, compatibility with general work environments and supplementary detailed control functions are needed.

14) Perception of Google AI Tools

Table 4-14. Changes in Teacher Perceptions of Gemini and NotebookLM Utilization

No.	Item (Google AI tools are ~)	Pre M(SD)	Post M(SD)	t	p
1	Effective in terms of teaching and learning	3.68(1.02)	4.6(0.57)	-4.433	0.000***
2	Improving students' class participation and motivation	3.76(0.87)	4.8(0.4)	-5.316	0.000***
3	Easy to learn how to use	3.56(1.15)	4.4(0.7)	-3.460	0.002**
4	Reducing overall teacher workload	4.08(0.95)	4.68(0.55)	-2.683	0.013*
5	Reducing lesson preparation time	4.04(0.93)	4.68(0.47)	-3.089	0.005**
6	Safe tools to use for learning	2.8(1.16)	3.92(1.07)	-3.501	0.002**
7	Possible to guide/control misuse or abuse	2.92(1.03)	3.64(1.18)	-2.469	0.21

*p < .05, **p < .01, ***p < .001

As a result of analyzing the changes in teachers' perceptions of utilizing Generative AI Gemini and NotebookLM, statistically significant positive changes were confirmed throughout teaching and learning. The post-average scores increased significantly compared to the pre-survey in most items, showing that teachers' perceptions of Generative AI tools improved overall.

Looking specifically, the item 'Effective in terms of teaching and learning' significantly improved from a pre-average of 3.68 points (SD=1.02) to a post-average of 4.60 points (SD=0.57) ($t=-4.433$, $p<.001$). This means that utilizing Gemini and NotebookLM was recognized as a tool that is practically helpful in actual lesson design and operation. In addition, the item 'Effective in improving students' class participation and motivation' significantly increased from a pre-survey of 3.76 points (SD=0.87) to a post-survey of 4.80 points (SD=0.40) ($t=-5.316$, $p<.001$), suggesting that Generative AI plays a positive role in terms of learning immersion and motivation induction.

The item 'It is easy to understand how to use Google AI tools' also significantly improved from a pre-survey of 3.56 points (SD=1.15) to a post-survey of 4.40 points (SD=0.70) (t=-3.460, p=.002), confirming that confidence in tool utilization competencies has increased. Positive changes also appeared concerning the reduction of teacher workload. The item 'Reduces the overall burden of teacher work' rose from 4.08 points (SD=0.95) to 4.68 points (SD=0.55) (t=-2.683, p=.013), and the item 'Reduces lesson preparation time' also significantly increased from 4.04 points (SD=0.93) to 4.68 points (SD=0.47) (t=-3.089, p=.005). This shows that Generative AI is recognized as a practical support tool that mitigates the burden of lesson preparation and administration. In addition, the item 'It is a safe tool to use for learning' showed a significant improvement from 2.80 points (SD=1.16) in the pre-survey to 3.92 points (SD=1.07) in the post-survey (t=-3.501, p=.002). This means that contrary to initial concerns, trust in safety increased after experiencing utilization.

On the other hand, the average for the item 'It is possible to guide and control misuse or abuse in class' rose from 2.92 points (SD=1.03) in the pre-survey to 3.64 points (SD=1.18) in the post-survey, but no statistically significant difference appeared (t=-2.469, requires interpretation against the 0.05 significance level based on p=.021). This suggests that while awareness of control and management competencies showed a tendency to improve, a relatively cautious perception was maintained compared to other items.

Synthetically, the experience of utilizing Generative AI tools (Gemini and NotebookLM) was found to have brought about positive changes in perception in most areas, including teaching and learning effectiveness, improvement of student participation, workload reduction, understanding of usage, and safety awareness. This can be seen as a result showing that Generative AI is establishing itself as an educational tool supporting teachers' class expertise and efficiency, beyond a simple supplementary tool.

2 Survey Analysis Results on Elementary School Students' AI and Digital Utilization Competencies

1) Survey Basic Information and Analysis Methods

Table 4-15. Basic information for elementary school students

Grade	Male (persons)	Female (persons)	Subtotal (persons)
2nd Grade	24	21	45
3rd Grade	1	4	5
4rd Grade	10	13	23
5rd Grade	85	75	160
6rd Grade	79	68	147
Total	**199**	**181**	**380**

This survey was conducted with the entire population of 490 elementary school students who participated in the project, and the data of 380 students who faithfully responded to both the pre- and post-surveys were utilized as the final analysis subjects. Some students were excluded from the analysis due to missing responses, responding at only one point in time (either pre- or post-survey), or incomplete responses. Accordingly, this analysis was performed based on strict sample selection criteria to accurately compare the pre- and post-changes of the same respondents.

The surveyed students consisted of students attending a total of 9 elementary schools, including Nonsan Buchang Elementary School, Seongyeon Elementary School, Sujeong Elementary School, Asan Elementary School, Yeomchi Elementary School, Dongshin Elementary School, Onyang Oncheon Elementary School, Cheonan Yongso Elementary School, and Handeul Mulbit Elementary School. The grades are evenly distributed from the 2nd to the 6th grade. The gender distribution was relatively balanced with 199 male students and 181 female students, enabling an analysis that is not biased toward a specific gender.

In this study, a paired samples t-test was applied to analyze the changes in students' perceptions before and after the project operation. The pre- and post-means and standard deviations were calculated for each item and analysis domain, and the t-value and significance level (p-value) for the mean differences were calculated to verify statistical significance. All statistical analyses were conducted only on the data of students who responded to the same pre- and post-items, focusing on intra-individual changes rather than inter-individual differences.

Such an analysis procedure minimizes the sample bias that can occur because the number of survey respondents is less than the total number of participating students. It serves as a measure to verify the effects of the project operation more reliably, and is utilized as baseline data ensuring the validity of the interpretation of the research results presented hereafter.

2) Changes in Students' Perceptions on the Use of Computers and AI in Schools

Table 4-16. Changes in Elementary School Students' Perceptions of Computer and AI Use in Schools

Category	Pre (persons)	Post (persons)	Change (%p)
Positive	331(87.1%)	328(86.3%)	▽0.8(%p)
Neutral	44(11.6%)	28(7.36%)	▽4.24(%p)
Negative	5(1.3%)	24(6.31%)	▲5.01(%p)

As a result of analyzing the change in perception regarding the use of computers or AI in schools, the 'Positive' response rate decreased slightly by 0.8%p from 87.1% in the pre-survey to 86.3% in the post-survey. This means that the overall positive perception was maintained at a high level, rather than the entire perception structure significantly changing.

On the other hand, 'Negative' responses increased by about 5.01%p from 1.3% in the pre-survey to 6.31% in the post-survey. However, in absolute numbers, it is still below 10% of the total, and it is necessary to consider that this is a very low ratio compared to the positive response rate (over 86%). This can be interpreted as a result of some students becoming aware of the technical and environmental difficulties (e.g., unstable school Wi-Fi, device slowdowns, etc.) they experienced during the actual usage process as their AI and digital tool utilization experience expanded.

In particular, it is possible that expectations for AI and digital tools were reflected somewhat ideally at the time of the pre-survey, while a more realistic evaluation was made based on actual usage experience in the post-survey. It is reasonable to view this change as a result that partially reflects the environmental constraint factors revealed in the actual utilization process, rather than the spread of negative perceptions.

Also, the fact that 'Neutral' responses decreased from 11.6% to 7.36% suggests that students have moved away from a simple reserved attitude to making clearer judgments. In other words, as perceptions materialized through the accumulation of experience, some moved to positive, and some shifted to limited evaluations.

In summary, students' overall perception of using AI and computers in schools still maintains a very high positive level, and the increase in negative responses seen in the post-survey is properly understood as a limited reaction due to technical and environmental factors. It is judged that the positive perception will be further strengthened if a stable network environment and device performance improvements are carried out concurrently in the future.

3) Usage Experience and Perception of Suitability for Devices Used in Class

Table 4-17. Analysis of Elementary School Device Usage Experience and Perception of Suitability

Rank	Device	Pre: Usage Rate (%)	Post: Suitability (Out of 5 points)
1	Chromebook	199(52.4%)	4.28(0.89)
2	Tablet	127(33.4%)	4.03(0.86)
3	Laptop	23(6%)	3.80(.97)
4	Desktop / PC	6(1.8%)	3.53(1.03)
5	Smartphone	11(2.9%)	3.45(1.15)
6	Projector	-	3.43(0.97)

As a result of the pre-survey, the Chromebook usage rate was the highest at 199 persons (52.4%), which is more than half of the total, and it also received the highest suitability evaluation in the post-survey with 4.28 points out of 5. This means that students perceive Chromebooks as the most suitable digital device for classroom learning through their actual class experience, and they are practically verifying its effectiveness as a learning-centric device.

In the case of tablets and laptops, the pre-usage rates were 127 persons (33.4%) and 23 persons (6.1%), respectively, which were relatively limited compared to Chromebooks. However, they recorded relatively high scores of 4.03 and 3.80 points, respectively, in the post-suitability evaluation. This suggests that through this project, students directly experienced various digital devices, forming standards to judge device suitability according to class purposes and utilization contexts, moving beyond mere familiarity.

Conversely, desktop PCs and smartphones showed relatively low levels in both pre-usage rates and post-suitability evaluations. This means that students' perceptions of devices optimized for the classroom environment in terms of mobility, collaboration, and learning management have become clearer.

In summary, this project is evaluated as having induced a shift in perception that allows students not only to reconfirm their preferences for devices they used heavily before, but to critically select and evaluate digital devices that fit the class purpose. This can be said to be a result showing that digital device utilization education operated in the direction of cultivating rational selection competencies according to the learning context, beyond the mere experience of using tools.

4) Changes in Digital Device Utilization Time

Table 4-18. Analysis of Changes in Elementary School Students' Weekly Device Usage Time

Category	Pre (SD)	Post (SD)	t	p
Device usage time per week	2.53(0.71)	2.88(0.63)	-8.277	0.000***

The weekly digital device utilization time in classroom lessons increased from a pre-average of 2.53 hours (SD=0.71) to a post-average of 2.88 hours (SD=0.63), and this change was confirmed at a statistically very significant level ($t=-8.277$, $p<.001$). This means that after the operation of this project, digital device utilization in classroom lessons did not stop at a temporary attempt but stably expanded into the actual class operation process.

In particular, the decrease in the post-standard deviation suggests that digital device utilization is not limited to a few students or specific classes, but has spread throughout the class at a relatively consistent level. This can be interpreted as an indicator showing that digital tool utilization has begun to establish itself as a natural part of the lesson design and execution process, rather than an optional activity.

These results are also in context with the previously confirmed results of increased class participation and interest, and improved perception of digital device suitability. In other words, students did not just use digital devices simply, but recognized them as tools practically helpful for learning and gradually expanded their utilization time.

In summary, the significant increase in digital device utilization time is evaluated as a core achievement demonstrating that this project qualitatively expanded students' digital learning experiences and brought about practical changes to the operation methods of classroom lessons.

5) Changes in Utilization Proficiency (Self-Efficacy) by Google Tool

Table 4-19. Analysis of Changes in Elementary School Students' Proficiency in Using Google Tools

Tool Name	Pre	Post	Change	t	p
Chromebook	3.34	4.1	0.76	-10.525	0.000***
Classroom	3.06	3.94	0.88	-10.508	0.000***
Gemini	2.83	4.02	1.19	-15.312	0.000***
Docs	2.56	3.15	0.59	-8.364	0.000***
Drive	2.46	3.05	0.59	-9.091	0.000***
Sheets	2.43	2.8	0.37	-5.296	0.000***
Slides	2.58	3.47	0.89	-11.268	0.000***
Gmail	2.78	3.11	0.33	-4.614	0.000***
Practice Sets	2.24	2.5	0.26	-3.868	0.000***
YouTube Interactive Questions	2.63	3.07	0.44	-5.182	0.000***
Maps	2.9	3.36	0.46	-5.918	0.000***
Read Along	2.29	2.66	0.37	-4.692	0.000***
Forms	2.60	2.84	0.24	-3.051	0.002***
Search	3.09	4.17	1.08	-13.095	0.000***
Calendar	2.72	2.79	0.07	-0.940	0.348
Overall	**2.70**	**3.27**	**0.57**	**-7.448**	**.023***

*p < .05, **p < .01, ***p < .001

As a result of analyzing the changes in utilization proficiency by Google tool through the elementary school student survey, the post-scores improved statistically significantly compared to the pre-scores in 14 items, excluding Calendar. The overall average score increased by 0.57 points from 2.70 points in the pre-survey to 3.27 points in the post-survey, and this change was confirmed at a statistically significant level (p=.023, p<.05). This means that elementary school students' confidence and proficiency in utilizing Google tools improved overall through this project.

The items showing the greatest improvement were Gemini (1.19 point increase) and Search (1.08 point increase), revealing prominent changes in Generative AI utilization and information search competencies. This suggests that elementary school students have begun to recognize Generative AI and search tools not simply as a means of finding information, but as tools for solving learning tasks and expanding their thinking.

In addition, high improvement margins were confirmed in tools directly linked to class activities such as Slides (0.89 points), Classroom (0.88 points), and Chromebook (0.76 points). This demonstrates that students have come to utilize digital learning tools more actively through actual class experiences like organizing materials, submitting assignments, and presentation activities. In addition, statistically significant improvements appeared in most tools including Docs, Drive, Maps, Read Along, YouTube Interactive Questions, and Forms ($p<.01$ or $p<.001$), which is analyzed to mean that students' utilization competencies for the overall digital learning environment grew evenly.

On the other hand, in the case of Calendar, the difference between pre- and post-scores was not large and was not statistically significant ($p=.348$). This can be interpreted to be because the frequency with which schedule management tools are directly linked to elementary students' class activities is relatively low, or a basic level of utilization had already been established.

In summary, this project showed the effect of supporting elementary school students to grow into the stage where they confidently use Google tools by recognizing them as tools applicable to actual learning, rather than as unfamiliar digital features. In particular, the large improvement margin seen in Generative AI (Gemini) and Search tools is a meaningful result showing that even at the elementary school level, AI-based learning tools can be utilized sufficiently effectively if appropriate guidance and lesson design are provided.

6) Changes in Difficulties Experienced When Using Technology/AI

Table 4-20. Analysis of Changes in Difficulties Elementary School Students Experience Using Technology and AI

Rank	Difficulty Type	Pre (persons)	Post (persons)	Change Pattern
1	No difficulty	358	546	▲ Large increase
2	Lack of knowledge (Do not know how to use)	178	205	▲ Increase
3	Personal information concerns	125	82	▽ Decrease
4	Access permission/ authorization issues	35	69	▲ Slight increase
5	Others	41	0	▽ Decrease
6	Lack of help	23	0	▽ Slight decrease

As a result of analyzing the changes in difficulties perceived by elementary school students during the technology and AI utilization process, it was found that the 'No difficulty' response increased significantly overall. While 358 students responded 'No difficulty' in the pre-survey, it increased substantially to 546 students in the post-survey. This suggests that the psychological barriers regarding technology and AI utilization were largely alleviated after the project.

On the other hand, the item 'Lack of knowledge (Do not know how to use)' increased slightly from 178 persons to 205 persons, and 'Access permission/authorization issues' also increased from 35 persons to 69 persons. These results can be interpreted as a consequence of students, who experienced specific problems in the actual usage process as technology utilization expanded, coming to recognize more realistic difficulties. In other words, it can be viewed as reflecting the aspect of transitioning from simple vague perceptions to responses based on specific usage experiences.

Conversely, 'Personal information concerns' decreased from 125 persons to 82 persons, and the 'Lack of help' and 'Others' items appeared as 0 persons in the post-survey. This shows that personal information protection and safe usage education, along with the teacher's support system during the project process, exerted an effect to a certain extent.

In summary, this project contributed to lowering the overall burden of technology and AI utilization for elementary school students, and it is reasonable to interpret the increase in some difficulty items as a process of perception materialization due to expanded utilization experience. In particular, the massive increase in the 'No difficulty' response is evaluated as a positive indicator showing that digital tool utilization is establishing itself as a natural part of learning activities.

7) Changes in Class Participation and Interest

Table 4-21. Analysis of changes in elementary school students' class participation and interest.

Item	Pre	Post	t	p
Class Participation	4.04	4.11	-1.521	0.129
Class Interest	4.31	4.31	-1099	0.902

Class participation rose slightly from a pre-average of 4.04 points to a post-average of 4.11 points, but the paired samples t-test results showed no statistically significant difference ($t=-1.521$, $p=.129$). This means that while there was a tendency for the level of class participation to be maintained and strengthened after participating in the project, it did not lead to a distinct change within a short period.

Meanwhile, class interest was maintained at almost the exact same level, from a pre-average of 4.31 points to a post-average of 4.31 points, and no statistically significant difference was confirmed ($t=-0.109$, $p=.902$). This suggests that students' class interest levels were already high from the time of the pre-survey, and it can be interpreted that this project played a role in stably maintaining the existing high interest and positive attitude, rather than newly raising class interest.

In summary, this project is evaluated to have contributed to sustaining and maintaining the already formed positive learning attitude, rather than greatly changing elementary school students' class participation and interest in the short term. When combined with the previously confirmed increase in digital device utilization time and improvement in Google tool utilization proficiency, this can be said to be a result showing that the qualitative stability of learning attitudes and the improvement of the class participation environment occurred together.

8) Changes in Perception of Utilizing Gemini

Table 4-22. Analysis of Changes in Elementary School Students' Perceptions of Gemini Utilization

Item	Pre	Post	t	p
Learning help	3.71	4.73	11.35	.001***
Problem solving	3.57	4.72	10.65	.001***
Class interest	3.72	4.73	9.59	.001***
Ease of use	3.58	4.72	10.12	.001***
Intention to use	3.70	4.77	10.72	.001***

Elementary school students showed statistically very significant improvements ($p < .001$) in all measured items, such as learning help, problem solving, and class interest, after the class utilizing Gemini. Before the class, there were vague worries and concerns such as "Will AI tools be difficult or will my personal information be leaked?" However, after the actual experience, the average score rose significantly by more than 1 point, recording a satisfaction level that far exceeded pre-expectations. Through impressions such as, "I was worried at first, but as I did it, I got used to it and it was so much fun," and "Gemini helped me well, making the class easier," students demonstrated that they came to perceive AI as a friendly helper. In particular, they showed a strong will to continue utilizing Gemini even when they go to middle school, suggesting that the positive AI success experience they underwent in their early grades became an important foundation for forming a self-directed learning attitude. Consequently, for elementary school students, Gemini transformed from a vague new technology into a 'reliable friend that helps make studying easy and fun.'

9) Descriptive Questions - Class Impressions

As a result of analyzing the responses to the descriptive questions, elementary school students generally perceived this class positively, and the main keywords were categorized into fun/interest, efficiency/help, diverse activity experiences, and improvement in participation. This is a consistent trend with the results of maintaining class interest and improving digital tool utilization proficiency confirmed in the quantitative analysis.

Meanwhile, some students presented improvement requests by mentioning difficulties in understanding and a lack of activity time, but this can be interpreted as a realistic opinion based on their actual class experience rather than a negative evaluation of the class itself.

The response content can be categorized as follows.

1) Class Satisfaction and Interest

Many responses were presented, such as "The class was fun," "It was an interesting activity," "It was an enjoyable experience," and "I want to do it again next time." This shows that digital devices and AI-based activities contributed to raising elementary school students' class immersion and forming positive emotions toward learning.

2) Perception of Efficiency and Help

Opinions such as "It helped a lot in class," "I was able to do assignments more conveniently," and "The class progressed quickly because we used the app" were confirmed. This suggests that the utilization of digital tools played a functional role in increasing the efficiency of the learning process and supporting assignment execution and understanding.

3) Diverse Activity Experiences

Through responses like "I experienced diverse activities" and "I learned a lot of new things," it can be confirmed that this class was perceived as a richer and more stimulating learning experience compared to the existing monotonous teaching methods. This is a result showing the effect of an activity design that stimulates the interest and curiosity of elementary school students.

4) Improvement in Participation and Changes in Learning Attitude

Responses such as "Class participation went up" and "I was able to actively participate in activities" show that the change in teaching methods induced students' active learning participation. This holds important educational meaning at the stage of forming elementary school students' learning attitudes.

5) Areas for Improvement and Requests for Betterment

For areas of improvement, difficulties in understanding such as "The explanation was difficult" and "Each felt complicated," and time constraints such as "There was not enough time for activities" were mainly mentioned. This suggests that there is a need for more sufficient conceptual explanations and step-by-step guidance during the class introduction stage, and a need to adjust time allocation considering the students' learning speed.

The descriptive responses of elementary school students show that this class was effective in increasing learning interest and participation, and suggest that digital and AI-based classes operated as sufficiently acceptable and positive learning experiences even for elementary learners. At the same time, the demands for comprehension support and securing activity time can be utilized as important implications for future class design improvements.

3 Survey analysis results on middle school students’AI and digital utilization capabilities

1) Survey basic information and analysis method

Table 4-23. Middle school student survey basic information

grade	man (person)	woman (person)	Subtotal (persons)
1st year middle school	23	17	40
3rd year of middle school	21	0	21
overall total	44	17	61

Paired samples t-test was applied to analyze pre- and post-perception changes, and pre- and post-means and standard deviations were calculated for each question and analysis area. Afterwards, statistical significance was verified by calculating the t value and significance probability (p value) for the mean difference. All statistical analyzes were performed based on the same respondent data for the same questions before and after, ensuring the reliability and validity of the analysis by focusing on intra-individual changes rather than inter-individual differences. This analysis procedure is used as basic data to systematically verify in what direction middle school students' AI and digital utilization capabilities have changed through project operation.

This survey was conducted using the same pre- and post-survey questions targeting middle school students who participated in the project, and its purpose was to analyze changes in students' AI and digital utilization capabilities and perceptions before and after the project was operated. For the analysis, only the data from students who responded to both the pre- and post-surveys were selected and used, and a total of 61 responses were included in the final analysis.

The students subject to analysis are comprised of first and third grade middle school students, and the study was structured to enable comparison and interpretation considering the different developmental stages and digital use experiences of each grade. The gender distribution was 44 male students and 17 female students, and this study was not limited to the perception of a specific gender but focused on identifying changes across the middle school group.

2) Changes in student perception regarding the use of computers and AI in schools

Table 4-24. Analysis of changes in perception of middle school students' use of computers and AI in schools

division	dictionary (person)	after death (person)	Change (%p)
positive	50(82%)	53(86.9%)	▲ 4.9%p
neutral	6(9.8%)	2(3.3%)	▽ 6.6%p
negative	5(8.2%)	6(9.8%)	▲ 1.6%p

As a result of analyzing the change in students' perception of the use of computers and AI in school, the rate of positive perception of technology use was 82.0% before the post. As a result of analyzing the change in high school students' perception of the use of computers and AI in school, the positive perception was found to have increased significantly (+68.7%p) from 21.9% beforehand to 90.6% after the post. On the other hand, neutral perception decreased significantly (-67.6%p) from 73.0% to 5.4%, and negative perception also decreased slightly (-1.1%p) from 5.0% to 4.0%.

These results suggest that, while before the project, many students withheld a clear judgment or showed a neutral attitude toward the use of computers and AI in schools, after participating in the project, they clearly formed a positive perception of technology use based on their actual use experience. In particular, the rapid decrease in neutral responses can be interpreted as an important change showing that students have directly experienced the advantages and limitations of using computers and AI, and have moved from the abstract recognition stage to the concrete evaluation stage.

Considering the slight decrease in negative perceptions, it is believed that the overall change in perception has the character of a positive shift based on understanding and acceptance of technology, rather than a critical rejection of it. This can be said to be a result that reflects that high school students have come to recognize the usefulness of using computers and AI in actual learning contexts such as learning efficiency, task performance, and information search.

In summary, this project showed a clear effect in changing high school students' perception of the use of computers and AI in schools from the 'neutral wait-and-see' stage to the 'positive acceptance' stage, and this can be used as important basic data to spread AI and digital-based learning in the future high school education field. It was found to be an increase of 4.9% points to 9%. On the other hand, neutral attitudes significantly decreased (-6.6%p) from 9.8% to 3.3%, suggesting that the majority of students have formed clearer perceptions and attitudes toward technology use. This can be interpreted as the result of a concrete judgment on the value and effectiveness of technology utilization through project participation.

Meanwhile, negative perception slightly increased by 1.6%p from 8.2% beforehand to 9.8% afterward. However, rather than the spread of an overall negative perception, it is reasonable to view this as the result of some students becoming more realistically aware of the limitations and difficulties in applying technology through actual experience using computers and AI. In other words, it can be interpreted as a change that occurred in the process of converting to an evaluation that reflects actual use experience, rather than a response from a simple perception survey stage.

In summary, after this project, middle school students were found to have strengthened their overall positive perception of the use of computers and AI in school, while breaking away from their existing reservations and forming clearer judgments. It is believed that these results can be used as basic data in the future to design more sophisticated AI and digital utilization support strategies that take into account student level and context of use.

3) Experience in using devices used in class and awareness of suitability

Table 4-25. Changes in middle school students'experience using devices in class and their perception of suitability

ranking	machinery and tools	Dictionary: Usage Rate (%)	Post: Goodness of fit (out of 5)
1	Chromebook	**68.9%**	4.18 points
2	smartphone	14.8%	3.79 points
3	Desktop/PC	6.6%	3.83 points
4	tablet	**4.9%**	4.13 points
5	laptop	4.9%	3.97 points
6	projector	0%	3.69 points

As a result of the pre-survey, the percentage of Chromebooks used was the highest at 68.9%, and in the post-survey, it received the highest suitability rating of 4.18 points out of 5. This means that middle school students recognize Chromebooks as the most suitable digital device for classroom learning through actual class experience, and clearly recognize their effectiveness as a learning-centered device.

Although tablets and laptops had relatively low pre-use rates of 4.9% each, they recorded relatively high scores of 4.13 and 3.97 points, respectively, in the post-suitability evaluation. This suggests that through this project, students have formed a standard by which they can judge suitability for learning based on their direct experience of using devices that they were not previously familiar with. In other words, it can be interpreted that the ability to select devices that meet the purpose of class has been strengthened rather than simply the frequency of use.

On the other hand, smartphones and projectors showed pre-use rates of 14.8% and 0%, respectively, but post-suitability evaluations were relatively low. This is interpreted as a result that reflects students' awareness that the devices may be useful for information search or auxiliary use, but have structural limitations in supporting learner-led activities or overall classroom instruction.

In summary, this project is evaluated to have contributed to expanding the awareness of middle school students so that they can evaluate digital devices based on their suitability for learning in actual class contexts, beyond device preference based on existing usage experiences. This can be said to be a result showing that education using digital devices went beyond simple exposure to tools and worked in the direction of cultivating rational choice capabilities according to learning purposes.

4) Changes in time spent using digital devices

Table 4-26. Changes in time spent using digital devices by middle school students

division	Dictionary (SD)	Postmortem (SD)	**t**	**p**
Device usage time per week	2.57 (0.67)	2.84(0.64)	-2.58	.012*

The weekly time spent using digital devices in the classroom increased from a pre-average of 2.57 hours (SD=0.67) to a post-average of 2.84 hours (SD=0.64). As a result of the paired samples t-test, this change was confirmed at a statistically significant level ($t=-2.58$, $p=.012$, $p<.05$). This means that the use of digital devices in classroom classes has substantially expanded since the project was launched.

Although the increase is relatively modest at 0.27 hours, considering that middle school students already have a certain level of experience using digital devices, the statistically significant increase in additional usage time can be interpreted as a meaningful change. In particular, the slight decrease in the post-test standard deviation suggests that the use of digital devices is not limited to specific students or classes, but is spreading more stably throughout the class.

Considering the results of increased positive awareness of AI and digital use and strengthened awareness of device suitability confirmed in the previous analysis, it is judged that middle school students recognize digital devices as a daily element of the learning process, not just an auxiliary means, and are gradually expanding the scope of use.

5) Changes in proficiency (self-efficacy) in using Google tools

Table 4-27. Changes in proficiency in using Google tools by middle school students

equipment	Prior mean (SD)	Posterior mean (SD)	increase/ decrease	t	p
Calendar	3.20 (1.21)	2.92 (1.13)	–0.28	1.525	.133
Chromebook	3.57 (1.18)	3.72 (1.10)	+0.15	–0.913	.365
Gemini	**3.26 (1.38)**	**3.72 (1.20)**	**+0.46**	**–2.544**	**.014***
Gmail	3.69 (1.30)	3.56 (1.26)	–0.13	0.753	.454
Google Classroom	3.33 (1.30)	3.66 (1.00)	+0.33	–1.896	.063
Google Documents	2.80 (1.34)	2.92 (1.24)	+0.12	–0.618	.539
Google Drive	2.92 (1.26)	3.03 (1.18)	+0.11	–0.661	.511
Google Forms	**3.36 (1.27)**	**2.93 (1.15)**	**–0.43**	**2.979**	**.004***
Google Maps	3.56 (1.23)	3.23 (1.18)	–0.33	1.830	.072
Google Search	3.74 (1.43)	3.52 (1.22)	–0.22	1.206	.232
Google Sheets	2.97 (1.28)	3.05 (1.15)	+0.08	–0.510	.612
Google Slides	2.72 (1.32)	2.84 (1.07)	+0.12	–0.775	.441
Practice Sets	**2.61 (1.30)**	**2.95 (1.18)**	**+0.34**	**–2.249**	**.028***
Read Along	2.77 (1.36)	2.82 (1.10)	+0.05	–0.312	.756
YouTube interactive questions	3.34 (1.46)	3.43 (1.18)	+0.09	–0.448	.656
Notebook LM	**3.21 (1.34)**	**2.87 (1.09)**	**–0.34**	**2.065**	**.043***
entire	**3.19**	**3.2**	**+0.01**	**-0.035**	**.308**

As a result of analyzing the pre- and post-test changes in proficiency (self-efficacy) in the use of each Google tool, it was confirmed that there was no consistent improvement in all digital tools, and that the use of tools was selectively reorganized depending on the purpose of class and the context of use. The overall average score showed little change from 3.19 points before to 3.20 points after, and the paired samples t-test results showed no statistically significant difference (p=.308). This does not mean that middle school students' confidence in using digital tools has increased overall, but rather that it has been adjusted to focus on the necessary tools.

Looking at each individual tool, Gemini showed a significant increase (t=-2.544, p=.014) from the pre-average score of 3.26 to the post-average score of 3.72, suggesting that generative AI tools were recognized as practical learning support tools in the process of task performance and information creation. Additionally, Practice Sets also significantly increased from 2.61 points in the pre-test to 2.95 points in the post-test (t=-2.249, p=.028), showing that confidence in using tools that support formative evaluation and individualized learning was strengthened.

On the other hand, a statistically significant decrease was confirmed for Google Forms (t=2.979, p=.004) and NotebookLM (t=2.065, p=.043). This can be interpreted as the fact that the tools were used selectively and limited to specific tasks or purposes, rather than being used constantly in all class situations. In addition, the average scores for Gmail, Calendar, Google Maps, Google Search, etc. decreased or did not show much change, which is interpreted as a result showing that middle school students are selectively using digital tools for learning purposes rather than indiscriminately expanding them.

Google Classroom's average score increased (+0.33), but it did not reach the 5% significance level at p=.063, which can be interpreted as a significant trend of increase. Chromebook, Docs, Slides, Sheets, Read Along, and YouTube interactive questions showed limited or statistically insignificant changes in scores, indicating that existing usage levels remained relatively stable.

In summary, rather than improving middle school students' overall proficiency in using Google tools, this project is evaluated as reorganizing students' digital learning strategies in a way that deepens their ability to use generative AI (Gemini) and learning evaluation and feedback tools (Practice Sets), and adjusts other tools according to class purposes. This can be said to be a meaningful result showing that middle school students have transitioned to the stage of selecting and using digital tools based on learning purposes rather than function.

6) Changes in difficulties encountered when using technology and AI

Table 4-28. Changes in difficulties experienced by middle school students when using technology and AI

ranking	Difficulty type	dictionary (person)	after death (person)	change pattern
1	no difficulty	71	85	▲Increase
2	Lack of knowledge (not knowing how to use it)	33	17	▽Large decrease
3	Privacy concerns	7	12	▲Slight increase
4	Access rights/permission issues	4	4	—No change
5	lack of help	3	2	▽Slight decrease

As a result of analyzing the changes in difficulties perceived by middle school students in the process of using technology and AI, it was found that the lack of knowledge on how to use it decreased significantly from 33 people beforehand to 17 people afterward. This means that sufficient basic understanding and experience using digital tools and AI was provided through project operation, and the initial entry barrier was effectively alleviated.

Additionally, the number of students who responded ‘lack of help’also decreased from 3 to 2, showing that the teacher and learning support system functioned at a certain level during the class process. These results suggest that there has been a change in the direction of overall resolution of difficulties due to lack of basic capabilities in utilizing technology and AI. On the other hand, the ‘no difficulty’response increased from 71 to 85, confirming that the majority of students recognized the use of technology and AI as a natural part of the learning process. This is interpreted as a key indicator that this project played a positive role in lowering the psychological burden of students' use of technology.

Meanwhile, ‘personal information concerns’slightly increased from 7 to 12. Rather than the spread of negative perceptions about the use of technology and AI, it is reasonable to interpret this as the result of awareness of personal information protection and security becoming more concrete and realistic based on actual experience of use. In other words, rather than uncritically accepting technology, students' level of understanding has deepened to the stage of recognizing the risk factors that may arise during use.

In the case of ‘access rights/permission issues’, the number of people remained the same both before and after, with 4 people, showing that the structural and environmental constraints on technology and AI utilization were maintained without significant changes before and after the project.

In summary, this project is evaluated to have substantially reduced the difficulties caused by lack of knowledge and support in middle school students' use of technology and AI, while at the same time transforming students' perception to a mature level in the direction of highlighting higher-order awareness factors such as personal information protection. This result goes beyond simply improving technology familiarity and shows progress toward forming attitudes towards responsible use of technology.

7) Changes in class participation and interest

Table 4-29. Changes in middle school student class participation and interest

item	dictionary	after death	t	p
Class Participation	4.230.86)	4.33(0.79)	-0.830	.410
class interest	3.98(0.99)	4.26(0.81)	-2.103	.04*

As a result of a pre- and post-comparative analysis of class participation and interest, class interest significantly increased from an average of 3.98 points (SD=0.99) beforehand to 4.26 points (SD=0.81) afterward (t=-2.103, p=.040, p<.05). This means that this project had a positive impact on significantly increasing middle school students' interest in learning.

On the other hand, class participation slightly increased from an average of 4.23 points (SD=0.86) beforehand to 4.33 points (SD=0.79) afterward, but there was no statistically significant difference (t=-0.830, p=.410). This can be interpreted as the fact that middle school students' class participation was already high before the project, and suggests that the level remained stable even after the project.

These results show that this project played a role in further strengthening learning interest while maintaining the already established high level of participation, rather than drastically changing class participation in a short period of time. In particular, digital tools and AI-based class activities stimulate middle school students' interest and immersion, which can be interpreted as a positive expansion of their emotional response to class and motivation to learn.

In summary, this project showed significant results in increasing middle school students' interest in class, and is evaluated to have contributed to stably maintaining and sustaining the existing high class participation attitude. This can be said to be a result that is in line with the increase in time spent using digital devices and changes in positive perception of AI and digital tools confirmed in the previous analysis.

8) Change in perception of Gemini usage

Table 4-30. Changes in perception of middle school students using Gemini

item	dictionary average	posterior mean	t-value	p value
study help	3.96	5.00	9.49	.001***
Help with troubleshooting	3.89	5.00	10.16	.001***
class interest	3.97	5.00	8.88	.001***
Easy to use	3.93	5.00	9.11	.001***
intention to utilize	3.90	5.00	9.01	.001***

Middle school students recorded higher post-satisfaction scores (out of 5.0 points) with Gemini classes than their prior expectations (3.9 points), showing statistically significant differences ($p < .001$) in all items. Although caution is needed in interpretation due to the small number of respondents, it is characteristic that educational acceptability was very high, with all participating students giving full scores to all questions. Students responded, “It was fun because it was very convenient and novel,”and showed no resistance to introducing new digital tools into class, adapting quickly and enjoying them. This shows that the high adaptability to digital tools in middle school can be maximized through interaction with Gemini, and it can be seen that it served as a catalyst to dramatically increase immersion in class beyond simple tool use.

9) Descriptive questions - Class impressions

As a result of post-open response analysis, middle school students showed overall high satisfaction and positive perception toward digital devices and AI-based project classes. In particular, they recognized that the teaching method using Chromebooks increased their concentration in learning and the efficiency of task performance, and they responded that their understanding of new technologies was expanded and their perspectives on learning methods changed through AI and project-based learning experiences. Some students also presented realistic requests for improvement, mentioning the inconvenience of using the device, restrictions on activity time, and the need for prior guidance. Rather than an overall negative evaluation, this is interpreted as a mature response suggesting a more specific direction for class improvement based on actual usage experience.

The responses can be categorized as follows:

1) Class satisfaction and interest

Many students expressed high satisfaction and interest in the overall class, such as “It was much more fun than reading a book,”“I was able to focus more on class,”“It was a lively class,”and “I hope to do it next time.”This trend is consistent with the results of increased interest in class confirmed in quantitative analysis.

2) Awareness of using digital devices

There were many responses such as “It was easy and convenient to use,”“It was convenient to process assignments in documents,”and “It was helpful for personal learning."On the other hand, some opinions were expressed that "it was a bit difficult to operate,"showing that there are individual differences in the ability to use the device. This suggests the need for level-specific guidance and auxiliary support systems in the future.

3) AI/project-based learning experience

Responses such as "I learned something new about AI,""I found the Albus project fascinating and interesting,"and "I liked the process of directly participating and solving problems"were confirmed. This shows that generative AI and project-based classes functioned as an inquiry-centered learning experience beyond simple information acquisition.

4) Changes in self-direction and learning attitude

Responses such as "It was good to be able to learn individually,""I wanted to do better on my own,""It was helpful in repetitive learning and understanding concepts,"and "I want to participate more faithfully in technology-related classes in the future"suggest positive changes in learning attitudes. This can be considered qualitative evidence showing that digital-based classes served as a factor stimulating learning motivation and self-direction.

5) Career awareness and expansion experience

Responses such as "I started thinking about a career in this field,""I started thinking about the AI technology field again,"and "Science became more interesting"show that some students provided an opportunity to expand their interest in the technology and AI fields and explore career paths.

Middle school students strengthened their interest in learning and self-direction through digital and AI-based classes, and some showed positive changes by expanding their career interest in technology and AI fields.

4 Results of survey analysis on high school students' AI and digital utilization capabilities

1) Survey basic information and analysis method

Table 4-31. High school student survey basic information

grade	man (person)	woman (person)	Subtotal (persons)
first year of high school	176	13	189
2nd year of high school	0	89	89
overall total	**176**	**102**	**278**

This survey was conducted using the same pre- and post-survey questions targeting high school students who participated in the project, and its purpose was to analyze changes in students' AI and digital utilization capabilities and perceptions before and after the project was operated. For the analysis, only the data from students who responded to both the pre- and post-surveys were used, and a total of 278 responses were included in the final analysis.

The students subject to analysis are composed of first and second year high school students, and given that they are students at a time when the difficulty of learning content is increasing and the demands for learning considering career paths and higher education are in full swing, there is a possibility that changes in perception of the use of AI and digital will appear more realistic and purpose-oriented. The gender distribution is 176 male students and 102 female students, with a sample composition that encompasses a variety of school types and learning contexts.

Paired samples t-test was applied to analyze pre- and post-perception changes, and pre- and post-means and standard deviations were calculated for each question and analysis area. Afterwards, statistical significance was verified by calculating the t value and significance probability (p value) for the mean difference. All statistical analyzes were performed based on data from the same respondent to the same pre- and post-test questions, ensuring the reliability and validity of the analysis by focusing on intra-individual changes rather than inter-individual differences.

This analysis procedure is used as basic data to systematically verify in what direction high school students' AI and digital utilization capabilities have changed through project operation.

2) Changes in student perception regarding the use of computers and AI in schools

Table 4-32. Changes in perception of high school students using computers and AI at school

division	dictionary (person)	after death (person)	Change (%p)
positive	61(21.9%)	252(90.6%)	▲ 68.7%p
neutral	203(73%)	15(5.4%)	▽ 67.6%p
negative	14(5%)	11(4%)	▽ 1.1%p

As a result of analyzing changes in high school students' perception of the use of computers and AI in school, positive perception increased significantly (+68.7%p) from 21.9% beforehand to 90.6% afterward. On the other hand, neutral perception decreased significantly (-67.6%p) from 73.0% to 5.4%, and negative perception also decreased slightly (-1.1%p) from 5.0% to 4.0%.

These results suggest that, while before the project, many students withheld a clear judgment or showed a neutral attitude toward the use of computers and AI in schools, after participating in the project, they clearly formed a positive perception of technology use based on their actual use experience. In particular, the rapid decrease in neutral responses can be interpreted as an important change showing that students have directly experienced the advantages and limitations of using computers and AI, and have moved from the abstract recognition stage to the concrete evaluation stage.

Considering the slight decrease in negative perceptions, it is believed that the overall change in perception has the character of a positive shift based on understanding and acceptance of technology, rather than a critical rejection of it. This can be said to be a result that reflects that high school students have come to recognize the usefulness of using computers and AI in actual learning contexts such as learning efficiency, task performance, and information search.

In summary, this project showed a clear effect in shifting high school students' perception of the use of computers and AI in schools from the 'neutral wait-and-see' stage to the 'positive acceptance' stage, and this can be used as important basic data to spread AI and digital-based learning in future high school education fields.

3) Experience in using devices used in class and awareness of suitability

표4-33. 고등학생 수업 활용 기기 사용 경험 및 적합도

ranking	machinery and tools	Dictionary: Usage Rate (%)	Post: Goodness of fit (out of 5)
1	tablet	**64.4%**	4.10 points
2	smartphone	56.1%	3.47 points
3	Chromebook	35.6%	3.95 points
4	laptop	**27.7%**	4.24 points
5	Desktop/PC	5.4%	3.83 points
6	projector	1.1%	3.68 points

As a result of the pre-survey, the smartphone use rate was the highest at 56.1%, but the post-suitability evaluation was the lowest at 3.47 points (out of 5). This means that although high school students frequently use smartphones on a daily basis, they do not recognize them as an appropriate teaching tool in the learning environment due to low concentration, limited screen size, and difficulties in learning management.

On the other hand, laptops (4.24 points) and tablets (4.10 points) recorded the highest scores in the post-fit evaluation. In particular, the tablet was a device with a high pre-use rate of 64.4%, and at the same time maintained a high level of suitability even afterward, showing that high school students positively evaluated both learning efficiency and ease of use through actual class experiences. In addition, although the laptop had a relatively low prior use rate of 27.7%, it received the highest suitability rating, suggesting that suitability for learning purposes was a more important criterion in device evaluation than frequency of use.

Chromebooks also received a relatively high suitability rating of 3.95 points, confirming that they are perceived positively as learning devices focused on class and assignment performance. On the other hand, both the pre-use rate and post-suitability for desktops/PCs and projectors were relatively low, which suggests that the characteristics of devices with limited mobility and individual use influenced the perception of suitability for learning.

In summary, these results show that high school students classify and evaluate digital devices based on actual learning efficiency and suitability for teaching, rather than simple ease of use or familiarity. In other words, devices designed with a focus on learning, such as laptops and tablets, are recognized as more suitable tools for teaching than general-purpose devices such as smartphones, which suggests that high school students' judgment standards for the use of digital devices have shifted to a more mature stage.

4) Changes in time spent using digital devices

Table 4-34. Changes in time spent using digital devices by high school students

division	Dictionary (SD)	Postmortem (SD)	**t**	**p**
Device usage time per week	1.68 (0.64)	2.07(0.61)	-8.936	.000***

In summary, this project is evaluated to have not only quantitatively expanded high school students' use of digital devices in class, but also qualitatively promoted a shift toward learning-oriented use in combination with the previous results of changes in perception.

As a result of comparing before and after participating in the study, it was found that the time spent using digital devices during class by high school students increased statistically significantly. The weekly time spent using digital devices increased from an average of 1.68 hours (SD=0.64) beforehand to 2.07 hours (SD=0.61) afterward, and as a result of a paired samples t-test, t=-8.936, p<.001, statistical significance was confirmed at the 1% significance level.

This means that after this project, digital devices were used in high school classes by being structurally integrated into the actual class process, rather than as a temporary or auxiliary tool. In particular, considering that high school students already had a certain level of experience using digital devices, it is noteworthy that the usage time increased so significantly within a relatively short period of time.

When interpreted together with the significant increase in positive perception of the use of computers and AI in schools confirmed in the previous analysis and the clear distinction between devices suitable for teaching, this result can be considered empirical evidence showing that high school students recognize digital devices as a core learning tool that supports learning efficiency and task performance, rather than a simple means of convenience, and are expanding the scope of use.

5) Changes in proficiency (self-efficacy) in using Google tools

Table 4-35. Changes in proficiency in the use of Google tools by high school students

Tool name	dictionary	after death	increase/ decrease	t	p
Chromebook	**3.28**	**3.96**	**+0.68**	**-7.575**	**.000*** **
Classroom	**3.80**	**4.33**	**+0.52**	**-6.317**	**.000*** **
Gemini	**3.77**	**4.18**	**+0.41**	**-5.111**	**.000*** **
Docs	**3.22**	**3.60**	**+0.38**	**-3.757**	**.000*** **
Drive	**3.62**	**3.96**	**+0.34**	**-3.818**	**.000*** **
Sheets	**3.03**	**3.40**	**+0.37**	**-3.626**	**.000*** **
Slides	**2.90**	**3.30**	**+0.40**	**-3.504**	**.001** **
Gmail	**4.14**	**4.31**	**+0.18**	**-2.527**	**.012* **
NotebookLM	2.81	2.98	+0.18	-1.573	.117
Practice Sets	2.60	2.75	+0.16	-1.484	.139

Tool name	dictionary	after death	increase/ decrease	t	p
YouTube interactive questions	3.01	3.16	+0.15	-1.298	.196
Maps	3.33	3.43	+0.10	-1.000	.319
Read Along	2.62	2.71	+0.09	-0.861	.390
Forms	3.67	3.72	+0.05	-0.546	.586
Search	3.82	3.80	-0.02	0.148	.882
Calendar	3.01	2.91	-0.10	0.984	.326
entire	**3.29**	**3.53**	**0.24**	**-2.617**	**.186**

As a result of analyzing changes in proficiency in the use of each Google tool, high school students' self-efficacy did not increase uniformly in all tools, but significant improvement was observed focusing on core classroom tools.

Specifically, Chromebook (+0.68, p<.001), Google Classroom (+0.52, p<.001), Gemini (+0.41, p<.001), Docs (+0.38, p<.001), Drive (+0.34, p<.001), Sheets (+0.37, p<.001), Slides (+0.40, p=.001) showed a statistically very significant improvement. This means that high school students' confidence in using learning-oriented tools was significantly strengthened as they repeatedly used the tools during actual classes and assignments. The significant rise of Gemini, a generative AI tool, suggests that high school students have come to perceive AI not as a simple information search tool, but as a learning tool that supports task performance and expansion of thinking.

On the other hand, NotebookLM (p=.117), Practice Sets (p=.139), YouTube interactive questions (p=.196), Maps (p=.319), Read Along (p=.390), Forms (p=.586), Search (p=.882), and Calendar (p=.326) did not show statistically significant changes. This can be interpreted as the fact that the tools were used as auxiliary tools in specific situations rather than as core tools for the overall class, or because a certain level of ability to use them was already formed.

The overall average increased from 3.29 points in the pre-test to 3.53 points in the post-test, but there was no statistically significant difference (p=.186). This means that high school students' digital self-efficacy did not increase rapidly overall, but rather showed a selective deepening structure in which core tools directly used for learning were strengthened.

In summary, rather than expanding the overall ability of high school students to use Google tools, this project is evaluated to have focused on strengthening the proficiency of core learning tools directly related to class management and assignment performance. This can be said to be a result that shows the transition to a mature utilization stage in which digital tools are selected and utilized based on learning purposes rather than function.

6) Changes in difficulties encountered when using technology and AI

Table 4-36. Changes in difficulties experienced by high school students when using technology and AI

ranking	Difficulty type	dictionary (person)	after death (person)	change pattern
▮	no difficulty	88 people (31%)	131 people (47%)	▲Significant increase
▮	Lack of knowledge (don't know how to use it)	139 people (50%)	46 people (16%)	▽Significant decrease
▮	Access rights/permission issues	49 people	39 people	▽Slight decrease
▮	Privacy concerns	46 people	40 people	▽Slight decrease
▮	lack of help	27 people	0 people	▽Resolved

As a result of analyzing the changes in difficulties recognized by high school students in the process of using technology and AI, the response that ‘I do not know how to use’, which was pointed out as the biggest difficulty before the study, decreased significantly from 139 people (50%) beforehand to 46 people (16%) afterward. This means that the basic usage capabilities and level of understanding of digital tools and AI utilization have been effectively improved through project operation.

On the other hand, the number of students who responded that there was ‘no difficulty’increased significantly from 88 (31%) beforehand to 131 (47%) afterward, confirming that the majority of high school students recognized the use of technology and AI as a natural part of the learning process. This can be said to be a key indicator that this project has contributed to substantially lowering the psychological and functional entry barriers to technology utilization. In addition, issues with access rights and permissions decreased from 49 to 39 people, and concerns about personal information also decreased slightly from 46 to 40 people, showing that structural inconveniences and anxiety factors regarding the technology use environment have been alleviated overall. In particular, the response of 'lack of help'decreased from 27 beforehand to 0 afterward, suggesting that teacher support, guidance system, and learning assistance during the class process were sufficiently effective.

In summary, this project is evaluated to have significantly resolved the difficulties caused by lack of basic usage capabilities in the process of using technology and AI among high school students, while also changing student perception in a way that lowers the overall burden of using technology. This is a trend that is consistent with the results confirmed in the previous analysis: increased time using digital devices, expanded positive awareness of the use of computers and AI in schools, and improved proficiency in using Google tools.

7) Changes in class participation and interest

Table 4-37. Changes in class participation and interest in high school students

item	dictionary	after death	**t**	**p**
Class Participation	4.22(0.75)	4.30(0.77)	-1.473	.142
class interest	4.03(0.83)	4.20(0.87)	-2.741	.007**

As a result of the pre- and post-comparative analysis of class participation and interest, class interest showed a statistically significant increase from the pre-average mean of 4.03 points (SD=0.83) to the post-test 4.20 points (SD=0.87) ($t=-2.741$, $p=.007$, $p<.01$). This means that this project contributed to significantly improving high school students' emotional commitment to class and interest in learning.

On the other hand, class participation slightly increased from an average of 4.22 points (SD=0.75) beforehand to 4.30 points (SD=0.77) afterward, but there was no statistically significant difference (t=-1.473, p=.142). This can be interpreted as the fact that high school students' class participation was already at a high level before the project, and suggests that this level was stably maintained and strengthened even after the project. These results show that this project played a role in further increasing interest in class while maintaining the existing high participation attitude, rather than drastically changing class participation in a short period of time. In particular, it can be interpreted that digital devices and AI-based class activities stimulate the interest and motivation of high school students, thereby strengthening their positive emotional response to class.

In summary, this project showed results in significantly improving high school students' interest in class, and is evaluated to have contributed to maintaining the already high level of class participation stably. This shows a consistent trend with the results confirmed in the previous analysis: increased time using digital devices, a positive shift in awareness of the use of computers and AI in schools, and improved proficiency in using Google tools.

8) Change in perception of Gemini usage

Table 4-38. Change in perception of high school students using Gemini

item	dictionary average	posterior mean	t-value	p value
study help	4.01	4.19	1.07	.291
Help with troubleshooting	3.90	4.48	4.47	.001***
class interest	3.81	4.06	1.35	.185
Easy to use	3.84	4.32	2.72	.010*
intention to utilize	3.78	4.42	3.70	.001***

High school students showed statistically significant improvement in the categories of 'problem solving ($p < .001$)' and 'intent to use in the future ($p <$

.001)'. The pre-expectations for 'learning help' and 'class interest' were already high at around 4.0 points and did not reach a significant difference with the post-score, but the fact that confidence in being able to solve problems on one's own through Gemini increased significantly is a very impressive achievement. Rather than just fun, students clearly recognized Gemini as a 'practical tool that increases learning efficiency,' leaving comments such as "It is efficient because it allows you to quickly summarize various materials and understand the key points," and "I was able to solve my questions by asking specific questions." In particular, the ability to easily explain and explain concepts when understanding them was difficult was highly evaluated, and this experience proves that AI has established itself as a practical 'learning partner' that strengthens academic capabilities and structures information beyond a simple object of experience.

9) Descriptive questions - Class impressions

As a result of analyzing the open-ended responses, high school students showed an overall positive evaluation of digital devices and AI-based project classes. The main responses were divided into four categories: new experiences and expanded awareness, increased interest, enhanced collaboration and communication, and improved learning efficiency. On the other hand, technical infrastructure issues and initial adaptation difficulties were presented as issues for improvement.

1) New experiences and expanded awareness

“It was good to learn more about AI technology”,

“It was a great opportunity to experience and learn various technologies.”

Many responses said, “It was awkward at first, but once I got used to it, it was effective.”

This means that high school students are accepting AI and digital classes as a new learning experience and an opportunity to expand their awareness, rather than simply using tools. In particular, the response that efficiency increased after the initial awkwardness shows that utilization capabilities have stabilized through the learning adaptation process.

2) Learning interest and class immersion

“The class was fun and not boring”,

The opinion, “Unlike existing classes, I was able to feel fresh fun,”shows that the change in class method led to emotional immersion in high school students. This trend is consistent with the significant increase in class interest confirmed in quantitative analysis.

3) Strengthening collaboration and communication

“It was nice to be able to communicate with friends and teachers using Google Classroom and chat.”

The response, “It was convenient to be able to give and receive feedback in real time,”shows that digital tools have contributed not only to learning efficiency but also to creating an interactive learning environment.

This suggests that important collaborative problem solving and feedback-based learning have been strengthened at the high school level.

4) Improved learning efficiency and sense of achievement

“We were able to save time and produce better quality results than when we did it without AI.”

The response, “It was convenient because the smartphone and Chromebook were linked,”shows that digital and AI tools played a role in increasing learning productivity and improving the quality of task performance.

This is an important result that shows that high school students perceive the use of technology as a tool to improve performance, not just as an element of interest.

Disappointments and requests for improvement

Negative comments were mainly categorized into technical infrastructure issues, device errors, and initial adaptation difficulties.

1) Infrastructure and device issues

“It was difficult to use Chromebooks because the school Wi-Fi performance was poor.”

The response, “It was inconvenient because there were times when the Internet was cut off or the device stopped working,”emphasizes the importance of a stable network environment.

2) Difficulty in initial adaptation

“It took me some time to use this feature because it was my first time using it.”

The opinion that “there are many functions, but it was disappointing that I didn’t know how to use them”suggests the need for prior guidance and step-by-step learning support.

3) Cases of inappropriate device use

The response, “I had friends who did something else during class,”shows the importance of self-regulation capabilities and a management system in the use of digital devices.

High school students' open-ended responses show that this project contributed to expanding awareness of AI and digital technology, increasing interest in class, strengthening collaboration and interaction, and improving learning efficiency. At the same time, the importance of the stability of technological infrastructure and initial guidance system was also raised. This can be seen as qualitative evidence showing that high school students perceive digital and AI-based learning as a tool connected to actual learning outcomes rather than simply as an element of interest.

5 Comprehensive interpretation of elementary, middle, and high school survey analysis results

As a result of this project, the time spent using digital devices and the proficiency in using Google educational tools, including generative AI (Gemini), were overall improved at all stages of elementary, middle, and high school, and statistically significant changes were confirmed in a number of indicators ($p < .05$). In particular, it has great educational significance in that it goes beyond a simple increase in use and shows structural changes in students' perceptions, attitudes, and overall learning strategies. The main analysis results and implications are as follows.

1) Structural change in awareness and attitude toward technology use in schools

Overall, positive perception of technology utilization was strengthened. In particular, in the case of high school students, there was a sharp transition from a pre-neutral response (73%) to a post-positive response (90.6%), clearly showing a shift in perception from a wait-and-see attitude toward technology to an active acceptance stage.

Elementary and middle school students also maintained or improved a high positive attitude of more than 85%, proving that the project served as an opportunity for students to experience the educational value of technology. This means that beyond simple exposure to technology, a process of reconstructing perception through actual learning experiences was activated.

2) Recognition of device suitability as a learning tool and expansion of usage time

At all school levels, Chromebooks were evaluated as ‘the most optimal tool for learning’after actual class experience. In particular, high school students evaluated the suitability for learning the lowest despite the high accessibility of smartphones, showing a mature judgment standard that values learning efficiency and suitability for task performance rather than simple convenience.

The time spent using digital devices per week increased statistically significantly ($p < .05$) at all levels of elementary, middle, and high school. This shows that digital devices go beyond the level of auxiliary tools and are actually integrated into the classroom teaching structure. In other words, this project is evaluated as driving digital transformation in the classroom through actual changes in class operation rather than formal introduction.

3) Developmental differences in Google tool proficiency

The improvement in proficiency in Gemini, a generative AI tool common to elementary, middle, and high schools, was most noticeable. This suggests that generative AI is becoming a learning tool in the process of information exploration, task performance, and thinking expansion. However, the characteristics of each school level are clearly distinguished.

Elementary school students' overall proficiency in Google tools increased evenly, showing an overall expansion of basic digital capabilities.

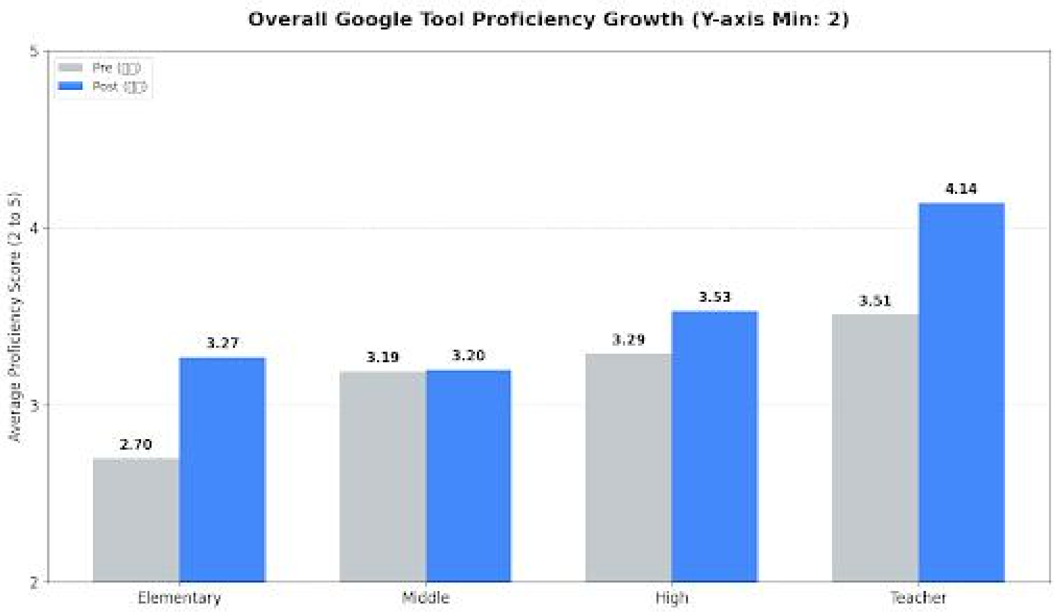
Middle school students tend to selectively use specific tools (Gemini, Practice Sets, etc.) depending on the purpose of class, and tool use appears to be reorganized from function-oriented to learning purpose-oriented.

High school students showed high growth in collaboration and management-oriented tools such as Classroom, Drive, and Docs, and their learning productivity and assignment management capabilities were strengthened.

This result shows that the use of digital tools is developing into the stage of ‘expansion →selection →strategic use’as the grade increases.

In particular, the graph above compares the average score of elementary school students, middle school students, high school students, and teachers in terms of proficiency in using Google tools before and after. Overall, post-post average scores increased in all groups, and relatively large improvements were seen in elementary school students and teacher groups in particular.

Elementary school students showed the most significant growth, rising by about 0.57 points from an average of 2.70 points beforehand to 3.27 points



afterward. This suggests that the ability to utilize basic digital technologies has expanded overall. High school students also rose from 3.29 to 3.53 points, showing that their ability to use learning-oriented tools has been strengthened. For middle school students, the average change was not large, from 3.19 to 3.20 points, but this can be interpreted as the result of deepening selective use of specific tools. The teacher group recorded the highest post-average score, from 3.51 to 4.14 points, showing that their capabilities in utilizing digital tools in terms of lesson design and operation were greatly strengthened.

Overall, this project led to structural changes that simultaneously improved the digital utilization capabilities of not only students but also teachers. In particular, the growth in the basic level (elementary school) and class management subjects (teachers) was notable, confirming the effect of strengthening the capabilities of the entire educational ecosystem.

4) Learning participation and emotional response

In the case of middle and high school students, interest in class increased statistically significantly ($p < .05$), showing that digital and AI-based classes had the effect of strengthening learning motivation. On the other hand, elementary school students' pre-interest level was already very high, and that level tended to remain stable even afterward.

Even in open-ended responses, students commonly

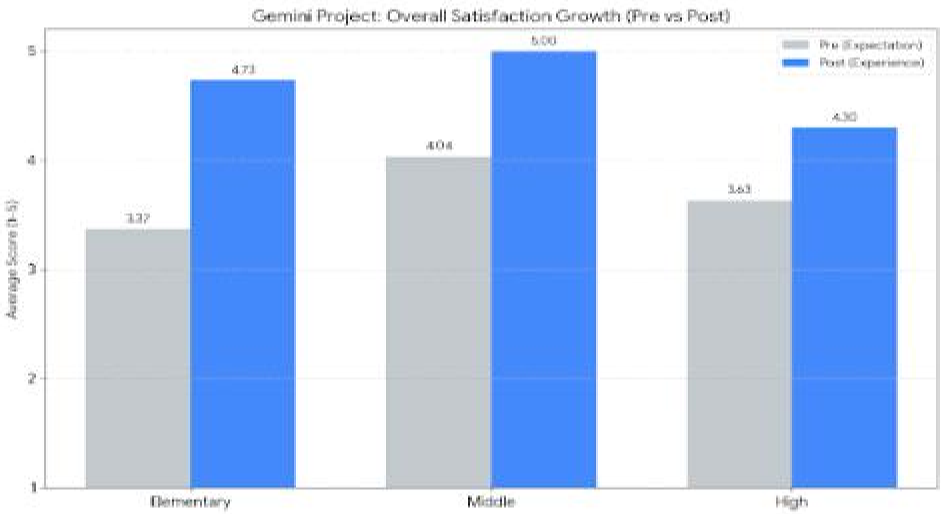
‘New experience’

‘Improving the efficiency of task performance’

‘Convenience of collaboration and communication’

was mentioned as a major advantage. This shows that technology use is recognized as a factor directly linked to learning outcomes, beyond a simple interest factor.

5) Post-satisfaction level compared to expectations for Gemini



The graph above is the result of comparing the average scores of Pre: Expectation and Post: Experience for the Gemini Project for elementary, middle, and high school students. As a result of the analysis, post-satisfaction at all school levels exceeded prior expectations, showing that overall satisfaction significantly improved after the project experience.

For elementary school students, the pre-expected average was 3.37 points, but the post-satisfaction level rose significantly to 4.73 points, showing that the project experience significantly exceeded expectations. Middle school students increased from a pre-expectation score of 4.04 points to a post-satisfaction score of 5.00 points, recording the highest absolute satisfaction level among the three school levels. High school students also rose from 3.63 points in pre-expectation to 4.30 points in post-satisfaction, clearly confirming their positive evaluation of the project.

These results suggest that the Gemini project went beyond simply arousing interest and improved the perceived utility and quality of the learning experience in the actual learning process. In particular, the fact that post-satisfaction was higher than prior expectations at all school levels shows that generative AI-based learning had an educational effect that met or exceeded students' expectations.

6) Limitations and future challenges

The initial barrier, 'lack of knowledge of how to use', has been largely eliminated at all school levels. However, as technology use became routine, infrastructure issues and the stability of the operating environment emerged as new challenges.

Elementary and middle school students suggested lack of activity time and complexity of some functions as needs for improvement.

High school students pointed out unstable Wi-Fi environment and device errors as major hindering factors.

This suggests that in order to spread AI and digital-based education in the future, the establishment of a stable network infrastructure, step-by-step advance guidance and basic competency support, and flexible curriculum design that take into account students' exploration speed and learning level must be implemented in parallel.

6 Analysis of interviews with teachers

1) Summary of analysis by key topic

As a result of the analysis, four core themes and corresponding sub-themes were derived: ‘Qualitative change in learning culture’, ‘Efficiency of teaching-evaluation process’, ‘Expansion of education through AI tools’, and ‘Practical barriers and demands in the field’.

Table 4-39. Analysis of key themes from interviews with teachers

key topics	subtopic	Summary of key findings
1. Qualitative change in learning culture	Active participation and initiative	- Change from passive learner to active producer - Arouse the interest of digital natives
	Strengthening collaboration and communication	- Collaborative learning through real-time simultaneous editing - Prevention of free riding - Encourage the participation of introverted students
	Visualize and embody learning	- Creating simulations and promoting visual understanding of abstract concepts (science, mathematics, etc.)
2. Streamlining the teaching-evaluation process	Immediate feedback and process-based evaluation	- Individual feedback through real-time comment/suggestion mode - Automatic accumulation and history management of evaluation results
	Streamline classroom management and administration	- Automation of data distribution and collection - Implementation of a paperless classroom - Reduce repetitive guidance
3. Expansion of education through AI tools	Collaboration with AI	- Idea generation using Gemini, etc. - Coding support - Production of customized materials
	Cultivating digital/AI literacy	- Prompt engineering learning - Verification of information reliability (confirmation of hallucinations) - Promoting ethical awareness

4. Practical barriers and demands in the field	Infrastructure and technical limitations	- Network instability - Device management (charging, damage) - Lack of teaching tool (monitoring) function
	Digital divide and ethical issues	- Differences in ability (typing, etc.) between students - Lack of copyright awareness - Difficulty controlling other activities (games, etc.)

2) Detailed analysis by topic

1) Qualitative change in learning culture

Teachers reported that the introduction of Chromebooks and Google tools went beyond simple changes in tools and fundamentally changed students' attitudes and learning styles. In particular, it was clear that communication became active through collaboration tools and students became the subjects of the class.

Active participation and initiative: Students felt a sense of accomplishment by producing their ideas directly, and even students who used to avoid giving presentations became more active in the digital environment.

"Compared to existing classes, as more students understood the meaning of key terms, the class progressed smoothly and 'learning' was observed. "Change from a passive learner to an active producer who searches for information and creates results on his or her own." "During presentation classes, I like creating presentation materials and have come to prefer giving presentations."

Strengthening collaboration and communication: Real-time simultaneous editing functions such as Google Docs and Slides have improved the quality of collaborative learning. The ‘version history’function served as an effective mechanism to prevent free riding.

“When talking about sensitive information that other students don’t want to hear, there is a part of me that feels comfortable using Google tools.”“Thanks to the history function, it is easy to restore and check which students are playing around, increasing productivity with the collaboration tool.""In particular, the number of students who find their own role and free ride in collaborative activities has decreased."

2) Streamlining the teaching-evaluation process

Teachers evaluated that tools linked to Google Classroom reduced administrative consumption and created an environment where they could focus on practical teaching activities and feedback.

Immediate feedback and process-centered evaluation: Feedback, which was only possible after submission of results, became possible in real time while work was being performed, which led to students' revision of their results and qualitative improvement.

"Based on students'learning outcomes (assignments, practice sets, Google forms, etc.), students'learning status or achievement can be identified and immediate feedback can be provided and reflected in class.""Teachers were able to observe the student's work (adequacy of career connections, application of scientific principles) and provide immediate in-line feedback.""As I received immediate feedback, I was able to see the self-direction to try again and again."

Data management and administrative efficiency: Physical constraints have disappeared as data distribution, collection, and storage are automated.

"It was very convenient when sharing a link... It felt simple and accurate because I could just enter Classroom and click.""It saves time in creating and distributing assignments and reference materials and makes it easy to store materials submitted by students.""Assignment management was the most convenient. Storing assignments took up a lot of space, so it was convenient because that problem was eliminated."

3) Expansion of education through AI tools

AI tools such as Gemini and NotebookLM are playing a role in lesson design and helping students' creative activities.

Collaboration with AI: Teachers used AI to create class materials, and students used AI to refine ideas, code, and write.

“I asked Gemini to write it... Gemini wrote the evidence accordingly, and I was able to teach effectively.”“Overview using NotebookLM, learning materials focusing on key keywords using Veo3”“Simulator production: Gemini was used as an AI co-creator... I requested a prompt to ‘generate the HTML code of the simulator I came up with’.”

Digital/AI Literacy: AI's hallucination phenomenon was used as an educational opportunity to develop critical thinking skills and foster the ability to ask questions through prompt engineering.

“By placing intentional errors in the AI-generated simulator code and having students find and correct them, we fostered an attitude of not accepting AI results uncritically.”"A class that makes you realize that the process of asking questions is important in order to use generative AI."

4) Practical barriers and demands in the field

Despite the positive effects, instability in technical infrastructure and difficulties in student management still remain challenges.

Infrastructure and technical limitations: Slow Wi-Fi, device charging issues, and the lack of monitoring tools to control student screens were major complaints.

“The connection to the school AP strangely did not work well. There were a lot of cases where an alarm was displayed saying that the device was out of range, so there was some inconvenience.”"The biggest problem is the stability of the network infrastructure. When all students watch videos at the same time, save to the cloud, and collaborate in real time, the school Wi-Fi speed slows down..." "It is difficult to control classes effectively because the use of teaching tools is not smooth." "There is an urgent need to introduce 'full screen monitoring software' like in the computer lab."

Digital gap and management issues: Differences in digital literacy among students (typing, etc.), device damage, and difficulty controlling other activities (games, etc.) were pointed out.

“The difference between students’levels is greater than you might think… Some children have never touched a computer before.”“An environment where typing was inevitable was created, so I was able to recognize the keyboard well and use it a little more skillfully.”"When talking about sensitive information that other students do not want to hear... using Google tools to talk comfortably" (This part is an advantage, but at the same time suggests the need for management) "It seems necessary to link with the student's cell phone. It seems that areas such as photo sharing are still lacking."

3) Comprehensive content

Teachers recognize that the use of Google tools and Chromebooks greatly contributes to increasing class efficiency and creating a student-centered collaborative learning culture. In particular, the introduction of AI tools has opened up new possibilities for creative class design. However, in order for this innovation to be sustainable, it appears that it must be supported by stable network infrastructure expansion, an effective student monitoring system (improvement of teaching tools), and training to strengthen teachers' device management and AI ethics education capabilities.

7 Analysis of interviews with students

1) Summary of analysis by key topic

As a result of the analysis, four core themes and corresponding sub-themes were derived: 'Feeling the efficiency of digital tools', 'High interest in utilizing AI functions', 'Technical difficulties in the digital class environment', and 'Experience active participation and cooperative learning'.

Table 4-40. Analysis of key topics from interviews with students

key topics	subtopic	the essence of the subject
1. Experience the efficiency of digital tools	Speed of data search and organization	Experience in quickly and easily obtaining and organizing necessary information without heavy data.
	Speed of operation and ease of performance	Improved task performance speed through ease of typing/document creation and collaboration
	Organization and clarity in learning management	Ease of assignment management, feedback, and grading criteria through Classroom
2. High interest in utilizing AI functions	Recognition of the usefulness and novelty of AI	Practical experience using Gemini, including explaining concepts, conceiving ideas, and helping with coding
	Limitations and ethical concerns of AI	Awareness of the need to prevent errors in AI answers, risk of plagiarism, and unconditional trust
3. Technical difficulties in the digital classroom environment	Experience with device and connectivity issues	Inconvenience caused by unstable Wi-Fi, frequent login/account errors, and lack of initial knowledge of how to use it.
	Difficulty concentrating due to temptation of activities outside of class	Experience with class concentration disruption due to accessing webtoons, YouTube, and games through Chromebook
4. Active participation and collaborative learning experience	Satisfaction with participatory activities	Dynamic activities such as game making, quizzes (blue kits), and presentations were mentioned as memorable activities.
	Efficiency and mutual help in the collaborative process	Convenience of real-time collaboration and solving problems that arise during collaboration through mutual communication

2) Detailed analysis by topic for elementary school students

Table 4-41. Analysis of key themes from interviews with elementary school students

parent topic	subtopic	Highlights
1. Transforming learning efficiency through AI and digital tools	Optimization of search and information acquisition	Easier to find data, faster information retrieval, AI summary function
	Change in productivity and speed	Improved typing skills, convenient recording, shortened task performance time
2. Production of creative output using generative AI	AI-based creation and coding	Gemini storybook creation, vibe coding game production, AI lyrics writing
	Multimedia collaborative production	Google Slide collaboration, photo/video insertion presentation material, cooperative learning through sharing
3. Technical obstacles and limitations in the digital transformation process	Infrastructure and connection instability	Wi-Fi disconnection, account/login errors, screen size limitations
	Imperfections in AI Interaction	Difficulty communicating with AI (no communication), image creation errors
4. Formation of digital citizenship for safe use	Data Security and Information Ethics	Comply with privacy rules, manage passwords, and prohibit access to dangerous links.
	Responsible device use attitude	Avoid doing other things (games, YouTube) during class, and be careful about damage to devices.

It was an opportunity to recognize the rule of refraining from activities other than learning, such as YouTube or games, while using devices, and to learn basic etiquette, such as prohibiting criticism in cyberspace.

1) Learning efficiency through AI and digital tools

Students experienced fundamental changes in the ‘speed’and ‘convenience’of learning after the introduction of Chromebooks and Google tools.

They responded that finding materials through AI and Google tools was much faster than using paper textbooks or general searches. In particular, learning efficiency increased in the process of using Gemini to summarize information or obtain desired content immediately.

Typing was considered to be more advantageous than handwriting in completing assignments, and its strengths were that it was easy to review later because records were left.

2) Production of creative output using generative AI

Creative activities that go beyond simple information acquisition and use AI as a partner have been actively carried out.

I performed high-level tasks that were previously difficult to do alone, such as creating a children's book while talking to Gemini or creating a game with coding help.

By sharing data with friends in real time through Google Drive and Slide, the cooperative attitude of sharing roles and helping each other was strengthened.

3) Technical obstacles and limitations in the digital transformation process

Infrastructure and technical proficiency issues emerged as ‘psychological and physical barriers’that still need to be resolved.

Frequent Wi-Fi disconnections and login errors were the biggest factors disrupting the flow of class.

Students felt frustrated when the AI could not understand the intent of the question or created an inappropriate image, and they also complained about the physical inconvenience of the small screen for working with multiple windows open at the same time.

4) Formation of digital citizenship for safe use

Expanding the use of digital devices has instilled in students awareness of ‘responsible use’.

They clearly recognized the importance of protecting personal information, and showed a willingness to practice the safety rules (password management, blocking dangerous sites) learned from their parents or teachers.

3) Detailed analysis by topic for middle school students

Table 4-42. Analysis of key themes in interviews with middle school students

parent topic	subtopic	Highlights
1. Recognize the effectiveness of utilizing AI and digital tools	Convenience-oriented efficiency awareness	It was evaluated positively in terms of reducing the burden of the learning process and improving accessibility rather than improving learning performance.
	Lack of awareness of its effectiveness as a learning management strategy	Rather than systematically managing learning or improving learning strategies using digital tools, the focus is on simple usability and ease of task performance.
2. Transitional characteristics of awareness and attitude toward AI use	Forming a critical acceptance attitude toward AI results	Experience the possibility of error in the information provided by AI, forming the perception that AI results should be verified rather than unconditionally trusted.
	Exploring the formation of AI utilization capabilities	Recognize the principles and limitations of AI utilization, such as the need to ask specific questions and recognize the possibility of plagiarism for effective AI utilization.
3. Limitations of social awareness characteristics of digital-based collaboration experiences	Social interaction experience through collaboration	Collaboration is perceived as centered on social interaction processes such as peer help, exchange of opinions, and conflict experiences rather than improving task productivity.
	Lack of awareness of the cognitive and productive value of collaboration	Emphasis on forming relationships with peers rather than co-constructing knowledge or improving task efficiency through digital collaboration tools
4. The need for self-regulation capabilities and support for learning structures	Immaturity of self-regulated learning capacity	A developmental stage in which self-regulated learning abilities are not sufficiently internalized, with a decrease in concentration due to external stimuli such as games and videos in a digital environment.
	Positive perceptions of external control and structure.	External support such as teacher screen control, step guidance, and activity structuring was perceived as helpful in maintaining focus on learning.

As a characteristic of the middle school period when self-regulation strength is not yet sufficiently internalized, it was suggested that locking, guidance, and step presentation play a role in supplementing the learning stability line.

1) Perception of efficiency is formed around ‘perceived

convenience'rather than 'performance'

Middle school students perceived the effectiveness of digital tools as centered on immediate tangible experiences such as 'convenient,''fast,'and 'easy to see,'rather than improving academic achievement or results.

"The time spent looking for materials was reduced,""I was able to concentrate because I could see the screen clearly even from the back seat,""It was convenient to be able to write just by typing."

This is interpreted as feeling the experience of reducing the burden of learning, rather than the perception of managing learning efficiently and strategically using digital tools.

2) Attitude toward AI utilization remains at the exploration and verification stage before 'tool utilization'

An attitude of actively using AI while being cautious at the same time has been repeatedly observed.

"Sometimes they gave me wrong answers, so I learned that I shouldn't blindly trust them", "I felt like it would be plagiarism if I submitted it as is", "You have to ask specific questions to get good answers"

It can be interpreted as a transitional characteristic in which we begin to recognize both the possibilities and limitations of AI at the same time.

3) Collaboration experience was perceived as a 'peer relationship experience'rather than a 'task performance method'

Middle school students perceived collaboration as centered around interaction processes with peers, conflicts, and helping experiences rather than role division or productivity.

"Conflicts may arise while editing the article,""As we shared opinions, roles were naturally decided,""I resolved it with help from a friend."

It was observed that collaboration using digitizer was not perceived as 'collaboration of technology and knowledge,'but was felt to be centered on social relationship experiences.

4) Immaturity of self-regulation and positive acceptance of external structures

Middle school students clearly recognized the difficulty in concentrating in the digital environment, but positively evaluated the teacher's external control and structuring as a solution.

“I couldn’t concentrate because of YouTube or games,”“I liked that the teacher had a lock function that prevented me from doing other things.”

3) Detailed analysis by topic for high school students

Table 4-43. Analysis of key topics from interviews with high school students

parent topic	subtopic	Highlights
1. Awareness of digital tool effectiveness	Optimizing learning outcomes	Efficiency is recognized based on performance, such as saving time, improving task completion, and improving performance evaluation quality. Using digital tools as a means of optimizing learning strategies
2. Attitude toward using AI	Idea generation and critical validation	AI is used as a draft and idea generation tool, but the possibility of error is recognized and the question specification and verification process are carried out in parallel. There is a clear tendency to perceive it as an auxiliary tool.
3. Perception of collaborative experience	Functional collaboration based on roles and responsibilities	Collaboration is understood with a focus on task completion and efficiency, including role division, simultaneous work, and responsibility performance.
4. Recognize feedback	Metacognitive reflection tool	Use feedback as a basis for self-examination and adjustment of learning, rather than as an instruction for correction. Reflection on the learning process and awareness of continuous improvement appear.

1) Recognizing digital tool efficiency from the perspective of ‘optimizing learning performance’

High school students perceived the effectiveness of Chromebooks and Google tools not simply in terms of convenience or interest, but in terms of learning outcomes such as saving time, completing assignments, and improving the quality of performance evaluations.

“The time it took to do assignments or search for information was reduced, so I was able to spend more time on other studies”, “I created presentation materials at the same time and the time was halved", "My ability to systematically organize materials improved."

It shows that digital tools are being used as a means to optimize one's learning strategy.

2) The use of AI is recognized as an 'idea generation tool'and a 'verification target'

In interviews with high school students, the attitude of actively using AI (Gemini) while also critically examining it was clearly revealed.

"It was quick and useful when drafting ideas", "Sometimes they gave me the wrong answer, so I learned not to blindly trust it", "I learned that good answers come only when you ask specific questions."

It was observed that rather than recognizing AI as a provider of answers, it was perceived as an auxiliary tool that expands thinking and an object that requires review and modification.

3) Collaboration is understood as a 'process of dividing roles and carrying out responsibilities'rather than a relationship experience.

High school students perceived collaboration experiences as centered on task completion and efficiency rather than peer relationships.

"Each person took on one page and created it at the same time to save time", "We divided the materials into items and assigned roles", "One person created a template and everyone followed it, so it was a success."

Unlike middle school students' collaboration, which focused on interaction and relationship experiences, high school students' collaboration shifted to functional collaboration centered on roles, responsibilities, and results.

4) Recognize feedback as an 'opportunity for self-reflection'rather than an 'instruction for correction'

They showed metacognitive awareness of their own learning process and weaknesses through Google Classroom feedback.

"I was able to objectively see why I was wrong", "I developed a habit of looking back on my own learning process", "It was refreshing to be able to improve even after submitting the assignment"

Unlike middle school students who perceived feedback as a tool for immediate correction, it was confirmed that high school students used it as a basis for self-examination and learning adjustment.

Ⅴ. Conclusion

1 Conclusion of the study

Overall, this study empirically demonstrated that the use of AI and digital tools can simultaneously strengthen students' learning experiences and teachers' teaching expertise, and that these two can result in interconnected changes. This has educational and policy significance in that it goes beyond the approach of introducing digital technology as a simple auxiliary means and shows the possibility of a platform-based teaching and learning environment where teachers and students grow together. In the future, there is a need to more systematically verify the sustainability and expandability of these models through long-term follow-up studies and differentiated designs that reflect regional and school conditions.

The Albus Project is an educational demonstration project planned and operated to empirically verify how the teaching and learning experiences of teachers and students change by integrating generative AI and digital education tools into the actual school class context. Beyond simple technology introduction or one-time experience, this project sought to present an implementation model that would allow AI and digital-based classes to be stably established in school settings through a circular operating structure that includes teacher training - mentoring - lesson design - lesson application - performance analysis. Based on the above analysis results, the main conclusions of this study can be summarized as follows according to the research purpose.

First, from the student perspective, this study confirmed that the Google Workspace-based class environment and the use of generative AI (Gemini) brought about positive changes in the overall learning experience, including learning participation and interest, at all elementary, middle, and high school levels. At all school levels, time spent using digital devices and proficiency in using Google tools and generative AI improved statistically significantly, and awareness of the use of computers and AI also changed positively. In particular, there was a clear tendency for Chromebooks to be recognized as 'device suitable for learning'after being applied to actual classes, and a change in perception of device suitability was also confirmed. Analysis of student interviews repeatedly showed that the accumulation of learning records, sharing of task performance processes, organizing information using AI, and expanding ideas provided practical help in understanding and performing learning. This is interpreted as a qualitative change in learning methods rather than a simple increase in technology use. By school level, elementary school students steadily expanded their basic digital utilization capabilities, while middle school students formed strategies to selectively use tools according to the purpose of the task, and high school students showed a clear shift in recognizing generative AI as a key means of increasing learning efficiency. These results show that AI and digital classes operate in different ways depending on the stage of development, suggesting the need for customized design for each school level.

Second, from the teacher's perspective, this project shows that the use of generative AI and digital tools went beyond simply relieving work burden and worked in the direction of expanding teachers' lesson design capabilities and expertise. As a result of the survey analysis, it was found that proficiency in using digital tools and generative AI and confidence in lesson design were significantly improved, and that teachers went beyond simply using tools and strengthened their ability to select and integrate them according to lesson goals. There was no significant increase in total class hours and major work areas, and in some areas, the work structure was streamlined, and the perception that it 'helped save time on major work'was also high. This means that there has been a restructuring of the way time is used rather than an increase in the total amount of work. In teacher interviews, responses were confirmed that generative AI improved the quality of lesson design by functioning as a tool for creating materials, assisting feedback, and expanding ideas rather than replacing teachers' professional judgment. In other words, teachers are positioned as professional implementers who strategically use AI as subjects of lesson design rather than technology adopters, and this is consistent with the teacher-led performance emphasized by the OECD Teaching Compass.

Third, from a comprehensive perspective, this study confirmed that each change in teachers and students appeared interconnected within the same instructional design context. Changes in teachers' class design and operation methods led to improvements in students' learning participation, interest, and self-efficacy, and the increase in students' digital utilization capabilities and positive awareness of AI operated in a virtuous cycle that increased the quality of class participation. This change is not simply a result of increased frequency of technology use, but also means that the class environment has been structurally reorganized. In particular, the implementation model that leads to teacher training - mentoring - lesson design - lesson application - performance analysis supports teachers so that they do not bear the burden of technology use alone, and lays a systematic foundation for implementing sustainable AI and digital lessons in school settings.

2 Research Recommendations

Lastly, at the level of follow-up research, follow-up research is needed to verify whether the effects identified in this study are limited to short-term changes or are maintained and spread over the long term. In addition, there is a need to conduct parallel research on the development of differentiated AI and digital teaching models that reflect the characteristics of each school level and subject, as well as the impact of generative AI use on the learning process and cognitive and ethical judgment. Through this follow-up research, AI and digital education will be able to go beyond a technology-centered approach and develop into a sustainable educational environment where teachers and students grow together.

The results of this study provide important implications for overall educational practice and policy and system design in applying AI and digital education to school settings. In particular, it was confirmed that generative AI and digital tools work most effectively under conditions that assist and expand teachers' lesson design and professional judgment, rather than replacing teachers. In that student participation and interest in learning also depend on how teachers design and use it in the classroom context rather than whether or not the technology itself is introduced, this suggests that the core of AI and digital education lies in class design centered on strengthening teacher capabilities.

First, in terms of educational practice, this study shows that support for AI and digital classes for teachers needs to move beyond a technology-use-focused approach to encompass the entire process of instructional design, operation, and reflection. The classes that were confirmed to be effective in this study generally set “what the student should learn”rather than “what tool to use”and selected appropriate digital tools and generative AI. Generative AI tended to improve student participation and the quality of the learning experience when used to support the learning process, such as organizing learning materials, expanding ideas, visualizing thinking processes, and assisting with feedback, rather than being used as a tool to provide the correct answer to a task. Additionally, learning understanding and self-efficacy improved significantly in classes designed to record and share students' thoughts before using AI and to compare, modify, and reconstruct AI results and their own thinking. This means that educational effectiveness is maximized when AI/digital classes are designed to focus on thinking processes rather than results. The accumulation of learning records and sharing of courses using collaborative tools such as Google Docs, Slides, and Classroom served as key factors in maintaining stable student participation, suggesting that further learning records can function as a reflection tool for students to check and regulate their own learning beyond evidence for evaluation.

Second, the results of this study clearly show that there are limitations in approaching the spread of AI and digital education at the level of city and provincial offices of education by focusing on simple device distribution or one-time training. Positive changes in teachers and students occurred in an operating structure in which training, mentoring, class application, and performance feedback were organically linked rather than the digital tool itself. Accordingly, rather than judging performance based on completion of short-term training, the Office of Education needs to establish a mid- to long-term operating system that continuously supports and manages teachers' actual lesson design changes and lesson implementation processes. Additionally, considering that the use and effectiveness of AI and digital tools differed depending on the digital capabilities of each teacher and the school context, on-site mentoring and lesson design consulting worked as a more effective support method rather than uniform training. This suggests the need to institutionalize a mentoring system and best practice sharing structure by region or school group at the education office level. In addition, as securing a stable network environment and sufficient class time has been confirmed as a prerequisite for the effectiveness of AI and digital classes, the Office of Education needs to redesign the digital class infrastructure from the perspective of creating a learning environment based on class operation rather than simply ‘distributing devices’.

Third, at the national level, there is a need to redefine AI and digital education policies away from business structures centered on technology introduction and focus on teacher professional growth and class implementation structures. This study showed that AI and digital tools are not a means of replacing or simply streamlining teachers' work, but that educational effectiveness is maximized under conditions that expand teachers' lesson design capabilities and professional judgment. Accordingly, policy performance indicators at the national level also need to move away from focusing on the use or frequency of AI use and include qualitative indicators such as changes in lesson design and improvement of learning experience. In addition, given that it is difficult to accumulate and spread changes in classes with a policy structure centered on single-year contest projects, a mid- to long-term policy frame that enables continuous implementation and feedback of results at school sites through multi-year and continuous policy design is required. Furthermore, considering that the use methods and effects of AI and digital tools differ depending on the elementary, middle, and high school levels, the national curriculum and teacher training system need to more clearly establish a step-by-step AI and digital competency system that reflects the development characteristics of each school level. In addition, ethical judgment and critical utilization capabilities resulting from the use of generative AI should also be systematically addressed within the national curriculum and teacher professional development system.

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An Analysis of Changes in Learning Experiences and Teaching Effectiveness Through the Use of AI and Digital Tools

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