Brain, Digital, & Learning

pISSN : 2384-2474
eISSN : 2586-7490

RESEARCH ARTICLE

Development of A Functional Model for An AI-based Adaptive Learning Platform

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ABSTRACT

This study aimed to examine how experts in AI-based learning perceive the categories of learning platform components to which AI technologies are applied, as well as the interrelationships among these components. It also conducted a theoretical and empirical analysis to derive a compositional model suitable for the ultimate purpose of learning. To achieve this purpose, a mixed-methods approach was employed, combining quantitative survey data with qualitative findings from expert focus group interviews. The analysis categorized functional components into two major contexts: a technological context, including AI algorithms, data analytics, and feedback systems, and a learning context, consisting of learning content, instructional strategies, and learner interaction. According to the results of the quantitative research, sub-factors within each context were categorized and analyzed to investigate whether they exist in a relationship with other sub-factors. As a result of this study, experts recognized the necessity of dynamic integration to support meaningful learning processes between technology and the learning context. Experts also hold different perceptions, depending on the group's perspective on the interdependency among sub-factors of an AI-based learning platform. However, experts shared a common opinion that AI technologies must interact with educational goals and adapt to learner's cognitive, behavioral, and affective characteristics in real-time, using data-driven insights generated by the learners. Accordingly, this study developed and proposed a model in which technological and pedagogical elements are functionally integrated within a data-driven context. The resulting learner-centered model envisions the future of AI-based adaptive learning platforms, offering both a theoretical foundation and practical guidance for system design.

Keywords : AI, Learning platform, Learning materials, AI-based learning, education 4.0

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Brain, Digital, & Learning
2025, Vol. 15, No. 3, 331-355

https://doi.org/10.31216/BDL.2025.15.3.2

Received: July 11, 2025
Revised: September 02, 2025
Accepted: September 07, 2025

Introduction

In education, 'Learning Materials (LM)' is defined as a concept encompassing various educational materials used to support the effective achievement of learning goals. Traditionally, learning materials have been developed with consideration for consistency with the curriculum, systematicity of subject content, and the cognitive characteristics of learners, often in a static and uniform form centered mainly on textbooks. However, with the development of digital technology and the shift in the educational paradigm, learning materials are being re-examined as a more expansive concept. Current learning materials are understood as a concept encompassing all materials and tools used for learning in the educational context, and this concept can be traced back to the long pedagogical tradition. In the 19th century, G.P. Brammer explained that the function and importance of 'learning materials' in pedagogy and pedagogy textbooks (1838) were classified and visualized and provided to students, and that the use of learning materials made classes enjoyable and easier to understand, and teachers could save time (Hansen & Gissel, 2017). This perspective can be applied to today's digital and analog learning materials, suggesting that learning materials can positively motivate learners, promote understanding, and improve learning outcomes. In addition, it shows that teachers function as a practical tool to structure teaching content and operate classes more efficiently.

Bundsgaard and Hansen (2011) view learning materials from three perspectives. First, from the perspective of viewing learning materials as 'text', at this time, the learning materials possess potential didactic value. The material has the potential to support teacher's classes and promote student's learning. Second, when learning materials are recognized as 'tools' used in the context of actual instruction, it acts as a realized teaching-learning potential. In other words, it focuses on the specific educational effects that occur during the actual use of learning materials by teachers and students. Third, from the perspective of evaluating the results of using learning materials over time, this is understood through the realized didactic potential, which has had a real impact on student's learning and teacher's classes. In other words, learning materials are not just auxiliary means but key educational media that expand and realize the possibilities of teaching and learning (Hansen & Gissel, 2017).

Meanwhile, the rapid development of digital technology and the spread of edu-tech have brought about essential changes in the form, function, and method of learning materials. In particular, introducing artificial intelligence (AI) technology enables the analysis of learner's response patterns, misconceptions, and achievement levels in real time, providing more precise and personalized data and significantly enhancing educational efficiency and accessibility. In addition, the automatic generation and recommendation functions for various multimodal content, such as voice, video, and simulation, play a crucial role in enhancing the learner's immersion and quality of learning experience while alleviating the burden of data design on instructors. In particular, through convergence with adaptive learning technology, AI-based learning materials analyze learner data in real-time and enable services such as personalized content provision, feedback, and learning path guidance based on this. Therefore, AI-based learning materials offer the potential to provide individualized learning experiences by precisely analyzing learner's achievement levels, learning styles, and preferences (Panadero et al., 2023).

With these technological advances, digital learning materials are evolving into a more dynamic and interactive form, surpassing the level of electronicization of printed materials. As a representative example, digital textbooks are one tool that has enabled learners to utilize digital content based on a standardized learning platform actively. However, digital textbooks continue to highlight limitations in their educational use, as their form and structure often prioritize technical implementation over educational content. On the other hand, with the recent spread of advanced artificial intelligence technologies, including Generative AI, AI Digital Textbook, Learning Record Store (LRS) platforms based on learning history, and various private AI learning platforms, the concepts and functions of learning materials are expanding in a more comprehensive and flexible direction. AI-based learning materials are evolving into integrated educational tools that offer diverse learning experiences and perform complex functions, such as customizing learning, providing real-time feedback, and analyzing learner behavior through AI algorithms, extending beyond simple content delivery.

However, further analysis is needed to determine whether these technology-oriented developments fully reflect the essential purpose of education, which is to promote learner's understanding, induce interest, and lead to cognitive transformation. The principle of "meet the learner where they are" is not just a technical adjustment but emphasizes the importance of understanding the learner's context and tailoring educational interventions accordingly (US Department of Education, 2023). AI-based learning materials have the potential to promote meaningful learning for learners; however, careful consideration must precede their development to ensure that technical design does not negatively impact learning (Kocé-Januchta et al., 2022). An interaction-based design that comprehensively reflects learner's background experiences, emotions, and motivations is required, which can only be achieved through the educational judgment and explanation strategies of human teachers, as well as the ability to capture and utilize 'teachable moments'. Therefore, AI-based learning materials must shift from a technology-oriented approach to a purpose-oriented approach in teaching and learning.

To enhance the effectiveness of AI-based learning platforms, it is crucial to comprehend how multidimensional components, including learning elements and operational elements, interact to shape learning experiences, as well as technical elements (Chen et al., 2020). AI technology extends beyond the level of technological automation of content, requiring sophisticated learning designs that consider the cognitive, affective, and social aspects of learners. Existing studies on AI-based learning platforms have generally focused on specific technologies or application cases or have limited their experiments to specific age groups or subjects (Kong et al., 2022). However, for the effective design of AI-based adaptive learning platforms, a multidisciplinary approach that considers the impact of technology on learning strategies and instructional design beyond technology-oriented analysis must be parallel (Pesovski et al., 2024). In particular, the recognition of the linkages between the technical and educational components of AI learning platforms, as recognized by experts, is a key criterion in determining the practical design and policy direction.

Therefore, this study aims to diagnose how experts perceive the categories of learning platform components to which AI technology is applied and to conduct a theoretical and practical search to derive a compositional model suitable for the ultimate purpose of learning. This research aims to propose the direction and design principles of the platform that align with the future-oriented educational environment rather than merely describing the functional structure of the existing platform. In particular, this study intends to contribute to the establishment of a prototype model for an AI-based learning platform that can be applied in the actual educational field by deriving an integrated composition system of technical contexts (e.g., AI algorithms, learning analysis, interfaces, digital technologies, etc.) and educational contexts (e.g., teaching strategies, cognitive load control, learner motivation, learning content, etc.).

Theoretical Background

The Trend on Learning Platform with AI

Recently, the educational environment has undergone rapid changes with the introduction of artificial intelligence (AI), which is providing breakthroughs through systematic service solutions, particularly in the field of personalized learning (Cardona et al., 2023). This AI-utilized learning system can be described as a system that provides customized learning content by analyzing learner's psychological state and behavioral data on the platform and provides appropriate learning feedback activities and materials by analyzing learner's previous academic performance and learning patterns (Maity & Deroy, 2024; Navhani et al., 2025; Wang et al., 2025). Therefore, the AI-utilized learning system can be described as an AI-based adaptive learning platform that adjusts content in real-time based on AI technology and provides personalized feedback based on data analysis on learner's knowledge experiences, achievements, learning styles, and learning emotions.

In general, these AI-based adaptive learning platforms can utilize statistical modeling and AI algorithms to analyze big data, as well as learner's cognitive, emotional, and behavioral data, to design optimized learning paths and provide them as learning support services through platforms. For example, according to Wang et al. (2025), the United States operates a platform that provides personalized learning content by analyzing individual learner's achievement levels in real time using innovative AI-based machine learning algorithms, such as Carnegie Learning, Knewton, and DreamBox. The use of these platforms has demonstrated an improvement in learner's understanding of learning content. China's Squirrel AI platform evaluates learner's understanding based on more than 10,000 knowledge points, recommends appropriate tasks, and optimizes individual learning paths through deep learning-based knowledge graphs (Wang et al., 2025). According to these studies, the use of AI-based learning platforms is effective in improving student's test performance and reducing school dropout rates.

Furthermore, unlike the United States and China, AI-based education in Finland focuses on improving creative problem-solving skills and improving social-emotional learning (Setälä et al., 2025). The AI-based learning support tools in Finnish schools provide students with self-directed learning opportunities, allowing them to explore subjects at their own pace and receive guidance from teachers. This approach has generally had a positive effect on psychological aspects as well, with students reporting a higher level of motivation and reduced test anxiety compared to evaluation-oriented AI learning models.

In this way, the AI-based adaptive learning platform demonstrates the potential of a system that offers individualized and customized learning experiences informed by AI algorithms that analyze data such as learner's experiences, knowledge, emotions, and behaviors. In other words, the AI-based adaptive learning platform demonstrates that it is possible to provide individualized educational services and support for learners within its platform structure by utilizing data analysis-based AI algorithms related to learner characteristics.

Realistic Limitations of Technology-Based Learning Materials

Like other social philosophies and values, the educational paradigm has undergone developmental changes in tandem with the times, reflecting the evolving philosophy and values of education (Table 1). The educational paradigm is generally shifting from Education 1.0 to the current Education 4.0. The change extends beyond one-way, knowledge-transfer-oriented education 1.0 and education 2.0, emphasizing two-way interaction between teachers and learners. It evolved into Education 3.0, which emphasizes learner-led participation, and Education 4.0, which focuses on AI, cooperative learning, and personalized adaptive learning. In particular, Education 3.0 is based on an educational philosophy that recognizes education as a process of constructing meaning rather than simply transferring knowledge and values the learner's leading participation (Utomo, Bon, & Hendayun, 2019). However, as the digital transformation and the spread of Edutech accelerated, a technology-oriented educational environment emerged (Canvas by Infrastructure, 2025), revealing a gap with the original philosophy of Education 3.0 and causing various problems. The first problem is the deepening of the phenomenon of purposeful technology. As technology, which was initially a tool for supporting teaching and learning, has become a standard for determining the success or failure of education, the tendency to judge the quality of education by technical specifications or platforms has intensified. Second, there is a concern that learner-centeredness will be weakened. On the surface, it aims for individualized and customized learning. In reality, the learner's initiative, inquiry, and critical thinking may be hindered by algorithm-driven uniformity in content delivery and a constrained interaction structure. In reality, learner's initiative, inquiry, and critical thinking are often suppressed by algorithm-based, uniform content delivery and a limited interaction structure. Third, educational content is being diluted. Content development that focuses on technical feasibility weakens the consistency between teaching and learning goals and educational content, resulting in an increasing number of classes that only perform formal activities rather than engaging in meaningful, conceptual learning. Fourth, the deepening of educational inequality is being confirmed. The gap in digital device accessibility, network environment, and digital literacy leads to an imbalance in learning resources, resulting in structural problems that deepen the learning gap.

Table 1. Developmental change of learning strategies and materials according to educational paradigm

Category	Education 1.0	Education 2.0	Education 3.0	Education 4.0
Core Value	Knowledge transmission	Interaction	Learner autonomy	Hyper-personalization, AI collaboration
Material Format	Textbooks, printed materials	Activity sheets, workbooks	Digital content, LMS	AI-based content, AR/VR, generative materials
Learner Role	Passive recipient	Participant	Self-directed explorer	Competency-based designer, collaborator
Material Design	Answer-centered, uniform	Inquiry-centered, open-ended	Flexible and customizable	Real-time personalization, adaptive design

In the end, these problems naturally required a return to the core value of education 3.0, namely learner-centered education —a process of constructing meaning between humans and the humanization of education. Due to this influence, the subsequent education 4.0 paradigm suggests that efforts to integrate and reconstruct AI-based technologies in an educational context are critically essential rather than simply instrumentalizing or absolutizing them.

A Paradigm Shift Toward Human-Centered Education with AI

As a reflection on technology-oriented education, such as AI and digital, the learner-centered educational paradigm was emphasized. In other words, Education 4.0 is a future-oriented educational paradigm that emerged in response to the rapid social and structural changes brought about by the Fourth Industrial Revolution. Beyond the existing knowledge transfer-oriented education, it focuses on learner-centered creative problem-solving, convergence capabilities, digital literacy, and human-machine collaboration capabilities (Verweij, 2024). This was formed in a flow in which the purpose, method, content, and structure of education were reorganized according to the transition from an industrial society-based education system to a digital-based society. Accordingly, learning materials are also changing from a simple knowledge transfer tool to a medium that supports learner's meaning composition and competency development (Table 1).

Education 4.0 is a paradigm that emerged after critically recognizing that the learner's initiative, cooperation-oriented learning, and meaning-building-oriented educational philosophy, as envisioned in Education 3.0, were not implemented correctly in reality due to the widespread adoption of technology-oriented learning materials. In particular, after the digital transformation, as learning materials became increasingly dependent on the implementation of technology or algorithm-based personalization, problems that weakened the learner's subjectivity and hindered the quality of educational content were revealed. As a result, Education 4.0 not only introduces technology but also provides a direction for critically integrating technology in an educational context and reconstructing it humanely.

The development of Education 4.0 requires a fundamental shift in the perception of learning materials. Education 4.0 redefines learning materials as dynamic learning tools that are carefully designed and support learner's experiences based on learning data, moving away from existing static content. In an artificial intelligence-based learning environment, learning materials go beyond simple means of information delivery and function as a key medium for optimizing educational experiences by collecting and analyzing various data such as learner's interaction records, learning speed, error types, and selection paths in real-time. These data-based learning materials not only measure learning outcomes but also contribute to improving the responsiveness and timeliness of education by providing an in-depth diagnosis and adjustment of the learning process. Accordingly, learning materials must evolve into interactive and adaptive forms that promote learner's semantic composition and proactive inquiry. Therefore, learning materials in the era of Education 4.0 should not merely introduce technology functionally but should incorporate educational design principles that encourage learner's participation and critical thinking. It is essential to have a sophisticated structure that aligns with the learning goal and educational context.

Therefore, learning materials in Education 4.0 need to go beyond 'technology-oriented tools' and be transformed into a core medium of human-centered learning design that focuses on providing meaningful experiences, emotions, social development, and learner growth (Zhang et al., 2023). This re-establishment presupposes efforts to avoid the blind acceptance of technology and to critically reconstruct technology and data within the educational context based on philosophical reflection on the purpose of education. In particular, educational design utilizing learning data should be implemented in a way that prioritizes human-centeredness and educational ethics. The significance of Education 4.0 can be further strengthened as a practical alternative to overcome the limitations of technology-oriented learning materials and preserve the essence of education. Therefore, in the direction of AI-based future education, the theoretical and practical paradigm of learner experience-oriented education should be implemented as a new educational model beyond the technology-based education paradigm.

Methodology

Research Procedure

This study was conducted according to the following procedure. First, a comprehensive study was conducted to lay the conceptual foundation of the research by examining prior research and related theories on artificial intelligence and digital education innovation learning platforms. Second, experts with direct experience in the verification screening of AI-based learning platforms were selected as participants in the study, and quantitative data were collected using a survey tool developed specifically for them. Third, although the overall perception trend of experts could be grasped through the survey, it was judged that a more in-depth exploration of the operation method and functional context of each component was necessary, so an expert group interview (FGI) was designed to supplement qualitative data, and interviews were conducted with some experts. Fourth, the collected quantitative and qualitative data were processed using appropriate analysis methods and then interpreted in an integrated manner to derive the structural characteristics and interconnection of expert perceptions. Fifth, a new educational innovation model and component were proposed based on these analysis results, and the applicability of the derived model, as well as its theoretical and practical implications, were presented (Fig. 1).

Fig. 1. Research procedure

Participants

Participants in this study consisted of experts who directly participated in the inspection and deliberation process for AI digital textbooks developed by the revised 2022 curriculum. They have worked as judges, chairs, and vice-chairs on the content and technical aspects of AI digital textbooks, focusing on mathematics, information, and English subjects, and have experience in analyzing and evaluating various components of AI-based learning platforms according to test criteria. Based on these practical participation experiences, they can be regarded as a group of experts with practical understanding and judgment ability on how technical and learning elements of AI-based adaptive learning platforms work in the actual educational field and are interconnected. In addition, many participants belong to various educational fields, including educational institutions (elementary and secondary schools). These education offieces, universities, and research institutes make them suitable subjects for analysis, given the even fieldwork, expertise, and policy linkage required by this study.

Development of the Survey Instrument

The questionnaire was developed to investigate the perception of experts quantitatively consisted of basic and response areas. The basic area was composed of items to understand the personal characteristics of participants such as gender, affiliated institution, position, and experience, and the response area was composed of a total of 7 items to measure perception of whether components corresponding to the technical and learning context of the AI-based learning platform function independently or interconnected. All questions were designed using a 5-point Likert scale to quantify the respondent's level of perception.

The development of the questionnaire was based on the self-verification result report of the AI digital textbook and the verification reference documents (CSAP, test items, driving items, UI/UX items, etc.). The skills and learning functions were classified by each central element and reflected in the questions. The draft question underwent a rigorous review process to ensure content validity, conducted by a panel of five experts in the fields of AI and digital education. Each question was revised and supplemented until an agreement was reached among the experts. The result of the reliability analysis (Cronbach's α) for the final question was confirmed to be 0.79, indicating that it is a tool with high internal consistency.

The survey was conducted with the voluntary consent of the participants after providing sufficient explanations regarding the study's purpose, the response method, and our information protection policy. A total of 136 experts participated in the online questionnaire, which was distributed to collect their responses. Table 2 summarizes basic information, including gender, age, affiliated institution, position, and experience, of the experts who participated in the survey. It also presents the characteristics of the study participants and the representativeness of the group.

Table 2. Result of basic information of participants (N=136)

Affiliation		Position		Career		Academic degree		Major	
Answer	N(%)	Answer	%	Answer	%	Answer	%	Answer	%
School & Education Office	73(53.7)	Teacher	73(53.7)	Less than 5 years	1(0.7)	Bachelor	16(11.8)	Education	88(64.7)
University & Research Institute	52(38.2)	Professor	49(36.0)	5-10 years	18(13.2)	Master	59(43.3)	Content subject	24(17.6)
Private Enterprise	11(8.1)	Researcher	14(10.3)	11-15 years	37(27.2)	Doctor	61(44.9)	Digital technology	24(17.6)
				16-20 years	23(16.9)				
				21-25 years	29(21.3)				
				26-30 years	13(9.6)				
				more than 30 years	15(11.0)				

The gender distribution of the participants was 58.1% male and 41.9% female, with an average age of 47.07 years. The affiliated institutions were distributed across various education-related institutions, including elementary, middle, and high schools, education offices, universities, research institutes, and private companies, and the region was also evenly distributed throughout the country, including Seoul, Gyeonggi, Gwangju, Daegu, and Busan, confirming that the participating group in this study was an expert group with even fieldwork, expertise, and regional representation.

Focused Group Interviews

Participants in the expert group interview were selected from those who responded to the survey, focusing on experts who played a key role in the review process of AI digital textbook verification. Specifically, it consisted of 16 people, including 16 chairs and vice chairs, eight content review experts, and eight technical review experts. Many of them have more than 10 years of practical experience in related fields, and in particular, the focus group participant was evaluated as having a high level of expertise in the structural characteristics and functional connections of AI-based learning platforms. Table 3 summarizes the affiliation, major, and career of the experts who participated in FGI.

Table 3. Composition of participants for FGI (N=16)

Subject	Expert	Major	Affiliation	Career	Experience of Evaluation committee
Mathematics	A	Statistics	University	20 – 25 years	Content
	B	Computer education	University	20 – 25 years	Technology
	C	Algebraic	University	15 – 20 years	Content
	D	Smart sensors and systems	University	more than 30 years	Technology
	E	Hermeneutics	University	10 – 15 years	Content
	F	Pedagogy	University	20 – 25 years	Technology
Information	G	Data Science	University	more than 30 years	Technology
	H	Computer science	University	25 – 30 years	Content
	I	Computer science	University	15 – 20 years	Content
	J	Information and communication engineering	University	more than 30 years	Technology
English	K	Multimedia English studies	School	more than 30 years	Content
	L	English education	University	15 – 20 years	Content
	M	information protection	Research institute	10 – 15 years	Technology
	N	educational engineering	University	10 – 15 years	Content
	O	Information and communication engineering	Research institute	5 – 10 years	Technology
	P	Data science	University	10 – 15 years	Technology

The FGI questionnaire consisted of four open-ended questions derived from the results of a survey conducted by experts in advance. Interviews were conducted online in a non-face-to-face manner, dividing participants into small groups based on their math, information, and English subject areas. After providing all participants with prior guidance on the purpose and procedure of the study and obtaining their consent to participate, the entire interview process was recorded and transcribed for use as qualitative data in the analysis. The purpose of this interview was not to elicit a specific consensus but to gather diverse experiences and perceptions from experts. The transcribed data were organized by item and then systematically classified and interpreted through expert opinions, using thematic analysis to derive in-depth insights into the functional relationships and contexts of the components of the AI-based learning platform.

Data Analysis

This study aimed to elucidate the functional relationship between the components of the AI-based adaptive learning platform in depth by integrating and analyzing the collected quantitative and qualitative data in a complementary manner.

First, the survey results, which are quantitative data, were used to understand the overall perception trend of the expert group through descriptive statistics and itemized response analysis. For components corresponding to both the technical and learning contexts, structural trends were quantitatively analyzed to determine whether experts perceived each function as independent, linked, or integrated. In addition, a one-way ANOVA was performed using the SPSS 29 program to confirm the difference in perception according to the major and degree level of the expert group, and statistical differences were reviewed through a post hoc test.

FGI, a qualitative data, was analyzed based on written responses collected in advance and real-time online interview content. The interview was conducted with a focus on exploring various perspectives rather than deriving a specific agreement, and the transcribed conversations were organized by item and then categorized through thematic analysis. Response types were classified into consensus responses within the expert group, responses with disagreement, and individual responses. The validity of the interpretation was increased through cross-review among the researcher group. In particular, after performing the first analysis based on the written responses submitted in advance, the qualitative data were systematized in a way that analyzed the opinions of respondents by the core content included in the question and categorized them based on common meaning.

Through this quantitative analysis, the structural trend of expert recognition was identified, and the context and background of the recognition were explored in depth through qualitative analysis, allowing for an empirical and multi-layered interpretation of the functional relationship between skill and learning components.

Model Construction for AI-enriched Adaptive Learning Platform

To systematically configure a learning platform using AI technology, it is necessary to identify key sub-factors that must be considered about the platform's functional nature and the educational utilization goal and to explore the categorical structure into which these factors are classified. In particular, it is essential to perform each functional definition and system categorization by distinguishing between the intrinsic attributes of the platform (e.g., data processing function, user interface, system operation structure) and external attributes (e.g., learner support function, teaching-learning effectiveness, teacher-learner interaction).

To this end, this study established a category domain based on the functional attributes and educational roles of components, as analyzed in the literature on learning platforms and digital learning materials utilizing AI technology. In particular, to ensure consistency with the teaching-learning support function that the AI-based learning platform aims to achieve, the teaching-learning competency framework utilizing digital technology was referenced. Through this, not only technical elements but also learning elements were analyzed in an integrated manner. Through this analysis, a conceptual categorization framework was derived to explain how each element interacts in a hierarchical or parallel relationship.

Based on this process, this study developed and proposed a 'human-centered AI-based adaptive learning platform' in which technical and learning elements interact and operate organically. This model functions as a theoretical framework that can structurally present the design principles, examination criteria, and curriculum connection directions of future learning platforms, including AI digital textbooks, and further contains policy and practical implications that can be applied to various educational practice fields such as teacher training, teaching-learning design, and policy-based platform development.

Results

Perception of Experts for AI-enriched Adaptive Learning Platform

To determine how experts perceive the categories and relationships of the learning platform components to which AI technology is applied, the survey results of the experts who participated in the AI digital textbook test were analyzed to calculate the average value, confirming their perceptions (Table 4). When looking at whether they agree with the confirmatory question about the independence and connection of learning and technical elements derived through literature review, the average response to 'the independence of learning and technical elements' was 4.32 (SD: 0.86). The average response to 'the independence of technical elements' was 4.38 (SD: 0.80). The percentage of respondents who answered 'very yes' and 'yes' was 88.97%, and most agreed that learning and technical elements could be composed independently. On the other hand, among the questions about the connection between learning elements and technology elements, responses to 'user interface and experience,' which is a basic function of AI learning platform, averaged 4.54 (SD: 0.75), responses to 'interaction and collaboration' averaged 4.55 (SD: 0.79), responses to 'data analysis and learning analysis' averaged 4.51 (SD: 0.81), and the average response to 'evaluation and feedback system' was 4.52 (SD: 0.77) and more than 90% of the respondents agreed. In particular, 97.79% agreed that there might be differences in learning effects if there are differences in the content elements constituting learning, such as 'difference in learning effects of the same AI technology.' In other words, on the AI learning platform, learning elements and technology elements may exist independently in a constructive context; however, in a functional context related to learning effects, they function interconnectedly.

This result is an intrinsic feature of the AI system, as it aims for adaptive learning, where the response varies depending on the input information provided from the outside and the learning diagnosis result for the user. Therefore, experts have found that AI technology-based learning platforms recognize that learning and technology elements can function independently and that these independent elements have strong interconnectivity, enabling them to achieve the purpose of learning.

Table 4. Result of experts' response for each item of survey

Evaluation category		Evaluation contents	M(SD)	Answer	
				N	%
Independence of learning and technological factor		Specific components should be categorized separately into learning context and technological context.	4.32(0.86)	Strongly Agree	49.26%
				agree	39.71%
				neutral	5.88%
				Disagree	3.68%
				Strongly Disagree	1.47%
Independence of technological factor		Foundational IT elements like security authentication, compliance with standards, and integrated authentication are seen as independent of the learning context.	4.38(0.80)	Strongly Agree	53.68%
				agree	35.29%
				neutral	6.62%
				Disagree	4.41%
				Strongly Disagree	0.00%
inter-connection between learning and technological factor Strong	user interface and experience (UI/UX)	Components related to user interface and experience (UI/UX) function through the integration of both learning and technological contexts.	4.54(0.75)	Strongly Agree	66.91%
				agree	23.53%
				neutral	6.62%
				Disagree	2.94%
				Strongly Disagree	0.00%
	interaction and collaboration	Components related to interaction and collaboration the learning and technological contexts.	4.55(0.79)	Strongly Agree	68.38%
				agree	23.53%
				neutral	2.94%
				Disagree	5.15%
				Strongly Disagree	0.00%
	data analytics and learning analytics	Components related to data analytics and learning analytics function through the integration of the learning and technological contexts.	4.51(0.81)	Strongly Agree	65.44%
				agree	25.00%
				neutral	4.41%
				Disagree	5.15%
				Strongly Disagree	0.00%
	assessment and feedback systems	Components related to assessment and feedback systems function through the integration of the learning and technological contexts.	4.52(0.77)	Strongly Agree	65.44%
				agree	25.00%
				neutral	5.88%
				Disagree	3.68%
				Strongly Disagree	0.00%
	Learning effect	Even when the same AI technology is applied, its effectiveness may vary depending on the learning content.	4.57(0.61)	Strongly Agree	60.29%
				agree	37.50%
				neutral	1.47%
				Disagree	0.00%
				Strongly Disagree	0.74%

Difference of Perception among Expert's Groups

In addition to subject content experts and subject education experts, AI and computer science experts who are technical context experts participate in the AI digital textbook verification process, which utilizes a learning platform enriched by AI technology. A survey of experts in each field who have participated in the verification process on whether the learning elements and technology elements of the AI technology-based learning platform function independently or in connection with them was conducted, and it recognized that they could exist and function independently, but they had no choice but to be interconnected in the ultimate aspect of learning. However, Table 5 shows the results of analyzing the response differences according to the type of major, degree, and affiliated institution to determine whether these responses are affected by the attributes of a specific group.

Table 5. Result of experts' response for each item

Item	Major			Academic degree			Affiliation		
	Education (n=88)	AI Tech (n=24)	Subject Content (n=24)	Bachelor (n=16)	Master (n=59)	Doctor (n=61)	School & Education Office(n=73)	University & Research Institute (n=52)	Private Enterprise (n=11)
1	4.24(0.95)	4.42(0.72)	4.50(0.59)	4.44(0.63)	4.34(0.96)	4.26(0.81)	4.30(0.92)	4.33(0.76)	4.36(0.92)
2	4.39(0.78)	4.17(1.01)	4.58(0.58)	4.06(0.77)	4.44(0.84)	4.41(0.76)	4.33(0.85)	4.50(0.85)	4.18(0.87)
3	4.58(0.77)	4.42(0.78)	4.54(0.66)	4.13(0.96)	4.57(0.81)	4.62(0.58)	4.52(0.84)	4.62(0.60)	4.36(0.81)
4	4.59(0.80)	4.33(0.92)	4.63(0.58)	4.31(1.01)	4.59(0.83)	4.57(0.67)	4.53(0.88)	4.60(0.69)	4.45(0.52)
5	4.57(0.81)	4.08(0.93)	4.71(0.46)	4.38(1.02)	4.46(0.88)	4.59(0.67)	4.51(0.88)	4.60(0.69)	4.09(0.70)
6	4.57(0.78)	4.25(0.85)	4.63(0.58)	4.38(1.02)	4.46(0.86)	4.62(0.58)	4.48(0.88)	4.69(0.54)	4.00(0.64)
7	4.58(0.64)	4.38(0.58)	4.71(0.46)	4.50(0.52)	4.58(0.70)	4.57(0.53)	4.59(0.64)	4.56(0.54)	4.45(0.69)

As a result of analyzing the average responses to each question from the expert group, according to their major, education-related majors and subject content studies majors strongly agreed on the connection between learning and technical elements. In contrast, AI technology majors agreed relatively weakly. In other words, AI technology majors acknowledge the connection between technical and learning elements; however, it can be seen that they also consider the independent function of individual elements. As a result of analyzing the differences according to the degree of experts, compared to bachelor's degrees, master's and doctoral degrees strongly agreed on the connection between learning and technical elements in the functional context of the learning platform using AI technology. It is possible that master's and doctoral degrees presented a somewhat reserved response because they are more confident in their expertise in related fields than bachelor's degrees. Lastly, according to the type of institution to which they belong, experts from private companies agreed relatively weakly on the connection between technical and learning elements compared to experts from schools, education office, universities, and research institutes. In the results, experts from universities and research institutes were included in the AI-related technology majors. However, the results classified according to the type of institution showed a lower degree of agreement because these experts were excluded. In particular, most private experts are AI technology-related majors and possess high expertise in technology but relatively low expertise in education. As a result, they show a relatively low rate of agreement on the connection between technology and learning. To confirm whether the difference in perception according to the characteristics of the group, as described above, is statistically significant, a significant difference was found in some content areas (Tables 6, 7, 8, 9).

As a result of analyzing the difference in response of the expert group according to the major, the difference between groups and groups in response to the connection between learning and skill elements in the 'data analysis and learning analysis function' was identified. In other words, there was a difference in the perception of the connection between technical elementary learning elements for data analysis and learning analysis functions, depending on the expert's major. As a result of performing a post-analysis to confirm the similarities and differences between groups, education majors and subject content majors converged into the same group, unlike AI technology majors. These results stem from the understanding that AI-based learning interacts with sub-elements, considering that learning, as an educational component, and learning content, as a content component, work together to enhance the learning process. On the other hand, AI technology majors recognize that technical and learning elements can function independently, at least in part, in terms of data analysis.

Table 6. ANOVA result of response according to expert's major

Item		Sum of squares	*df*	Mean square	*F*	*p*
Interconnection between learning and technological factors in data analytics and learning analytics	Between group	5.610	2	2.805	4.529	.013*
	Within group	82.383	133	0.619		

*:p<.05

Table 7. Result of post-hoc analysis on item 5 according to expert's major

Major	N	Subgroup for $P = 0.05$	
		1	2
AI Tech	24	4.083	
Education	88		4.568
Subject Content	24		4.708

As a result of analyzing the difference in response of the expert group according to the affiliated institution, statistically significant differences were identified in the perception of the connection between learning and technical elements in the context of assessment and feedback systems. Depending on the institution to which they belong, experts had differing perceptions of the connection between evaluation and feedback functions. As a result of performing a post-analysis to confirm similarities and differences, experts from private companies, schools, education offices, universities, and research institutes gathered in the same group, unlike experts from these institutions. This result is because the group of experts who participated in the verification process is divided into education workers and the rest of the private companies. Since education workers comprise incumbent elementary, middle, and high school teachers, as well as university professors, they correspond to those who majored in subject education and subject content studies among the majors discussed above. Most AI technology majors are university professors or employees of private companies, but university professors tend to respond differently to private company workers in terms of evaluation and feedback. Since university professors are also educators, this means that even AI technology majors who are less related to education, unlike private company experts, recognize that learning and technical elements should be linked in terms of evaluation and feedback.

Table 8. ANOVA result of response according to expert's affiliation

Item		Sum of squares	*df*	Mean square	*F*	*p*
Interconnection between learning and technological factors in assessment and feedback systems	Between group	4.638	2	2.319	4.096	.019*
	Within group	75.296	133	0.566		

*:p<.05

Table 9. Result of post-hoc analysis on item 6 according to expert's affiliation

Affiliation	N	Subgroup for $P = 0.05$	
		1	2
Private Enterprise	11	4.000	
School & Education Office	73		4.480
University & Research Institute	52		4.692

Most responses regarding the connection between AI learning platform functional elements and learning content elements were similar among subject education majors and subject content majors. In contrast, there was a notable difference in the responses from AI technology majors. Therefore, while AI technology majors agreed relatively weakly on the connection between the technical and learning areas, education-related majors strongly agreed, indicating that they perceived each other differently.

AI technology majors are divided among universities, research institutes, and private companies, and there are differences depending on the institution to which they belong as a result of examining whether they consistently respond to the linkages by area. In particular, experts from universities and research institutes strongly agreed with school experts on the evaluation and feedback functions, while experts from private companies agreed weakly. Therefore, while experts from private companies agree on the connection between the technical and learning area elements of the learning platform using AI technology, the fact that they acknowledge it is weaker than other expert groups suggests that the technical area element has structural independence from the learning area element. However, under the condition that it functions as a learning platform, it must be linked to the learning area. In addition, the strong agreement between subject education majors and subject content studies majors regarding the connection compared to other majors suggests that, from an educational perspective, learning content and learning methods will inevitably have an impact. Therefore, the learning platform utilizing AI technology is divided into a technical context and a learning context; however, this means that the technical area, represented by digital AI, and the learning area, represented by learning content and methods, must be interconnected. In addition, it was found that the sub-elements of the technical and learning areas interact within the platform where the learning function is implemented, and the sub-elements of each area function more strongly than the inter-area connections.

It is necessary to confirm whether this interpretation of the expert group's survey response is valid. To achieve this, 16 members of the expert group were selected to participate in a FGI on the questionnaire response. Most of the expert opinions participating in the FGI were similar to the questionnaire responses, but more detailed interaction relationships between factors were confirmed (Table 10).

Table 10. Result of focus group interview with experts

Response Category	Summary of Responses	Respondents
Independence of technological elements	Some technologies such as system, security, and network can operate independently of learning content. Platform-based technologies may function regardless of content.	A, B, C, D, E, F, G, H, I, J, K, L, N, M, O, P
Interconnection between learning and technological elements	Technologies that interact with learners are closely linked to learning content. Technology alone cannot explain learning effectiveness and must be aligned with educational goals. Various AI platform features (e.g., UI/UX, tutor, ethics) operate integrally with learning elements.	A, B, C, D, E
Interconnection between learning and technological elements	From an educational perspective, "content" refers to subject matter and learning objectives, which must be tightly linked to technology. The connection between content and technology is essential; technology serves as a key support mechanism rather than a standalone tool. Even within the same platform, learning outcomes may vary depending on the content.	B, C, G, H, I, J, K, L, O, P
Integrated function of learning and technological elements	Even when the same AI technology is used, learning outcomes may vary depending on instructional methods, learner characteristics, and educational standards. Technology is merely a tool, and the educational context is the key determinant.	D, E, F
Differences in technological effectiveness by learning context	The structure of the AI model and its data configuration differ based on learning content, leading to variability in effectiveness. The same AI features may yield different outcomes depending on the learner and content.	A, B, D, F
Differences in learning outcomes by learning content and methods	Due to differences in educational standards and how content is presented in textbooks, even the same topic may lead to different results. The application of technology is closely related to the pedagogical criteria and subject matter of the curriculum.	C, E, H, I, J
Interconnection between technological and learning contexts in data analysis	From a data analysis and feedback context, technological and learning elements are interrelated. It is difficult to separate these elements and consider them functioning independently.	B, D, E, H, I, J, O

In particular, experts suggested that hardware components such as systems, security, and networks can function independently in terms of technology. Hardware components can be viewed as related to the physical infrastructure. On the other hand, when the learning platform interacts with users through learning content, the technical elements and learning elements function effectively. In particular, the implementation of learning, the ultimate function of the learning platform, is said to function by interacting with technical and learning elements from a software perspective. Therefore, it was confirmed that the components of the learning platform using AI technology need to be distinguished between the hardware component aspect and the software function aspect. In other words, the hardware component aspect refers to the physical components of the platform, such as the server system, data storage, and network devices. In contrast, the software component aspect corresponds to the platform's functional components.

In discussing whether learning effectiveness varies depending on the content and method of learning, many experts responded that the form and type of interaction between the technical area element and the learning area element, which are functional components of the software aspect, may vary depending on the learning content and method. Therefore, functional elements in the software aspect can be divided into sub-elements in the technology area, such as AI algorithms, data analysis modules, data path tracking, and feedback systems. Additionally, sub-elements in the learning area include learning goals, learning content, learning strategies, and methods for each subject. In addition, the technical and learning areas' sub-elements function independently, but ultimately, they are interconnected, so the effectiveness of learning can be different. In addition, it is challenging to distinguish between learning and technical elements in the context of learning, as the function of learning is implemented through continuous interaction with elements from both the technical and learning areas within the framework of learning data analysis and feedback. Therefore, in terms of the software function of the AI-based learning platform, the sub-elements can be divided into a technical context and a learning context, and they interact through the data processing context.

Based on the above results, the functional aspects of the learning platform utilizing AI technology in the focus group are categorized into technical and learning contexts. From a structural perspective, among AI and digital functions, certain elements are independent of learning content or methods, such as systems, security, and networks. On the other hand, it was recognized that functional elements related to learning effects, such as interaction and learning analysis, could not function independently of technical elements because the learning content and methods influenced them. In addition, it is suggested that learning content and learning methods, which are sub-elements of the learning context, influence AI and digital functions by interacting with each other during the learning process. This is because, in the case of a learning platform utilizing AI technology, most functions, such as diagnosis and feedback on learning outcomes generated by learners and activities using courseware, may vary depending on the learning method. Learning methods may also be diversified according to individual learning content. Therefore, the components of an AI-based learning platform should be divided into an integrated and interconnected context in which technical and learning elements function independently. Additionally, the interaction between elements in different areas should be modeled in an interactive form within the context of learning data analysis.

Model Construction of AI-enriched Adaptive Learning Platform

To maximize the effectiveness of the learning platform, it is necessary to examine the interaction relationships between components and elements from the perspective that the AI-based adaptive learning platform is a system that provides personalized and customized learning experiences by analyzing data such as learner's experiences, knowledge, emotions, and behaviors. In other words, to effectively utilize an AI-based customized learning platform, it is necessary to analyze the specific sub-elements that constitute personality and utilization goals based on their conceptual definition and to categorize each sub-element into the areas where they are combined. In other words, it is necessary to identify and categorize the elements according to the structural properties of the AI-based adaptive learning platform and its functional properties. In particular, considering the ultimate goal of supporting the teaching and learning of an AI-based mat dance learning platform, it is necessary to present a categorical framework for how the sub-elements should have a hierarchical or parallel relationship, sympathizing not only with the technical sub-elements but also the learning sub-elements.

According to the US Department of Education, AI-based customized learning contributes to improving learner's participation and academic achievement, and it is suggested that it consists of the following five main elements (Cardona et al., 2023). The first element is customized learning paths, where various data, such as the learner's achievement level, learning preferences, and learning speed, are analyzed in real time to provide a path composed of optimized learning content tailored to each individual. Second, it utilizes adaptive learning technology, where the AI system employs learning support technology that adjusts and provides content in real-time, based on learner's responses and achievement data, to match the difficulty and type of content. Third, it utilizes virtual tutors based on AI technology that operate 24 hours a day, identifying vulnerable areas in individual learners and providing customized practice questions and feedback corresponding to these areas through AI technology. Fourth, it utilizes automated task technology, and AI leverages technology that automates repetitive and time-consuming tasks, such as scoring and providing basic feedback. Fifth, it utilizes content creation technology and digital technology that can quickly generate various types of content, such as customized lecture data, evaluation questions, and learning images.

In addition, for the effective implementation of an AI-based adaptive learning platform, it is necessary to construct a composition that considers various contextual factors such as the learner's current state, goal orientation, motivation level, time constraints, and social relationships. Abu-Rasheed et al. (2023) proposed learner profiling, learning data profiling, technology and environment profiling, learning method profiling, and data collection and analysis skills as key components of an AI platform for implementing an effective learning recommendation system. First, learner profiling includes basic information, prior knowledge, cognitive level, and learning style of learners, which are used to select customized content and design learning paths. The second is learning material profiling. The format of learning materials (text, video, quiz, etc.), difficulty, subject area, and related metadata are included and are essential elements to support learning content suitable for learners. The third is technology and environmental elements, which include technical environments (devices, network states), physical environments (noise, lighting), and social interaction environments (relationships with teachers and peers). Fourth, it is an element of a recommended algorithm based on a learning method. In configuring a platform for effective AI-based personalized learning, key learning method elements, such as constructivist learning, self-regulated learning, and situational learning, are essential (Vorobyeva et al., 2025). In addition, the composition of learning methods, including learner's autonomy and motivation, social interaction, and personal experiences, can be presented as factors that can increase the effectiveness of learning using AI. Finally, data science and technology enable the implementation of an AI-enforced learning platform. This allows learner's situations to be collected, analyzed, and fed back in real-time through data collection devices, data analysis algorithms, and learning management systems (LMS). Therefore, AI-based customized learning platforms go beyond simply referring to systems with technical functions and correspond to designs in which learner-centered learning methods and materials are organically integrated with data science and technology.

Considering the results and discussions of expert response analysis on the composition and functionality of AI-enforced personalized learning platforms, the composition of learning platforms can be proposed primarily in the technical and learning contexts. The technological context encompasses digital systems, including web-based interfaces, cloud storage, and learning analysis engines, which focus on the digital and AI technologies utilized by the platform, as well as machine learning and deep learning algorithms based on learner data (Yılmaz, 2024). The learning context explains how the learning platform utilizes digital technology and AI to implement appropriate learning strategies based on learning theory, recommend customized learning content, and provide feedback to learners. By applying methods such as adaptive learning, intelligent tutoring systems (ITS), metacognitive support, and individual feedback (Abu-Rasheed et al., 2023; Sajja et al., 2024), the provision of simulations, chatbots, learning materials, and diagnostic questions align with the learning context. Although the technical context and learning context may exist independently of each other within the structure of an AI-based customized learning platform, it can be said that they complement each other in terms of the function and effectiveness of learning activities on an AI-based adaptive learning platform.

The sub-elements of the technology context and the learning context can be divided into two key components: the digital infrastructure element, which constitutes the infrastructure and operational base of the AI platform, and the AI technology element, responsible for implementing the intelligent functions of the customized learning system. Since the digital technology element is the foundation on which the AI platform operates, it may include cloud storage, web, and mobile UI, big data processing systems, and visualized dashboard systems (KERIS, 2024; Fan et al., 2023). The AI technology element comprises an algorithm that serves as the core of adaptive learning, including customized learning recommendations, deep learning-based learner modeling, a natural language processing chatbot, real-time problem generation, interactive feedback, and dynamic learning path proposal (Maity & Deroy, 2024; Sajja et al., 2024). AI technology is responsible for customized learning functions, including learner data analysis, actionable modeling, personalized learning paths, and content provision.

The sub-elements of the learning context can be divided into learning strategies, which involve the selection and execution of learning approaches, and learning resources, which facilitate the presentation of relevant content. The learning method element is related to the application of teaching and learning strategies appropriate to the learner's state and is linked to an intelligent learning system (ITS) that tracks and feeds back the learning state in real-time (Abu-Rasheed et al., 2023; Y ı, 2024). Adaptive learning adjusts the level and speed of learning by analyzing learner's learning performance patterns in real time and enables learning design tailored to the learner's cognitive needs and psychological state (Baradari, 2025; Vorobyeva, 2025; Yılmazı, 2024). Therefore, the learning method element performs the basic function of providing teaching strategies to achieve the learning effect of learners within the AI-based customized learning platform. Learning content refers to the provision of specific types of content suitable for learning by the platform, including personalized content such as chatbots, multimedia learning materials, problem banks, and Generative AI-based questions (Chan & Li, 2025). In the AI learning platform, learning content can be divided into knowledge composition units at the conceptual level and mapped to the learner's current knowledge, thereby defining the form and depth of educational materials presented to learners (Baradari et al., 2025).

As discussed above, the AI-based adaptive learning platform can be described as a system composed of technical and learning contexts, featuring a functional feature that links sub-elements of the technical context and sub-elements of the learning context through learning data analysis. (Fig. 2). In other words, the AI-based learning platform is not just a technical tool but a sophisticated personalized education system based on cognitive science and learning theory, and it can be seen as a system in which technical and learning elements interact organically.

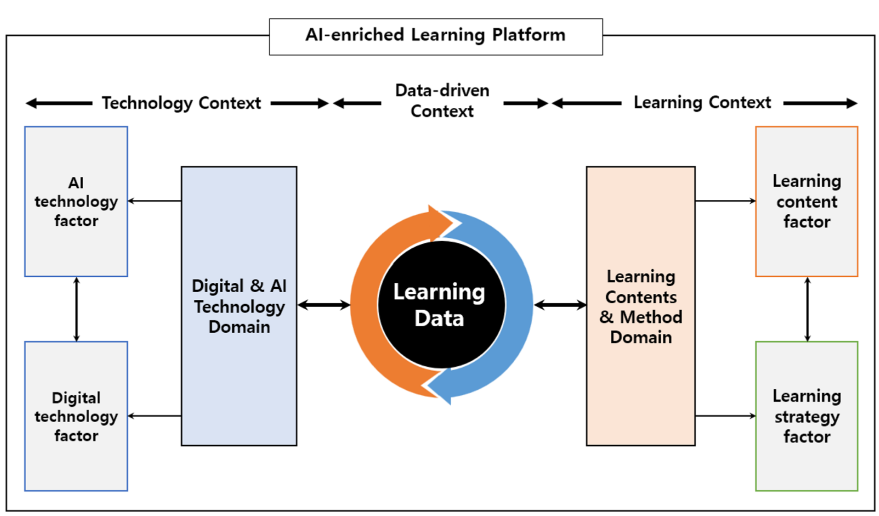

Fig. 2. Framework of the platform model for AI-enriched adaptive learning

Discussions

The components of the AI technology utilization platform are divided into technical and learning contexts, and the sub-elements of the technical context can be categorized into digital and AI, and the sub-elements of the learning context can be categorized into learning content and learning method elements. Additionally, it was discovered that when the sub-elements of the technical context and the sub-elements of the learning context are interconnected through learning data processing and function in a balanced manner, the effectiveness of the instructor's teaching support and the learner's achievement can be enhanced. The results of analyzing the empirical perceptions of experts on the AI technology-based learning platform also confirmed that there is an area where the sub-elements of the platform function in an integrated connection with the area where they can be independently constructed and functioned. Based on these quantitative and qualitative data, the functional composition of a human-centered AI-based adaptive learning platform for learning could be modeled and presented using AI technology.

Personalized learning aimed at a human-centered AI-based adaptive learning platform aims at classes in which learning speed and teaching methods are optimized according to the needs of individual learners (Bernacki et al., 2021), and teaching strategies, learning content and learning objectives must be variously adjusted according to the specific needs of learners (Vorobyeva et al., 2025). In particular, various AI technology elements such as machine learning (ML), natural language processing (NLP), and intelligent tutoring system (ITS) can be integrated into the education system to enable the provision of customized learning methods and learning content tailored to learner's preferences, achievement levels, and learning styles (Sajja et al., 2024). Additionally, it is necessary to dynamically adjust the content according to the learner's experience level and learning goals by analyzing and tracking learning data within the platform and providing personalized digital content recommendations and feedback on results (Pesovski et al., 2024).

From this perspective, experts have emphasized the need to balance digital and AI technologies with learning content and methods in order to achieve the ultimate purpose of learning and the functional goal of the learning effect. Above all, these functional elements should enable feedback through the analysis of various unstructured and structured data, including cognitive development level, background knowledge and experience, preferences, learning styles, and affective characteristics of human users, such as learners and instructors.

Human-centered AI-based learning refers to future-oriented learning in which AI systems function as a base tool to expand human experiences, interact with humans and AI systems, and support human activities by utilizing AI technology for data analysis and processing created by humans, which is a direction connected to what Education 4.0 suggests. The functional compositional model for the AI-based adaptive learning platform presented in this study proposes a future-oriented, human-centered approach to AI-based adaptive learning, where learning elements and technology elements are functionally balanced through interaction with each other via data-based analysis. In particular, it not only functions to provide content appropriate to the learner's needs and learning speed but also suggests the direction the learning platform should go in order to contribute to improving learning motivation and effectiveness. However, the fact that the correlation and direction between the existence of sub-factors of individual elements constituting the model and the systemic interaction are not distinguished will need to be supplemented in the future. In particular, it will be possible to develop an integrated model that maximizes the effectiveness of an AI-based adaptive learning platform if the elements of the learning context interact with the user and instructor, as well as how the elements of the technical context interact with the developer.

The AI-based learning platform will be able to achieve the ultimate goal of customized learning for learners when the components of the technical context and the learning context are biased in a specific direction, or the operational center is not inclined toward a specific context from the perspective of a goal-oriented system aimed at achieving learning effects. In other words, positive synergy can be achieved if the functional and learning elements of the learning platform are configured and operated to complement each other according to the flow of data generated by the user. Therefore, the AI-based learning platform should be configured to effectively support learning-related activities centered on learners and instructors who are users by shifting away from a technology-oriented perspective. In this respect, the AI-based learning platform should balance the technical and learning functional elements by focusing on the user's learning experience rather than on the technical function.

Conclusions and Educational Implications

This study investigated expert's perceptions of adaptive learning platforms that utilize AI technology, employing both quantitative and qualitative analyses, and theoretically examined the empirical results to draw the following conclusions.

First, the functional components of an AI-based adaptive learning platform can be divided into a technical context and a learning context. Learning is an activity in which learners and instructors constantly interact socially, and it corresponds to the process in which learners use learning materials to interact cognitively. However, with the emergence of an AI-based adaptive learning platform, which is a new form of a learning tool to which digital technology is applied and is a learning space and a system that provides learning materials in the form of content and evaluates and gives feedback to learners, it must be recognized from a new perspective. In particular, it can be divided into a technical context, where the interaction between digital technology elements and AI technology elements occurs in the functional aspect of learning implementation, and a learning context, where the interaction between learning content elements and learning method elements takes place. In particular, elements of the technical context function in connection with digital and AI areas, and elements of the learning context function in connection with each other within the learning content and method areas so that learners and instructors can learn within the platform.

Second, the functional components of an AI-based adaptive learning platform can be structurally independent, but they must constantly be interconnected with the learning component in terms of learning functionality. The components that make up an AI-based adaptive learning platform may exist independently in terms of structure, depending on the expert group's perception analysis, and some of the technical elements may function independently of the learning function. However, technical elements must constantly interact with the learner's flow and processing of data while the learner's self-directed learning activities are carried out through the platform. Through this, ultra-personalized learning can be achieved that reflects the cognitive, functional, and affective characteristics of individual learners. By accumulating data, continuous learning improvement and detailed feedback can be provided.

Third, the functional components of the AI-based adaptive learning platform should function with a focus on expanding and supporting human experiences. According to the functional composition model of the AI-based adaptive learning platform proposed in this study, the technical and learning context should function as a learning platform by interacting with the data processing context, and the learner experiences, expands, and constructs learning through the AI-enforced learning platform. In addition, data-driven interactions between technical and learning elements should provide hyper-personalized feedback to learners and offer new learning opportunities based on accumulated data. Therefore, from the perspective of future-oriented education, an AI-based adaptive learning platform should be designed and function in a way that allows technical and learning elements to interact, supporting learners in expanding and constructing their experiences.

The AI technology utilization learning platform confirmed that functional components exist independently and function according to the composition of significant interaction relationships, presenting the functional direction of a future-oriented AI-based adaptive learning platform. Therefore, based on the results of this study, the following educational applications and additional research can be proposed.

First, when designing and implementing an AI-based adaptive learning platform, it is necessary to develop systematic design criteria and evaluation indicators that reflect the functional interaction of technical and learning elements. Currently, various AI-based learning platforms have been developed and distributed; however, due to their technology-oriented structure and functions, there are no clear indicators to evaluate the differences from past computer-based learning (CAI), their suitability for learning activities in the school field, or their suitability for learner-centered learning activities. Therefore, design criteria and evaluation indicators that consider the interaction and balance of technical and learning elements should be established to implement the design and function of the adaptive learning platform, which is continuously being developed.

Second, follow-up studies are needed to demonstrate the effectiveness of developing and applying AI-based adaptive learning platforms that support various educational environments and hyper-personalized learning. Although various Edutech contents and platforms with AI technology are being presented, empirical research on learning effectiveness is insufficient, which makes it difficult to accurately understand how to expand learner's experiences and what positive and negative effects exist through AI. Therefore, when using a learning platform designed to enable learner-centered AI-based adaptive learning, it is necessary to demonstrate the theoretical possibility as practical applicability by analyzing the effects of change and learning observed by instructors and learners from various angles.

Third, additional research should be conducted to categorize and address problems that may arise when using an adaptive learning platform that incorporates AI technology. The use of AI technology necessitates the collection and processing of data, which raises various issues, including the protection of personal information, algorithmic bias, and the potential for hallucinations in Generative AI. To protect learners and maximize the effectiveness of learning, it is necessary to monitor and categorize various problems that arise when using an AI-based learning platform for learning activities. In addition to responding to problems that arise during learning activities, it is necessary to present countermeasures tailored to the types of problems and the degree of damage that occur in various situations within the school field in order to effectively address them both before and after learning. Above all, since problems that arise can be diverse depending on the learning content, research should be conducted to categorize problems and damages that occur in each subject's learning situation, breaking away from the general level of comprehensive response perspective.

Acknowledgements

This study was supported by 2024 Research Grant from Kangwon National University (No.202404500001).

Conflicts of Interest

The authors declared no conflicts of interest.

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