

An Exploratory Study of Elementary School Teachers' AI Competencies: Based on Teachers' Experiences and Perceptions*

Seungyeon HAN

Hanyang Cyber University
Korea

Jiyoung LIM**

Seoul Women's College of Nursing
Korea

This study aims to explore how teachers perceive and experience AI in the context of education, particularly with the introduction of AI digital textbooks, and to derive AI competencies from these experiences and perceptions. To achieve this, individual interviews were conducted with five elementary school teachers who possess high expertise in AI education. Through inductive analysis, the study identified the AI competencies and behavioral indicators of teachers. The results revealed a total of eight competencies and eighteen behavioral indicators, categorized into three domains: knowledge (understanding, evaluation, instructional design), skills (utilization, management), and attitudes (self-efficacy, professional development, leadership). Based on these findings, implications for promoting the development of teachers' AI competencies were discussed.

Keywords : AI Education, Teacher Competencies, Teacher Perception, Teacher Professionalism

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** Corresponding author: Seoul Women's College of Nursing, jylimedutech@gmail.com

Introduction

Artificial Intelligence (AI), defined as a “machine-based system that, by following a set of user-defined objectives, makes predictions, recommendations, or decisions that influence real or virtual environments” (UNICEF, 2021; p. 16), plays a pivotal role in driving innovation and change across nearly all aspects of human life, including health, medicine, finance, and culture. Consequently, AI is increasingly emphasized as a fundamental competency for future society members, making the enhancement of learners' AI competencies a crucial educational task. In response to this need, South Korea's revised 2022 curriculum has integrated AI into subjects like technology and home economics, as well as information technology, and offers elective courses such as “Artificial Intelligence Mathematics” and “Foundations of Artificial Intelligence” (Korea Ministry of Education, 2022). This demonstrates a national effort to ensure that all students develop AI competencies. Furthermore, the role of AI as a tool to enhance the effectiveness and efficiency of education is gaining increasing importance. The 2022 revised curriculum emphasizes the creation of educational spaces and environments that support digital-based learning, with the development and introduction of AI-enhanced digital textbooks marking the formal integration of AI into public education (Korea Ministry of Education, 2023).

For teachers, AI now holds dual significance: it is both content that needs to be taught and a tool for enhancing the effectiveness and efficiency of instruction. Against this backdrop, various studies have sought to understand teachers' perceptions of AI and to identify the competencies they need to develop (Lim et al., 2024; Heo & Kang, 2023; UNESCO, 2023). These studies not only provide valuable foundations for developing support strategies for competency development but also offer tools to measure individual teachers' AI competency levels.

However, to successfully integrate AI into education, it remains essential to understand and define teachers' perceptions of AI and the necessary competencies from the perspective of practicing teachers. Previous studies on teachers' AI

competencies have typically relied on literature reviews of national and international research articles and policy reports, as well as expert Delphi surveys (Kim et al., 2020; Heo & Kang, 2023). While these studies have made significant theoretical and practical contributions by presenting well-validated competency frameworks at a time when AI is being newly introduced into education, it is also crucial to actively incorporate the voices of practicing teachers in the process of defining competencies. This is particularly important because the perceptions, behaviors, and experiences of high performers in the field often reveal the knowledge, skills, and personal characteristics necessary for successful job performance (Lee, 2009). A qualitative approach enables researchers to capture the nuances and complexities of how teachers interact with AI in their professional practice. The voices from practitioners provide opportunities to explore how AI competencies manifest in real classroom settings and professional development contexts.

Research that reflects workshop results involving practicing teachers to derive AI competencies (Lim et al., 2022), that captures teachers' actual instructional behaviors and personal characteristics through interviews to identify competencies and behavioral indicators (Lee et al., 2022), or that derives competencies from data collected through surveys and interviews with teachers at AI-leading schools (Kim & Kwon, 2023) can all be seen as efforts to incorporate the experiences and characteristics of practicing teachers into their AI competencies. Nevertheless, as noted by Marrelli et al. (2005) regarding competency model research methodologies, various methods of collecting data from the field carry inherent strengths and weaknesses.

Moreover, including data collected from top performers is particularly important for describing competencies, as it allows researchers to distinguish average performers from top performers based on competencies (Campion et al., 2011). However, a limited number of studies so far have focused on teachers with sufficient experience and knowledge in AI education. This indicates that there has not yet been sufficient research on effective educators in AI instruction to clearly define the

competencies required for teachers in this field. Therefore, it is crucial to adopt diverse research methodologies and interpret the results comprehensively, making further attempts to collect data from the field to inform and reflect in AI competency development for teachers.

Given that AI-enhanced digital textbooks will be formally introduced in public education starting in 2024, beginning with the elementary school level, the AI competencies of elementary school teachers are particularly important factors that will significantly influence the adoption and spread of AI in education. Therefore, this study aims to explore how elementary school teachers perceive and experience AI in educational settings and to derive competencies based on these insights. This research is necessary to understand elementary school teachers' AI competencies from their own perspectives. By focusing on the experiences of teachers who are at the forefront of AI implementation, it is expected to identify competencies that are grounded in real-world educational contexts. Competencies grounded in the experiences and needs of practitioners can serve as directly applicable frameworks within educational settings. Notably, by gaining insight into the challenges and barriers to AI integration that teachers encounter, this research provides implications for designing carefully designed strategies that effectively address these obstacles.

Two research questions were derived to achieve the research objective:

1. What AI competencies can be derived from teachers' experiences and perceptions?
2. What behavior indicators for AI education can be derived from teachers' experiences and perceptions?

This study adopted a qualitative research approach to allow an in-depth exploration of teachers' lived experiences and perceptions. Interviews were conducted with elementary school teachers who possess high levels of expertise in AI education and the results were analyzed to identify the AI competencies and behavioral indicators required for teachers. The findings of this study are expected

to contribute to the provision of insights for the future development of teacher competencies.

Theoretical Background

AI and Education

In education, the role of AI is broadly divided into two categories: learning about AI, which involves understanding AI concepts and principles, and learning with AI, which refers to the use of AI to support teaching and learning (Holmes et al., 2019). This distinction in the concept of AI in education has become increasingly diversified and expanded as educational and societal demands, such as the need for AI talent development and the enhancement of educational effectiveness and efficiency through AI, have grown. Based on the distinction made by Holmes et al. (2019), the role of AI in education can be categorized as follows:

First, the terms emphasizing the learning of AI concepts and principles (learning about AI) include AI literacy education, AI content education, AI comprehension education, AI development education, AI value education, and AI ethics education. Although there are differences in the specific definitions of these terms, they mostly focus on equipping learners with AI knowledge and skills by learning about the concepts, principles, laws, and algorithms of AI. Moreover, these terms emphasize the recognition of AI's societal value and the formation of ethical attitudes (Lim et al., 2022; Kim et al., 2020). Examples reflecting this perspective include AI4K12's (2019) "Five Big Ideas for AI Education" and Canada's Actua (2020) AI education framework, which both provide detailed suggestions on what should be included as content in AI education.

Learning with AI, which involves using AI as a tool to support teaching and learning (Hong et al., 2020), is often referred to as AI-assisted learning. However,

even within this term, the way researchers define the purpose of AI utilization varies (Kim et al., 2023). For instance, Han et al. (2021) differentiate between using AI as a tool to achieve subject-specific goals (AI-integrated education) and using AI for educational policies and administrative tasks (AI in educational administration). Moreover, recent trends highlight AI's role as an active participant in educational execution and operation. The Korea Ministry of Education (2023) announced plans to expand the use of AI courseware that provides personalized education to individual learners and AI tutors that analyze learners' states and propose tailored strategies. In this context, AI functions in various ways to assist in lesson design, implementation, and administrative work reduction.

Additionally, the term AI-integrated education has emerged to encompass both the content integration with various subjects and the instrumental use of AI (Heo & Kang, 2023). Although the definition of AI-integrated education varies, the Korea Ministry of Education (2020) defines it as education that fosters AI literacy by integrating AI content or elements with other subjects. Prior research generally reflects this definition by focusing on enabling the understanding of AI concepts and principles through connections with other subjects (Hong et al., 2023).

As discussed, AI is being introduced into education for a wide range of purposes and forms, and its role in education continues to expand. For example, beyond cognitive learning, recent proposals have suggested the use of AI for social-emotional learning (SEL) (Park et al., 2024), indicating that AI is expected to play a central role in a broad range of areas, contributing to the holistic development of learners while enhancing educational efficiency and effectiveness. As the role of AI diversifies, the competencies required of teachers will inevitably also become more diverse. Although there may be differences in the terminology used to describe AI's role in education, for teachers—who are the main agents of educational practice—AI is both content that must be taught and a tool that must be utilized. Therefore, teachers are expected to develop comprehensive competencies to introduce AI into their lessons, based on an understanding of AI's impact and value in both educational

settings and society.

AI and Teacher Competencies

As AI becomes increasingly important in education, research on teacher competencies for AI education has also become more active. These studies vary slightly in the competencies they propose, depending on how they define the role of AI. For instance, previous studies on teacher competencies for AI education have defined these competencies in a manner aligned with the perspective of Holmes et al. (2019), who distinguish between *learning about AI* and *learning with AI*. For *learning about AI*, which focuses on understanding concepts and principles of AI, it is essential for teachers to have a firm grasp of AI from a content knowledge perspective. In contrast, *learning with AI*, which emphasizes enhancing effectiveness and efficiency of learning by expanded learning experiences, requires teachers to focus on successfully integrating AI as a tool for teaching and learning (Han et al., 2021; Heo & Kang, 2023). Therefore, this study also examines previous research on teacher competencies by distinguishing between these two perspectives. It further reviews the specific competencies included under each perspective.

Kim et al. (2020), who define teacher competencies from the perspective of *learning about AI*, focus on analyzing the curriculum based on AI education literature and reflecting this in the derivation of competencies. Their study defines teacher competencies as an integration of content knowledge, technological knowledge, and pedagogical knowledge based on the TPACK framework (Mishra & Koehler, 2006). In addition to teaching knowledge and platform usage skills, they emphasize the need for knowledge about AI principles and concepts, such as problem-solving, reasoning, and ethical knowledge. Similarly, Kim & Kwon (2023) also identified 22 competencies using the TPACK framework, reporting that teachers in AI-leading schools recognized the importance of content knowledge, specifically knowledge of AI principles and concepts, as the most significant.

From the perspective of *learning with AI*, Lee et al. (2022) suggested teacher competencies by focusing on the process of preparing and implementing lessons using AI: preparation, design, implementation, and evaluation. In addition to competencies centered on teaching practice, it emphasizes the development of teacher professionalism as a key aspect of AI education competencies. Although Lee et al. (2022) included competencies such as understanding AI and making ethical evaluations, which align with the *learning about AI* perspective, their competency framework focuses on using teacher's understanding about AI to enhance teaching and learning. Similar approaches can be found in the studies by Heo et al. (2024). Heo et al. (2024) also proposed AI competencies for teachers, which included *AI and digital basics* encompassing AI concepts, principles, and ethics, as well as *AI and digital education implementation*, which covers the ADDIE process for instructional design, and *professional participation* including professional development and social engagement. Heo & Kang (2023) also presented teacher competencies as AI literacy, which includes AI concepts and principles, and AI-integrated education competencies with the ability to utilize AI in the design, implementation, management, and evaluation of lessons. They identified five competencies and 39 behavioral indicators related to lesson design, development of educational materials, lesson implementation, educational management, and evaluation.

However, defining teacher competencies along these distinctions may lead to merely supplementing the existing knowledge and roles of teachers with AI. Therefore, it is important to move beyond simply categorizing competencies based on specific roles and tasks related to AI integration in education. Efforts are still needed to examine and define these competencies from a more holistic and integrated perspective. In this sense, there have also been attempts to comprehensively define teacher competencies for AI education. UNESCO (2023) proposed a draft AI competency framework for teachers, categorizing it into five aspects: (1) a "human-centered mindset" that responsibly applies AI in education based on an understanding of the risks and impacts of AI on humans and society, (2)

ethics related to AI, (3) “AI basics and applications” that involve understanding AI concepts and principles and applying them in education, (4) “AI teaching methods” for effective AI education, and (5) “AI for teacher professional development.” Also, Kim et al. (2023) classified competency areas based on knowledge, skills, and beliefs. The “knowledge” area includes knowledge about AI itself, teaching methods, and integrated education. The “skills” area includes the ability to utilize AI in lesson design and implementation, while the “beliefs” area encompasses ethical, open-minded attitudes and teacher self-efficacy.

In summary, while there are some differences depending on the focus and scope of the research, most studies commonly suggest knowledge of AI concepts, principles, and ethics as fundamental competencies required for teachers to introduce AI into education. They also propose AI utilization competencies centered on instructional design activities, such as preparing, implementing, and evaluating lessons. This aligns with the general educational approach of defining the curriculum around educational content and methods. However, there are differences in how affective aspects of teacher competencies, such as teachers' openness and self-efficacy toward AI, their participation in society through AI, and their mindset regarding the relationship between AI and humans, are defined across studies. These differences suggest the need for an in-depth understanding of teachers' perceptions and attitudes toward the role and function of AI in education and comprehensive approach to define teacher competencies.

Research Methodology

Participants

To derive teacher competencies in AI, it is crucial to select participants who possess advanced knowledge and skills in AI, have extensive experience in actively

applying AI, and hold strong educational beliefs about AI's potential in education. Therefore, participants for this study were selected using purposeful sampling (Patton, 2002). The specific criteria for participant selection in this study included: having at least a master's degree in AI or a related field, having experience in directly developing or applying AI tools in the classroom, serving as instructors in relevant training programs, and having achievements such as awards in research associations or competitions. The study's participants consisted of five elementary school teachers, whose characteristics are summarized in Table 1.

Table 1
Research participants

Name	Gender	Teaching Experience	Region	AI-related experience
A	M	15yrs	Incheon	Created AI tools for writing classes and uses AI tools for drawing and discussions for classes. Leads teaching training programs and teaches students coding.
B	M	18yrs	Seoul	Belongs to AI leading school. Initiates various AIED projects for schools. Uses AI tools for classes. Teaches students coding. Publish books about AIED.
C	M	14yrs	Seoul	Belongs to AI leading school. Initiates various AIED projects for schools. Uses AI tools for classes. Leads teaching training programs. Publish books about AIED. Awarded excellence award from AI contest.
D	F	15yrs	Seoul	Leads teaching training programs and teaches students coding. Publish research papers about AIED.
E	F	21yrs	Gyeonggi Do	Uses AI tools for classes and counseling. Leads teaching training programs. Published books about AIED. Awarded excellence award from AI contest.

Data Collection

The primary data collection method used in this study was the Behavioral Event Interview (BEI). BEI allows for a detailed exploration of specific incidents where teachers successfully or unsuccessfully used AI in their teaching practice. This method helps uncover the competencies that contribute to effective AI integration in education. BEI protocol was designed to elicit specific behaviors in successful and unsuccessful cases of AI integration. Key questions included: Describe a specific situation where you successfully integrated AI into your teaching. What did you do that contributed to this success? Can you recall a time when you faced challenges in using AI in your classroom? How did you approach these challenges? What specific knowledge, skills, or attitudes do you believe were crucial in these situations?

Each teacher participated in real-time interviews conducted via the online video conferencing platform Zoom, lasting over an hour. With the teachers' consent, the interviews were recorded and fully transcribed for analysis. The interview protocol was developed based on a review of existing literature on AI competencies and refined through pilot interviews with two elementary school teachers. The interview protocol focused on several key areas, including perspectives on AI in education, current practices and examples of AI's educational applications, characteristics of lessons involving AI, specific cases and tools used, factors that promote or hinder AI use, and opinions on professional development related to AI. During the interviews, additional questions were posed based on the researcher's notes, memos, and the teachers' responses through probing.

Data Analysis

The analysis of the interviews was conducted using an inductive approach, as outlined by Kvale & Brinkmann (2008), which involves three steps: simplification, categorization, and interpretation. Initially, the interview content was analyzed in its

natural language form to gain contextual understanding. The statements were then condensed according to their meaning, and corresponding codes were assigned. Initial codes were generated based on key behaviors and competencies mentioned by participants. Codes were grouped into potential themes representing broader competency areas. These codes formed the basis for identifying the competencies related to AI use. Themes were reviewed and refined, resulting in the final categorization of competencies into knowledge, skills, and attitudes domains which were ultimately categorized into the domains of “knowledge,” “skills,” and “attitudes,” based on established frameworks in the literature (Baumert & Kunter, 2013; Darling-Hammond, 2006; European Commission, 2013). Finally, clear definitions and examples were developed for each competency and behavioral indicator.

To ensure the content validity of the competencies identified in this study, seven experts who did not participate in the interview reviewed the initial competency model using a 5-point Likert scale to evaluate its comprehensiveness, relevance, and clarity (Fitzpatrick, 1983). The experts rated the model's comprehensiveness at an average of 5.00 (SD = 0.00), relevance at 5.00 (SD = 0.00), and clarity at 4.86 (SD = 0.38). They also provided qualitative feedback, which was used to refine the model. Based on their suggestions, we added two behavioral indicators and clarified the descriptions of three competencies.

Research Findings

The study's findings are summarized in the table below, which presents eight competencies, and 18 behavioral indicators categorized into three domains: knowledge, skills, and attitudes (refer to Table 2).

The AI competencies derived from teacher interviews regarding their experiences and perceptions of AI-integrated education were categorized into three domains: knowledge, skills, and attitudes.

Table 2
Elementary school teacher's AI education competencies and behavior indicators

Category	Competency	Behavior Indicator
Knowledge	Understanding	Explore appropriate AI tools Understand characteristics and functions of AI tools
	Evaluation	Assess reliability and validity of AI tools Determine whether the AI tool is suitable for the learning objectives Assess reliability and validity of data generated from AI tools
	Instructional design	Define problem that can be solved using AI tools Design AIED aligned with achievement goals Design adaptive instruction based on learner analysis
Skill	Utilizing	Apply AI tools for effective instruction Employ AI tools for efficient instructional design, development, and implement
	Management	Monitor and provide feedback using AI tools Cope with technical challenges using AI tools
Attitude	Self-efficacy	Show interest in innovative tools Enjoy using and learning about AI tools
	Professional development	Participate in teacher training programs voluntarily Participate in AI study group voluntarily
	Leadership	Help colleague and share self-created tools for AIED Lead teacher training program or AI study group

Knowledge

The knowledge domain pertains to the foundational understanding necessary to design and develop instruction using AI, encompassing three key competencies: understanding, evaluation, and instructional design.

Understanding

The first competency, understanding, refers to the ability to explore AI tools that can be utilized in the classroom, based on a fundamental knowledge of AI.

“You need to at least know that there are tools available for use in class... so you can seize opportunities to apply them whenever the situation arises. (Omitted) If you know just a bit about how these tools make things easier, you might think, ‘This could help me achieve my goals,’ even if it’s just a small piece of knowledge.” (Teacher A)

“Most teachers say, ‘This isn’t that difficult, you can use it this way if you want to,’ (Omitted) but many don’t use these tools because they’re not even aware of their existence... Once it becomes easier, it’s likely to spread widely.” (Teacher C)

“Before I even get the chance to apply what I’ve learned, it changes again, so I constantly need to learn new things, but there’s often not enough time to actually try out what I’ve learned.” (Teacher D)

As highlighted in the teacher interviews, recognizing the educational value of AI and effectively integrating it into lessons requires an exploration of available tools and an understanding of their functions and characteristics. Teacher B, in particular, noted that unlike previous introductions of new educational technologies, the past year saw significant advancements in AI, leading to a heightened awareness of the need for change in education. As a coordinator at an AI-leading school, Teacher B has personally observed this shift. However, as Teacher D pointed out, by the time teachers become proficient in using a particular tool, new AI tools may already have emerged, rendering previous tools obsolete. Teacher A echoed this sentiment, questioning whether teaching certain tools is timely or if they are already outdated. While exploring available tools is important, keeping up with the rapid evolution of AI technology remains a challenge.

The representative behavioral indicators derived from the teacher interviews for the first competency in the knowledge category, Understanding, can be summarized as: *Understanding the functions and characteristics of AI tools* and *Exploring available AI tools*.

Evaluation

The second competency, evaluation, involves assessing the reliability and validity

of AI tools, determining whether they align with instructional objectives, and evaluating the reliability and validity of data generated by AI tools.

“There’s a lot of talk about AI... and there’s a sense that we must do it... Sometimes it’s done disruptively without any alignment with the curriculum... There’s no guiding principles or philosophy. It’s just done because it’s AI, without a clear goal. While the idea that coding is fun can have educational benefits, without a guiding principle, it lacks direction. There must always be a clear goal.” (Teacher A)

“There are limitations, like age restrictions, that can make logging in difficult. And given the nature of elementary education, the tools need to be simple and intuitive to be effectively utilized.” (Teacher B)

As highlighted in the teacher interviews, the emergence of AI as a new tool should not lead to its uncritical adoption. Instead, it is crucial to assess whether the tool aligns with established educational principles and philosophies. The primary focus should be on determining whether the AI tool is appropriate for achieving the specific instructional objectives. This implies that the use of the tool should not become an end in itself, but rather a means to effectively accomplish educational goals. Particularly in the context of elementary education, it is essential to evaluate whether the tool is suitable for the developmental characteristics of young students and aligns with the elementary school curriculum.

“When students receive feedback from a chatbot, there are sometimes errors. So, I explain to the students that this AI was developed in the United States, which might cause some errors in handling Korean. (Omitted) For example, in a career guidance class, there was incorrect information because the AI introduced a system that doesn’t exist in Korea, so I had to correct that information for the students.” (Teacher C)

“I had the opportunity to observe an AI coding class where students were faced with the trolley dilemma: if a sensor in a self-driving car fails, it could result in the death of the person inside the

car. The AI then asks which group of people outside should be saved—one group includes a thief, and the other includes a businessman. I found myself deeply concerned about whether it's appropriate to ask elementary students to make such a choice, raising significant ethical considerations.” (Teacher D)

The interviews highlighted the importance of teachers verifying the reliability and validity of the data generated by AI during the teaching process and correcting or providing feedback to students as necessary. In particular, ethical considerations should not be overlooked when assessing the validity and reliability of these tools. While new tools can offer innovative educational experiences, it is essential to thoroughly review the content they deliver before integrating them into instruction. Consequently, the key behavioral indicators derived from the teacher interviews are: *evaluating the reliability and validity of AI tools, determining whether the AI tool aligns with instructional goals, and assessing the reliability and validity of data generated by AI.*

Instructional Design

The third competency in the knowledge domain, instructional design, involves defining problems that can be solved using AI tools and designing adaptive instruction that aligns with achievement goals and is tailored to the learners' needs.

“When trying to solve problems in other subjects, we think about how AI can make solving those problems easier... When trying to achieve existing instructional goals more effectively, the priority is to determine what problem we want to solve with AI and what exactly we want to achieve with it.” (Teacher A)

“Our school had a significant issue with students who were falling behind, so we were in a situation where we needed to address this. (Omitted) We started using AI-based problem-solving tools, and I realized, 'Oh, these tools really do help in overcoming these challenges, and they're quite convenient,' so I became captivated by them.” (Teacher B)

“Students really dislike revising their writing. I think it's because there's naturally some variation,

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so I make it as easy as possible (so that they only need to type to get it done). It's not particularly difficult, so in elementary school, there aren't really big gaps between students.” (Teacher C)

“I think identifying the problem is the first step. If you don't have a clear sense of the problem, then you might just be using the tool because the Ministry of Education says so, which could be risky.” (Teacher E)

One of the common characteristics observed among the teachers who participated in the interviews was their ability to identify problems in the educational context that could be addressed using AI. This highlights the importance of not just trying out new tools as they emerge but rather identifying the specific challenges within the educational environment and determining how best to apply these tools to address those challenges. This approach is closely related to the ability to align the use of AI tools with educational goals and to design instruction accordingly.

“After setting the goal, we then look for tools that can actually be used... The most important and necessary part is setting the goal.” (Teacher A)

“I am already familiar with various AI tools, and for reaching the learning objectives, I consider how to design and apply AI in the lessons.” (Teacher B)

“My main interest is integrating AI principles with the curriculum achievement standards, and I first think about what exactly we want to achieve in each subject according to those standards.” (Teacher D)

It also emphasized the ability to analyze the learner's level and design adaptive instruction. This can be interpreted as a reason for using the tools, as the need for customized lesson design was derived based on learner analysis.

“Students really dislike and struggle with writing, and they find it difficult to even come up with ideas... But when they write with the help and collaboration of AI, those who couldn't even start before can complete their writing and feel a sense of achievement. Here, the important consideration

is to assess the differences in students' abilities and interests.” (Teacher A)

“Some students find drawing quite difficult... We could provide more opportunities for them. There are significant differences in skill levels between students; some don't even have basic skills... Not all students are highly interested... They don't really like complicated things, preferring something they can input and understand immediately. The differences in individual interest and skill level... The gaps are indeed quite large.” (Teacher B)

“I started because I wanted to give more specialized feedback tailored to each student's individual concerns.” (Teacher E)

In the case of Teacher B, when students were not proficient in basic computer skills, such as typing or using basic shortcut commands, the teacher designed lessons that incorporated pair or group activities based on preliminary assessments of basic literacy skills, allowing for the use of peer helpers. The teacher also recognized that students differ not only in their computer literacy but also in the speed at which they complete tasks and their level of interest in different subjects. Although it is challenging to satisfy all students, efforts were made to incorporate this diversity into the lesson design. The teachers emphasized that considering students' levels and interests in advance is essential and should precede the selection and use of tools.

As a result of the teacher interviews, the key behavioral indicators identified were: *Identifying problems that can be solved using AI*, *Designing lessons that utilize AI tools aligned with achievement goals*, and *Analyzing students' levels and designing customized lessons*.

Skills

The skills domain includes competencies necessary for the effective and efficient application of AI tools in teaching and learning, divided into two key competencies: utilization and management.

Utilization

The first competency, utilization, refers to the ability to apply AI tools for effective instructional design and efficient classroom management.

“(It’s difficult to internalize awareness of disabilities) so we designed and coded a tool that could be used by visually impaired individuals, and we engaged students in activities where they actually used the tool. This allowed them to fully empathize with the challenges faced by visually impaired people, achieving the educational goals and even going beyond them, with a higher level of internalization.” (Teacher A)

“With the traditional method, students would just present and that would be the end, but by actually demonstrating how the tool works, I found that it significantly improved their problem-solving abilities.” (Teacher B)

As mentioned above, the use of AI tools to enhance the effectiveness of lessons was frequently cited. Additionally, regarding the efficient design and operation of lessons, the teachers provided the following insights during the interviews.

“Recently, I’ve been interested in using ChatGPT’s API to reduce workload or applying it in Google Sheets to collect responses when assigning tasks to students.” (Teacher B)

“With digital-based writing, I can quickly provide feedback to many students. I find it difficult to check handwritten work... But when it’s done on a computer, it’s quick, so let’s try it. Collecting and checking worksheets can be a bit tedious... It’s easier to check, and students can give feedback to each other more easily.” (Teacher C)

“I created a tool to provide feedback on students’ writing, and I’m actually using it in class... All the things I imagined are realistically achievable. I tried it out, faced some failures, but it didn’t work as I expected.” (Teacher C)

“Using the mail merge function in Google Sheets, I can send individual emails to students... providing bulk feedback is possible... AI automation has been incredibly helpful.” (Teacher E)

There were frequent mentions of the usefulness of AI tools for providing feedback on student assignments. Providing personalized feedback to a large number of students through written surveys or analyzing assignments can be inefficient, both physically and timewise. While digitizing surveys or utilizing existing educational technologies can streamline these processes, the application of AI goes further, enabling more sophisticated feedback generation and management.

In relation to this, Teacher C modified existing tools or developed new ones for use. *“When ChatGPT first came out, I learned that it was possible to provide writing feedback using some functions in spreadsheets, but it was difficult for elementary students to access spreadsheets. From that point, over three months, I interacted with ChatGPT, constantly trying and refining methods, asking questions, and adjusting until I could provide writing feedback to students using spreadsheets. Even without learning JavaScript, ChatGPT wrote the code as I imagined, despite my lack of coding skills. I expanded the scope of AI usage based on what I learned in graduate school.”*

Based on the teacher interviews, the key behavior indicators identified are *Utilizing AI tools to enhance instructional effectiveness* and *Utilizing AI tools for efficient instructional design, development, and implementation*.

Management

The second competency in the skills domain, management, involves monitoring learning processes using AI tools, providing feedback, and effectively addressing technical issues that may arise during instruction.

“Some students have poor attitudes... Since everything in digital-based activities is recorded (both the process and the results), I can use the dashboard to show students and parents that the student has actually completed the task and made significant progress. With automated features like grading, there’s no argument with the teacher, and since everything is recorded, students can participate in class without feeling psychological pressure.” (Teacher C)

“I can also show parents the data for their child, and if I tell them that the next lesson will be challenging unless this concept is clearly understood, it resonates more than just vaguely asking

them to help their child study. It doesn't lead to emotional upset either.” (Teacher E)

As indicated by the remarks from Teachers C and E, using AI to record and provide data about students' participation and performance allows for more objective feedback exchanges between teachers, students, and parents. This process of monitoring learning progress and analyzing outcomes reduces the psychological burden on both teachers and students. From the parents' perspective, having access to objective data about their child's learning process and assessments helps them better understand how to support additional learning at home.

Based on the results, the key behavioral indicators identified include: *Monitor and provide feedback using AI tools* and *Cope with technical challenges using AI tools*.

Attitudes

The attitudes domain includes competencies related to the teacher's mindset towards AI, encompassing three key competencies: self-efficacy, professional development, and leadership.

“There are times when the internet connection gets overloaded, and even though I have received thorough training in advance, many instances occur where the class doesn't proceed as planned due to unexpected variables. I realized that we need to allocate much more time than initially planned. Although a lot of effort goes into the preparation stage, it's often inevitable that such difficulties arise during the execution stage. In such cases, I often try to be flexible, like suggesting that the students work together with a nearby classmate. Additionally, I sometimes utilize various programs or educational technologies that I am familiar with as a backup in case things don't go as planned.” (Teacher B)

Even during a class, as illustrated by the examples above, unexpected situations such as internet connectivity issues, device malfunctions, or individual student login problems can arise, despite thorough planning and rehearsal beforehand. While

resolving technical issues or individual challenges is important, it is also crucial to be flexible in handling these situations to ensure the class proceeds smoothly. It is essential to prepare alternative solutions for various scenarios.

Based on the teacher interviews, the key behavioral indicators identified include *Monitoring and providing feedback on the learning process using AI* and *Flexibly addressing technical issues when utilizing AI tools*.

Self-Efficacy

Self-efficacy refers to the teacher's interest in new tools, a curiosity-driven approach, and enjoyment in learning about and using AI tools.

“I've always been interested in tools that allow me to create content, so when the Ministry of Education's initiative aligned with my interests, I was really excited about it. I really enjoy creating tools and using them in my classes... I think there needs to be some kind of trigger that makes you want to use it, that opens your mind to it.” (Teacher A)

“Creating something is, in a way, similar to a programmer's perspective... When you see the final product after the process, and you're satisfied with it, it feels really great... For me, creating things is like a hobby.” (Teacher A)

“I've always liked computers, even back in college... I have a bit of a 'geek' personality, and that was true even in high school. (When I was creating a program to give feedback to students) I spent about three months working on it... I would persistently search for solutions, working until 2 or 3 AM. I think I tend to get really immersed in things.” (Teacher C)

“Actually, even back in middle and high school, I had a liking for subjects like technology and home economics... I guess I'm just the type of person who enjoys trying out new things and using technology in new ways in education. I have a somewhat open-minded approach to it.” (Teacher D)

As seen in the above examples, the teachers who participated in the interviews

showed a high level of interest in new tools and were highly motivated to try them out. Even when they encountered trial and error, they tended to enjoy the process and embraced the application of new concepts. The teachers described themselves as having a “programmer's mindset,” demonstrating a willingness to take on challenges, accept failures, and immerse themselves in learning new things, which can be considered a maker mindset.

Thus, the key behavioral indicators derived from the teacher interviews include *demonstrating an exploratory attitude toward new tools* and *enjoying the use and learning of AI tools*.

Professional Development

Professional development encompasses the teacher's proactive efforts to enhance instructional design expertise related to AI, including participation in various training programs and research activities.

“I feel a sense of satisfaction when I achieve the level I wanted, whether it's entering that program into a competition or conducting a lesson and seeing good results.” (Teacher A)

“I find myself taking a lot of training courses on my own. It seems like I have no choice but to study a lot on my own, so I'm putting in more effort myself.” (Teacher B)

The teachers emphasized the importance of participating in training programs that enhance their own professional expertise, rather than merely attending specific training sessions such as those focused on AI education. For example, they shared experiences of being more dedicated to attending basic literacy training sessions aimed at addressing learning deficiencies. They exhibited a proactive approach in seeking out training or research opportunities that align with their goals, rather than simply learning new tools.

Accordingly, the key behavioral indicators derived from the teacher interviews are: *Actively participate in various training programs on their own initiative* and *Proactively engage in*

research on AI utilization in education.

Leadership

Leadership involves sharing self-developed AI tools with colleagues, providing support to fellow teachers, and leading initiatives to promote AI integration in education.

“I can easily share something I’ve made with many others... I’ve shown what I’ve created and even considered conducting training sessions; I enjoy collaborating in this way.” (Teacher A)

“When I conduct training sessions at school, I feel very proud, and I find it really enjoyable to participate in teacher study groups or form communities. Sharing examples is really important.” (Teacher C)

“I shared my experiences from attending training sessions or how I conducted lessons, telling other teachers, ‘If you do it this way, you can conduct AI-integrated classes,’ and guided them through such examples.” (Teacher D)

Teachers led internal and external training sessions and actively participated in study groups. They were eager to share the tools they developed and new methods or approaches with other teachers and even put in extra hours late into the night to prepare the necessary environment. In the interview, there was also a conversation about these efforts. The term “dedication” was suggested in the initial behavior indicators by the research team but was deemed inappropriate. The teachers emphasized that such sharing and spreading of knowledge were natural in the school environment and were not done with any deliberate intent to spread or share.

Thus, the representative behavior indicators derived from teacher interviews are: *helping colleagues with AI-integrated lessons and sharing self-developed AI tools and leading AI tool utilization training or research.*

Conclusion and Discussion

Discussion

This study aimed to identify the AI competencies perceived by teachers from the perspective of AI as a tool to support teaching and learning, based on their experiences. This study contributes to the field of AI in education by providing an empirically grounded model of elementary school teachers' AI competencies. Unlike previous research that relied primarily on literature reviews or expert opinions, this study derives competencies directly from the experiences of teachers actively using AI in their classrooms. This approach reveals nuanced insights into the practical challenges and opportunities of AI integration in elementary education.

The significance of this study lies in its focus on deriving competencies from the actual experiences and perceptions of teachers who actively use AI in educational settings, rather than solely relying on expert perspectives or literature reviews.

This study revealed eight key competencies across three domains: knowledge, skills, and attitudes. These findings both confirm and extend previous research on teacher competencies for AIED. For instance, the competency of understanding within the knowledge category aligns with prior studies (e.g., Heo et al., 2024; Heo & Kang, 2023; Kim et al., 2023; Kim & Kwon, 2023; Lee et al., 2022). Similarly, the evaluation competency (Heo & Kang, 2023; Lee et al., 2022; UNESCO, 2023) and instructional design competency (Heo et al., 2024; Kim & Kwon, 2023; Lee et al., 2022; Lim et al., 2022) have also been recognized in earlier studies.

Notably, the behavioral indicator “identify problems that can be solved using AI tools” under the instructional design competency has not been explicitly mentioned in previous research. This emphasizes the importance of a systematic approach to instructional design, where teachers identify educational challenges and devise solutions using AI tools, rather than indiscriminately adopting new tools or methods. Teacher E’s remark that AI was adopted to solve a problem encountered during

instruction, rather than simply because it was recommended, highlights the significance of problem identification in the effective use of AI in education. Creativity in teaching, fostered by a deep understanding of educational contexts and critical thinking, is crucial for the successful integration of AI into education.

The competencies related to skills, such as utilization and management, have also been confirmed by prior research (Heo et al., 2024; Heo & Kang, 2023; Kim & Kwon, 2023; Kim et al., 2020; Kim et al., 2023; Lee et al., 2022; Lim et al., 2022; UNESCO, 2023). However, this study's findings diverge from previous research in that it combines the competencies of monitoring and providing feedback into a single behavioral indicator. This integration was emphasized during discussions with teachers, who argued that monitoring for the sake of monitoring is meaningless; rather, the value lies in analyzing the data generated by AI and providing feedback based on that analysis.

Another noteworthy finding is the frequent mention of using AI to provide feedback for efficient instruction. Teachers indicated that AI-generated feedback reduces the psychological burden on both teachers and students, as it is perceived as more objective. This aligns with Park et al. (2021), who noted that AI-generated feedback is more readily accepted, potentially leading to greater educational effectiveness.

The self-efficacy competency within the attitudes category is partially acknowledged in previous research (Kim & Kwon, 2023), where it is treated as a general attitude. However, this study goes further by identifying specific behavioral indicators related to self-efficacy. The participating teachers consistently demonstrated a high level of interest in new tools and a strong motivation to explore and utilize AI in their teaching. While this characteristic may not be expected of all teachers, fostering curiosity and interest is essential for successful AI integration. Providing opportunities for teachers to experiment and succeed with AI tools is therefore crucial.

The competencies related to professional development and leadership within the

attitudes category have also been identified in previous research (Heo et al., 2024; Kim et al., 2023; Lee et al., 2022; UNESCO, 2023). However, the leadership competency, specifically “leading teacher training programs or AI study groups,” emerged as particularly significant in this study. This is likely due to the characteristics of the participants, who were not only self-directed in their professional development but also actively engaged in sharing their knowledge and leading training and research efforts. The participants emphasized that their efforts to lead and share should not be viewed as acts of service or dedication, but rather as a natural part of the collaborative culture that exists among elementary school teachers. Nonetheless, their leadership and willingness to share undoubtedly contribute to the broader dissemination and adoption of AI in education.

While ethics-related competencies were highlighted in previous research, they were not explicitly mentioned in the teacher interviews of this study. The ethical issues surrounding AI in education are diverse, including concerns about copyright, plagiarism, and data privacy. The teachers in this study focused primarily on ethical considerations related to the age-appropriateness of AI tools for elementary students and the ethical dilemmas presented in AI-related content. While ethics were not a major focus of this study, it is likely that the teachers' strong ethical awareness led them to view ethical AI use as a given, rather than something that needed to be explicitly addressed.

This study offers several unique contributions to the field of AI in education, particularly in the context of elementary schools. Unlike previous research that often relied on theoretical frameworks or expert opinions (e.g., Heo & Kang, 2023; Kim et al., 2020), this study derives AI competencies directly from the lived experiences of practicing elementary school teachers. This approach revealed nuanced insights, such as the critical importance of 'problem identification' within the instructional design competency, which has not been explicitly highlighted in previous models. Furthermore, while existing studies tend to treat monitoring and feedback as separate competencies (Lee et al., 2022; UNESCO, 2023), the findings suggest a more

integrated approach, reflecting the realities of AI use in elementary classrooms. Additionally, this study uniquely emphasizes the role of teachers' exploratory attitudes and enjoyment in using AI tools, aspects that have been underexplored in previous competency models. These findings not only complement existing theoretical frameworks but also provide a more grounded, practice-oriented understanding of AI competencies specific to elementary education. By bridging the gap between theoretical constructs and practical application, this study offers valuable insights for teacher education programs and professional development initiatives aimed at enhancing AI integration in elementary schools.

Implications

To enhance AI competencies, several factors can be suggested, including the establishment of an appropriate environment, fostering learning communities, leadership development, providing incentives, and integrating AI with the formal curriculum. It is crucial to create an environment that supports the effective utilization of AI in education. This goes beyond merely providing physical infrastructure and includes creating conditions that allow teachers to experiment and innovate with AI tools. This study suggests an environment characterized by psychological safety and the provision of sufficient time and resources dedicated to education and research.

As noted by the participants in this study, teachers with high levels of AI utilization not only demonstrated an inquisitive attitude toward new tools but also exhibited resilience, persisting despite failures. Resilience in overcoming failures is significant not only for teacher's psychological well-being but also a quality of education (Bae & Chu, 2020). This is particularly evident in engineering fields, where the programming process inherently involves a cycle of trial and error (Kim & Choi, 2021). In a culture that does not tolerate mistakes or failures, taking risks on new approaches becomes challenging. Therefore, to encourage AI integration in education and to enhance

teachers' AI competencies, it is essential to create a psychologically safe environment. Such an environment should allow for experimentation and accept both mistakes and failures.

Additionally, teachers need to be provided with time and resources to explore new teaching methods and tools. The classroom situation often does not provide the conditions for teachers to sufficiently try new things, go through trial and error, or apply new teaching methods and tools. The lack of both time and resources makes it impossible to create an environment conducive to experimentation, and there is a need for adequate environmental support and preparation rather than relying solely on individual capabilities. There is a need for systemic support that allows teachers to experiment and learn from both successes and failures in AI integration. This could involve dedicated time for AI exploration in teachers' schedules, access to a variety of AI tools, and a supportive administrative structure that encourages innovation.

Second, leadership plays a crucial role in supporting AI adoption and use. This includes both formal leadership from administrators and informal leadership from teacher-experts. After establishing the necessary infrastructure in the classroom, it is crucial to train a substantial number of specialized teachers and support the widespread adoption of AI in education. Developing a cadre of AI-proficient teachers who can serve as mentors and leaders can significantly accelerate the adoption of AI in schools. These teacher-leaders can provide peer support, share best practices, and help translate abstract AI concepts into practical classroom applications. According to a report by Han et al. (2023), teachers generally have a positive attitude toward using AI in education, but their actual level of usage is quite low. In practice, many teachers in the field often experience significant stress due to the introduction of new tools and the demands of managing digital devices. The participants in this study demonstrated high interest in using EdTech, including AI, and exhibited leadership within their communities, so they did not face significant difficulties in designing and implementing lessons individually. However, to

effectively and efficiently introduce and apply new methods and tools in lessons, it is necessary to raise teachers' interest and enhance their competency in using these tools. We cannot rely solely on the beliefs and dedication of a few teachers. As mentioned in the first point, it is essential to establish a system that provides substantial support and motivation for teachers, reduces their workload outside of lessons, and enhances their capabilities.

Third, financial support and incentives can play a significant role in encouraging teachers to develop their AI competencies. According to the current government policy, in some cases where teachers pursue a graduate degree in AI-related fields, more opportunities for participation in graduate programs have been made available due to tuition being reduced by 50% or more, or the tuition being fully covered by the education office. All teachers have noted that this has increased the number of practical application cases. Such support can increase motivation for teachers to engage with AI education, even among those who may not have previously shown interest in educational technology.

Fourth, for AI to be effectively used in education, it must be integrated into the formal curriculum rather than treated as an add-on or optional component. In schools where AI is not designated as part of the formal curriculum, there is no mandatory requirement to use it, and without specific incentives, it may be perceived as an additional workload. When AI is integrated into the curriculum, it becomes a natural part of the teaching and learning process, encouraging teachers to develop and apply their AI competencies in meaningful ways. Teachers attempt new methods and utilize tools to achieve educational goals, which in turn enhances related competencies. Therefore, tools and methods cannot be considered separately.

Limitations of the Study

This study has several limitations as follows. First, the teachers who participated in this study maintained an instrumental perspective that focuses on using AI for

teaching and learning support, rather than learning the concepts and principles of AI. Therefore, the competencies identified in this study do not encompass those required for teaching the concepts and principles of AI. The categorization of competencies may vary depending on one's perspective on AI, and the importance of these competencies may also be interpreted differently. It would be meaningful for future research to analyze how competencies might be categorized based on the experiences and perceptions of teachers with different perspectives on AI.

Second, this study focused on elementary school teachers, so it does not cover the competencies required for secondary school teachers. Since the characteristics of each subject and the learners differ, the level and type of AI utilization in education can also vary, making it difficult to apply the findings of this study directly. Research on competencies specific to secondary school teachers is needed, and consideration should be given to the types and levels of AI utilization.

Third, this study primarily used interviews with five teachers as the main method of data collection. However, to enhance the validity of qualitative research, efforts to achieve triangulation are generally required. In this study, multiple researchers conducted analyses and worked to align their results, and the findings were confirmed with the research participants through a member-checking process using Interviews. Nonetheless, a more comprehensive approach would involve continuous observation of teachers' classes to refine and elaborate the behavioral indicators and collecting and analyzing data on how teachers' behaviors and competencies are perceived from the learners' perspective.

Based on this, the following future research is proposed. Research can be conducted to establish a teacher competency model for AI-based education using the competencies identified in this study as foundational data and to explore ways to develop tools for diagnosing these competencies. Measuring and diagnosing competencies are expected to provide a foundation for successful competency development. Additionally, teacher training programs designed based on these competencies can be established, and tailored training for teachers according to their

competency levels can be proposed based on diagnostic results. The competencies identified in this study, which consist of knowledge, skills, and attitudes, are expected to offer valuable perspectives on what types of teaching and learning activities can be emphasized in training programs.

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Seungyeon HAN

Professor, Dept. of Educational Technology, Hanyang Cyber University.

Interests: Instructional design, Online education, Digital media literacy

E-mail: synhan@hycu.ac.kr



Jiyoung LIM

Assistant Professor, Seoul Women's College of Nursing

Interests: Digital media literacy, Technology enhanced learning, Instructional design

E-mail: jylimedutech@gmail.com

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