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Exploration of an AI-Integrated Education Competency Measurement Tool for Pre-Service Special Education Teachers: An Education Service Approach

Sung-Wan Kim*

*Professor, Dept. of Secondary Special Education, Korea Nazarene University, Cheonan, Korea

[Abstract]

The purpose of this study is to explore a reliable and valid tool to measure the competencies of pre-service special education teachers for AI-integrated education from the perspective of education service. To achieve the goal, relevant prior studies were analyzed, leading to the derivation of a latent measurement model comprising four domains and nine criteria. Based on the model, an initial measurement tool consisting of 19 preliminary items was developed. A survey on item importance was conducted with 100 pre-service special education teachers. Exploratory factor analysis revealed that the items were grouped into two factors (value & interaction experience delivery competency, systemic approach & value co-creation competency) and the selected items demonstrated high internal consistency as components of each scale. Additionally, discriminant analysis was conducted for an initial exploration of how the derived factor structure may relate to actual group characteristics. But its result showed that the factor structure may not sufficiently explain differences between groups of students.

▸ Key words: AI-integrated education, Competency, Pre-service special education teacher, Special education service, Measurement tool, Exploration

[요 약]

이 연구는 교육서비스 관점에서 AI 융합교육을 위한 예비특수교사역량을 측정하기 위한 잠재모형을 도출하고 그것을 바탕으로 신뢰롭고 타당한 측정도구를 탐색하는 데 목적이 있다. 연구목적을 달성하기 위해 관련 선행연구를 분석한 후, 4개 영역과 9개 준거로 구성된 AI 융합교육 예비특수교사역량 측정 잠재모형을 도출하였다. 이 모형을 토대로 19개 예비 측정문항으로 구성된 측정도구를 개발한 후, 예비특수교사 100명을 대상으로 문항중요도 설문을 실시하였다. 탐색적 요인분석 결과, 각 측정준거에 속한 문항들이 2요인(가치・상호교류 경험제공 역량, 시스템적 접근・가치공동 창출 역량)으로 묶여지는 것으로 확인하였으며, 선정된 문항들은 각 척도를 구성하는 문항으로서 높은 내적합치도를 보였다. 또한 판별분석을 통해 도출된 요인구조가 실제 진단 특성과 어떠한 관계를 가지는 지에 대한 초기적 탐색을 수행하였으나, 요인구조가 집단 간의 차이를 설명하기에는 한계를 가지는 것으로 분석되었다.

▸ 주제어: AI 융합교육, 역량, 예비특수교사, 특수교육서비스, 측정도구, 탐색

• First Author: Sung-Wan Kim, Corresponding Author: Sung-Wan Kim
*Sung-Wan Kim (kimstar52@kornu.ac.kr), Dept. of Secondary Special Education, Korea Nazarene University
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I. Introduction

Artificial Intelligence (AI) has exerted a profound influence across nearly all domains of human life, and education worldwide is no exception. The Korean government announced three major educational reform policies in 2023, including digital education innovation. In alignment with these initiatives, the field of special education has also sought to implement various policy measures, such as the inclusion of customized digital education for students with disabilities in the Sixth Five-Year Plan for Special Education Development (2023–2027).

Although the government has made sustained efforts to enhance digital literacy for students with disabilities, there remains a need for a more systematic and comprehensive digital education policy roadmap that can be effectively applied in special education settings [1]. Furthermore, rapid socio-economic changes driven by digital technological advancement have heightened the demand for AI-based educational environments tailored to special education. For AI education to be effectively and substantively implemented in special education contexts, AI learning must be integrated across diverse special education subjects and embedded within everyday classroom instruction [2].

In the educational domain, the application of AI has emphasized the provision of personalized, customized, and adaptive learning environments that reflect the individual characteristics of learners with special educational needs [3]. Various efforts have been undertaken to implement AI-integrated education within special education, and these initiatives have revealed both their effectiveness and limitations. For example, Seoul Narae School utilized augmented reality applications and Google AI platforms, and these instructional practices were found to contribute to improvements in physical movement among students with hemiplegia and enhanced concentration among students with acquired disabilities [1]. In addition, integrating AI into special education has been shown to positively influence the functional and social outcomes of students with disabilities, particularly by promoting inclusivity and improving communication skills [4]. Nevertheless, concerns have been raised regarding the limitations of applying AI to students with diverse disability characteristics and the persistence of educational inequities [5].

Even when pre-service teachers receive AI-integrated education, it remains difficult to determine whether their competencies are effectively enhanced and transferable to actual educational practice [6]. Consequently, it is uncertain whether future pre-service special education teachers are sufficiently prepared to respond to AI-integrated education demands, underscoring the need for a valid and reliable tool to measure their competencies.

AI-integrated education refers to educational practices that involve understanding the fundamental concepts and principles of AI and integrating them into various subjects or educational activities. Previous studies have explored digital competencies of special education teachers [7], the development of competency measurement tools for pre-service teachers in AI-integrated education [8], AI literacy competencies for teachers [9], AI teacher competency models [10], AI teacher competency frameworks [11], technology utilization competencies [12], analyses of instructional competencies among faculty specializing in AI-integrated education [13], classifications of teaching competency types [14], and the development and validation of instructional competency scales for AI-integrated education teachers [6,15,16]. However, these studies have primarily focused on the perspectives of educators as providers.

For AI-integrated education to be meaningfully applied in special education settings, the development and operation of individualized programs tailored to students with disabilities are crucial [2]. This highlights the necessity of focusing on the competencies of special education teachers who approach AI-integrated education from the perspective of learners as education service recipients. Accordingly, there is an urgent need for a valid and reliable measurement tool capable of identifying and measuring the competencies of pre-service special education teachers to support their effective preparation.

From this perspective, an education service approach—which emphasizes systemic and ecological strategies for educational problem-solving and the co-creation of value between learners and educators—may provide a valuable framework for the successful integration of AI into special education [17,18]. This approach underscores concepts such as student agency, teacher agency, and co-agency, aiming to foster instructional innovation through rich learning experiences supported by close interactions not only between teachers and students, but also among parents, local communities, and the state [19].

The education service perspective maintains that value is created through dynamic interactions among multiple stakeholders surrounding education, rather than solely through the actions of educators and learners [18,19]. In essence, this perspective extends beyond value-in-exchange to encompass value-in-use, value-in-experience, and value-in-life [20].

Accordingly, the purpose of this study was to explore a measurement tool for pre-service special education teacher competencies for AI-integrated education from an education service perspective. The specific research questions were as follows:

1. What is the latent model for measuring pre-service special education teacher competencies for AI-integrated education from an education service perspective?
2. Is the measurement tool for pre-service special education teacher competencies for AI-integrated education valid and reliable?
3. Can the derived factor structure of the developed measurement tool be used to exploratorily examine differences between groups of students?

II. Literature Review

1. AI-Integrated Education and Competencies

Before examining competencies specific to AI-integrated education, it is necessary to first review the general competencies of pre-service special education teachers that form the foundation for AI-integrated education competencies. Kim (2016), adopting an approach based on the National Competency Standards (NCS), systematized the common core job performance competencies of pre-service special education teachers into a hierarchy of core competencies, competency units, and competency unit elements [30].

Another study [21] classified instructor competencies for AI-integrated education into three groups—design competency, implementation competency, and evaluation competency—based on the instructional execution process.

There has also been research that classified special education teachers' AI-integrated education competencies into latent profile types [22]. This study identified three latent profiles based on competencies related to AI understanding: the 'AI-integrated education expert type,' the 'AI-integrated education practitioner type,' and the 'AI-integrated education potential type.'

Lorenz and Romeike (2023) proposed the AI-Pack framework, which comprises AI-related Knowledge (AI-K), AI-related Pedagogical Knowledge (AI-PK), AI-related Content Knowledge (AI-CK), and AI-related Pedagogical Content Knowledge (AI-PCK). Additionally, Kim and her colleagues (2023) conducted a study to develop an AI competency measurement tool for pre-service teachers, consisting of cognitive competency, instructional competency, and technology acceptance and performance competency.

In AI-integrated education, substantial differences exist among instructors not only in AI utilization and integrated instruction but also across all instructional activities, including lesson design and preparation, instructional delivery and management, evaluation, and teaching-learning methods [14]. This suggests that the quality of education provided to students may vary depending on teachers' competencies, highlighting the importance of ensuring robust AI-integrated education competencies among all teachers to deliver high-quality instruction in practice [13].

Nevertheless, previous studies on the development of competency measurement tools for AI-integrated education have largely focused on educators from the perspective of education service providers, thereby revealing an educational limitation in terms of insufficient attention to learners as education service recipients.

2. A Latent Model of Pre-Service Special Education Teachers' Competencies for AI-Integrated Education

In this study, the competencies of pre-service special education teachers for AI-integrated education were derived based on the perspective of Service-Dominant Logic (SDL), emphasizing value co-creation through close interaction between learners and instructors.

Specifically, the core characteristics of services—intangibility, inseparability, heterogeneity, and perishability[24]—were adopted as the theoretical foundation, and these characteristics were applied to the educational context to derive competency elements aimed at addressing each attribute.

This process goes beyond a simple listing of elements and is grounded in a theoretical mapping process that reinterprets key concepts of service theory within the educational context and transforms them into a structured competency framework.

In consideration of four strategies proposed to address the limitations arising from these service characteristics—namely, visualization, management of user touchpoints, systemic approaches, and the creation of memorable experiences [24,25]—this study identified four core competency factors for pre-service special education teachers in AI-integrated education from an education service perspective. These factors are value experience delivery, interactive experience delivery, opportunities for an integrated approach, and opportunities for value co-creation. Based on these factors, a latent model of pre-service special education teacher competencies for AI-integrated education was proposed, as illustrated in Figure 1.

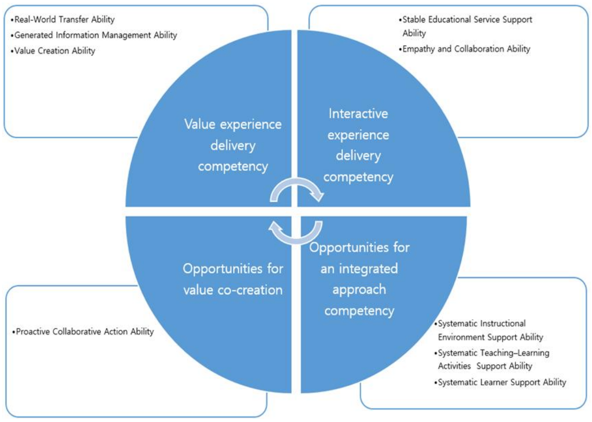

Fig. 1. A Latent Model

To develop a latent model of competencies for pre-service special education teachers in AI-integrated education from an education service perspective, this study comprehensively reviewed prior studies on AI-integrated education and teacher competencies, as well as literature related to education services. In particular, each construct was derived based on teacher competency elements identified in previous research and theories of education service.

First, the competency of 'value experience delivery' was derived, for overcoming the limitation of intangibility characteristic of education service, from the premise that AI-integrated education should offer learning experiences connected to students' real lives. This construct reflects prior studies emphasizing the practical application of AI-integrated education and learner-centered education [7,8], as well as research on education services highlighting value creation through learning experiences [20]. In addition, the ability to manage generated information was included based on studies emphasizing information utilization and ethical management in digital environments [27].

Second, the competency of 'interactive experience delivery' was derived based on the inseparability characteristic of education service, reflecting prior studies that emphasize the importance of interaction and collaboration between learners and teachers [8,15,27]. In particular, empathy and collaboration were conceptualized based on prior research highlighting the importance of learner-centered interaction in AI-based learning environments.

Third, the competency of 'opportunities for an integrated approach' was derived as a strategy to overcome the heterogeneity of education service. This construct reflects studies suggesting that AI-integrated education should be operated as a comprehensive system encompassing learning environments, instructional activities, and learner support, rather than being limited to a single lesson context [11,15,27].

Fourth, the competency of 'opportunities for value co-creation' was conceptualized, for tiding over the perishability characteristic of education service, based on service-dominant logic, emphasizing that value is co-created through interactions between learners and teachers [19,20]. This construct also reflects prior research highlighting the teacher's proactive role in curriculum implementation and collaborative problem-solving processes.

In sum, the supporting references for each construct are summarized in <Table 1>.

Table 1. The Academic Foundations of Latent Model

Area	Sub-area	Sources
1. Value Experience Delivery	Real-World Transfer Ability	[15, 26]
	Generated Information Management Ability	[27]
	Value Creation Ability	[7, 21]
2. Interactive Experience Delivery	Stable Educational Service Support Ability	[15, 21, 26]
	Empathy and Collaboration Ability	[27]
3. Opportunities for an Integrated Approach	Systematic Instructional Environment Support Ability	[11, 15, 21, 27]
	Systematic Teaching-Learning Activities Support Ability	[15, 21, 27]
	Systematic Learner Support Ability	[21, 27]
4. Opportunities for Value Co-Creation	Proactive Collaborative Action Ability	[2, 15, 27]

III. Methods

1. Participants

This study conducted an online survey to examine the perceived importance of a latent competency model for pre-service special education teachers in AI-integrated education from an education service perspective. Participants were randomly sampled from a population of pre-service special education teachers, and data were collected via an online questionnaire. The survey consisted of 19 items based on the proposed latent competency model, and respondents rated the importance of each item using a five-point Likert scale. The participants were undergraduate students majoring in special education, selected using convenience sampling.

Data collection was carried out over approximately five months, from May 1 to September 30, 2025, using an online survey. A total of 100 valid responses were included in the final analysis[1].

1) As data were collected through voluntary participation using an online survey link, it was difficult to accurately determine the total size of the population to whom the survey was distributed. Therefore, the response rate could not be calculated. Although the sample size may be insufficient for conducting exploratory factor analysis, this study was designed as an initial stage of instrument development employing exploratory analysis. Therefore, the results were interpreted with caution.

Regarding the characteristics of the respondents, 39 participants (39%) were male and 61 participants (61%) were female. The distribution by academic year was as follows: 9 first-year students (9%), 25 second-year students (25%), 39 third-year students (39%), and 27 fourth-year students (27%). In terms of prior experience with AI-related coursework, 38 respondents (38%) reported having taken at least one AI-related course, while 62 respondents (62%) reported no such experience.

2. Instrument

After analyzing and synthesizing findings from relevant prior studies, measurement items were developed based on the derived latent model. The detailed structure of the measurement items and the results of the reliability analysis are presented in Table 2.

Table 2. Structure of questionnaire

Area	Sub area	No. of Item	Cronbach α
1. Value Experience Delivery	Real-World Transfer Ability	1.1.	.918
	Generated Information Management Ability	1.2.	
	Value Creation Ability	1.3.-1.4.	
2. Interactive Experience Delivery	Stable Educational Service Support Ability	2.1.-2.2.	.871
	Empathy and Collaboration Ability	2.3.-2.4.	
3. Opportunities for an Integrated Approach	Systematic Instructional Environment Support Ability	3.1.-3.2.	.957
	Systematic Teaching-Learning Activities Support Ability	3.3.-3.5.	
	Systematic Learner Support Ability	3.6-3.8.	
4. Opportunities for Value Co-Creation	Proactive Collaborative Action Ability	4.1.-4.3.	.899
Total			.974

Table 3. Measurement Items

Area	Item
1. Value Experience Delivery	1.1. I can connect AI-integrated education learning content to real-life contexts.
	1.2. I can safely manage and utilize information generated and collected during AI-integrated education.
	1.3. I can design AI-integrated lessons appropriate for students with different levels of disability.
	1.4. I can connect basic AI principles with learning content and learning tasks.
2. Interactive Experience Delivery	2.1. I can support AI-integrated education by considering learners' levels and interests.
	2.2. I can flexibly use AI-based software in alignment with learning objectives.
	2.3. I can interact with students using AI technologies.
	2.4. I can collaborate with an AI teaching assistant.
3. Opportu-nities for an Integrated Approach	3.1. I can understand and support learning environments for AI-integrated education (e.g., cloud-based student devices and classroom wireless networks).
	3.2. I can use AI ethically in relation to instructional materials.
	3.3. I can maintain alignment among educational objectives, content, and evaluation in AI-integrated education and clearly communicate this to learners.
	3.4. I can select instructional methods appropriate for AI-integrated education.
	3.5. I can design learning evaluations for AI-integrated education that align with curriculum achievement standards.
	3.6. I can provide support to learners in areas where they experience difficulties during AI-integrated education.
	3.7. I can design learner motivation strategies using digital tools.
	3.8. I can provide AI-based emotional support by considering individual learner characteristics.
4. Opportu-nities for Value Co-Creation	4.1. I can effectively handle teaching-learning and administrative tasks using AI technologies.
	4.2. I can understand and implement AI-integrated education policies to support changes in the educational system.
	4.3. I can redesign AI-integrated curricula according to a school's educational context.

The reliability of the items across the four measurement domains was examined, yielding Cronbach's alpha coefficients of .918, .871, .957, and .899, respectively. The overall reliability for the full set of 19 items was .974, indicating a high level of internal consistency.

3. Procedures

To derive a latent measurement model, this study analyzed and synthesized relevant domestic and international prior research. Based on the proposed latent model, specific measurement items were developed.

Content validity was examined by four experts who hold doctoral degrees in education and have more than 10 years of experience in related research or teaching. All experts possessed extensive experience in digital education.

The content validity evaluation was conducted using the I-CVI (Item-level CVI)[28] and the Modified Kappa coefficient. Based on I-CVI values, five items (Items 2.2, 3.1, 3.8, 4.1, and 4.2) were classified as non-major characteristics[2)].

In addition, to address the limitation that CVI does not account for chance agreement, the Modified Kappa coefficient was calculated for each item. Modified Kappa values were calculated to adjust for chance agreement among experts [32]. The results indicated that most items demonstrated good to excellent levels of agreement ($K^* \geq 0.67$). However, item 4.2 showed a low Kappa value ($K^* = 0.20$), indicating insufficient agreement beyond chance and suggesting the need for revision or removal. They were revised based on the CVI criteria and Modified Kappa values. For example, Item 4.2 was modified from "The ability to implement AI education policies to drive changes in the education system." to "The ability to understand and implement AI-integrated education policies to support changes in the educational system."

These items (Items 2.2, 3.1, 3.8, 4.1, and 4.2) were revised and refined, and a total of 19 items were included in the final survey instrument. Using the developed preliminary items, exploratory factor analysis and reliability analysis were conducted to examine the validity of the measurement tool. In addition, discriminant analysis was performed to evaluate the functional adequacy and classification performance of the developed instrument.

4. Analysis Method

Using the data collected from the item-importance survey, descriptive analyses were conducted. To identify the underlying factors influencing pre-service special education teacher competencies for AI-integrated education from an education service perspective, an exploratory factor analysis (EFA) was performed. A principal component model was adopted, and principal axis factoring was used for factor extraction. For factor rotation, the orthogonal varimax rotation method was applied. To evaluate the functional adequacy of the measurement tool derived from the results of EFA and reliability analysis, a discriminant analysis was conducted.

Discriminant analysis[3)] was additionally conducted to exploratorily examine the extent to which the factor structure derived from the exploratory factor analysis could account for differences between groups.

IV. Results

1. Results of EFA and Reliability Analysis

Based on the analysis of data collected from an online survey of learners that assessed the importance of each measurement item, the descriptive statistics are presented in Table 4.

The overall mean score across all items was 3.70 on a five-point Likert scale, with item-level mean scores ranging from 3.56 to 3.84. These results

2) According to prior research [31], an I-CVI value of 1.00 is recommended when the number of experts is four or fewer. However, in this study, a criterion of 0.80 was inevitably applied to prevent excessive item elimination, considering the potential applicability of the items.

3) Since discriminant analysis was conducted using the same sample, it has inherent limitations. Therefore, the results should not be interpreted as evidence of validity, but rather be considered at an exploratory and reference level.

indicate that, overall, the items were perceived as moderately to highly important for evaluating pre-service special education teacher competencies for AI-integrated education.

Table 4. Mean and standard deviation

Item No.	Mean	SD	Item No.	Mean	SD
1.1	3.80	.888	3.3	3.68	.909
1.2	3.71	.844	3.4	3.77	.920
1.3	3.64	.990	3.5	3.66	.934
1.4	3.71	.946	3.6	3.74	.928
2.1	3.73	.897	3.7	3.79	.957
2.2	3.53	.969	3.8	3.71	.935
2.3	3.79	.988	4.1	3.73	.920
2.4	3.71	1.008	4.2	3.64	.948
3.1	3.60	.932	4.3	3.56	.946
3.2	3.84	.813			

The results of the exploratory factor analysis indicated that the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy was .936, exceeding the recommended threshold of .50, and Bartlett's test of sphericity was statistically significant (p = .000), even at the 99% confidence level. These results confirm the presence of common underlying factors among the items.

To examine whether items associated with each measurement criterion clustered into distinct factors, principal axis factoring was employed for factor extraction, and the varimax orthogonal rotation method was applied. The percentage of variance explained by Factor 1 was 68.4%, while Factor 2 accounted for 5.346% of the variance. All items exhibited factor loadings of .50 or higher (see Table 5).

Table 5. Relative Importance and Proportion of Variance Explained by Each Factor

Area		Eigen value	Explained Variance (%)
Factor I	Value and Interaction Experience Delivery Competency	12.997	68.405
Factor Ⅱ	Systemic Approach and Value Co-Creation Competency	1.016	5.346

Furthermore, based on a comprehensive consideration of eigenvalues and the scree test results, the items across the measurement criteria were determined to be adequately explained by a two-factor solution.

Table 6. Results of EFA & Reliability Analysis

Area	Item	Factor I	Factor Ⅱ	Cronbach α	
Value and Interaction Experience Delivery Competency	1.4.	.851		.942	
	1.3.	.824			
	1.2.	.790			
	2.3.	.737			
	2.1.	.734			
	1.1.	.698			
	2.2.	.687			
	2.4.	.545			
Systemic Approach and Value Co-Creation Competency	4.1.		.795	.966	
	3.4.		.793		.974
	3.2.		.774		
	3.8.		.771		
	3.7.		.753		
	3.6.		.738		
	3.5.		.734		
	3.1.		.733		
	3.3.		,721		
	4.3.		.701		
	4.2.		.687		

The results of the exploratory factor analysis indicated that the four domains initially proposed in the latent measurement model were statistically reorganized into two factors. Rather than representing a mere reduction, this result can be interpreted as reflecting the integrated operation of conceptual relationships among the measurement domains.

Specifically, the competencies of 'value experience delivery' and 'interaction experience delivery' share a common focus on direct interaction with learners and the formation of learning experiences. Accordingly, these competencies were integrated into a single factor, labeled 'value and interaction experience competency.'

In addition, the competencies of 'opportunities for an integrated approach' and 'opportunities for value co-creation' share macro-level and structural characteristics, such as educational environments, system structures, and collaboration among multiple stakeholders. Therefore, these competencies were grouped into a single factor, labeled 'systemic approach and value co-creation competency'.

To examine whether the items selected through the exploratory factor analysis demonstrated internal consistency as components of each scale, a reliability analysis was conducted. The overall reliability coefficient (Cronbach's α) was .974, indicating a very high level of internal consistency (see Table 6).

2. Results of Discriminant Analysis

A discriminant analysis tested whether the sub-factors of the measurement tool— 'value and interaction experience delivery competency' and 'systemic approach and value co-creation competency' —could validly distinguish between groups of students based on their characteristics, using the sub-factors as independent variables and group membership as the dependent variable.

In this study, pre-service special education teachers were classified according to their experience with AI-integrated education-related coursework. Based on their responses, participants who had completed at least 15 weeks of AI-integrated education coursework were considered to have acquired basic understanding and practical competencies related to AI-integrated education, whereas those without such coursework were classified as lacking AI-integrated education competency. Accordingly, two groups were defined: AI-integrated education competency present and AI-integrated education competency absent.

To identify the relative contribution of each independent variable, a stepwise discriminant analysis method was employed, minimizing Wilks' Lambda. The detailed results are presented in the following table.

Table 7. Result of Discriminant Analysis[4] : Distinguishing student Groups

Independent Variable	Wilks' Lambda(p)	Discriminant Function
Value and Interaction Experience Delivery Competency	.982 (.180)	.918
Systemic Approach and Value Co-Creation Competency	.984 (.208)	.385
(Constant)		-4.823
Eigenvalue		.019
Explained Variance		100
Wilks' Lambda(p)		.981 (.401)

The discriminant function was expressed as follows:

AI coursework experience (present/absent)=−4.823 + 0.918 (Value and Interaction Experience Delivery Competency) + 0.385 (Systemic Approach and Value Co-Creation Competency).

The independent variables were entered sequentially in the order of Factor I (Value and Interaction Experience Delivery Competency) and Factor II (Systemic Approach and Value Co-Creation Competency). However, Wilks' Lambda was .981 (p = .401), indicating that the result was not statistically significant. This suggests that the discriminant function did not sufficiently explain the differences between groups.

Despite the lack of statistical significance, the classification accuracy of the discriminant function suggested a moderate level of predictive utility. Specifically, the correct classification rates were 76.3% for the competency-present group and 35.5% for the competency-absent group, with an overall classification accuracy of 51% (see Table 8).

Table 8. Classification Accuracy Results

Unit: Persons (%)

		Predicted Group Membership		Total
		Competent	Non-competent	
Original Group Member-ship	Competent	29(76.3%)	9(23.7%)	38 (100%)
	Non-compe tent	40(64.5%)	22(35.5%)	62 (100%)

Overall Classification Accuracy: 51.0%

4) Furthermore, as this analysis was conducted using the same sample, the results should be interpreted with caution and only at an exploratory level. Therefore, it is difficult to conclude that the assessment tool developed in this study effectively discriminates between groups. The findings should be interpreted at an exploratory level.

V. Conclusions

This study aimed to explore a measurement tool for pre-service special education teacher competencies for AI-integrated education from an education service perspective. The results of the study can be summarized as follows.

First, the latent model of the measurement tool consisted of four measurement domains—value experience delivery competency, interactive experience delivery competency, opportunities for an integrated approach competency, and opportunities for value co-creation competency—and nine measurement criteria: real-world transfer ability, generated information management ability, value creation ability, stable educational service support ability, empathy and collaboration ability, systematic instructional environment support ability, systematic teaching-learning activity support ability, systematic learner support ability, and proactive collaborative action ability.

Second, the results of exploratory factor analysis indicated that the original measurement model was revised into two higher-order competency domains: 'value and interaction experience delivery competency', and 'systemic approach and value co-creation competency'. The reliability coefficient for this revised model was a very high level of internal consistency. Although the exploratory factor analysis results differed from the initially proposed latent model, the sub-factors were consistently grouped within the revised domains, suggesting that the original measurement domains and criteria remained conceptually meaningful.

The finding that the four measurement domains proposed in this study were reorganized into two factors can be interpreted as evidence that competencies derived from a service-oriented perspective function in a more integrated manner within actual educational contexts. In particular, competencies centered on learner experience and interaction tend to converge into a single practical domain, while structural and environmental competencies—such as systemic approach and value co-creation—also appear to be closely interconnected. This suggests that teacher competencies in education service contexts are not manifested as isolated functions, but rather as interactive and integrated constructs.

Third, the result of discriminant analysis was that the discriminant function did not sufficiently explain the differences between groups. The lack of statistical significance in the discriminant analysis may reflect the structural complexity of competencies in AI-integrated education, which cannot be adequately explained solely by whether pre-service special education teachers have taken AI-related coursework. In other words, competencies for AI-integrated education are likely influenced not only by formal coursework but also by multiple factors, such as individuals' levels of digital literacy, prior experience with technology, learning attitudes, and practical teaching experiences. In particular, in AI-based educational environments, learners' self-directed exploration and informal learning experiences may also play a critical role, suggesting that group classification based on a single variable has inherent limitations.

The discriminant analysis conducted in this study was an exploratory analysis based on the same sample, and thus has limitations in being considered a rigorous validation procedure. Nevertheless, this analysis is meaningful as an initial exploration of how the derived factor structure may relate to actual group characteristics.

These findings offer several important implications. First, the study is significant in that it developed pre-service special education teacher competencies for AI-integrated education from an education service science perspective. While education has traditionally been characterized by instructor-centered content delivery, AI-integrated education—by its nature—supports the implementation of service-dominant logic, emphasizing value co-creation through close interaction between learners and instructors. In this regard, adopting an 'education service' perspective provides a meaningful and beneficial approach [29].

Previous studies on teacher competencies for AI-integrated education have primarily focused on instructional competencies such as lesson design, implementation, and evaluation [15, 21]. In addition, a considerable number of studies have emphasized AI literacy or technology utilization competencies [7, 11]. However, these studies tend to view education from a teacher-centered perspective of knowledge transmission, with relatively limited attention to learners' experiences and value creation processes.

In contrast, this study adopts a service-oriented perspective and incorporates learner experience, interaction, and value co-creation as core elements, thereby differentiating itself from previous research. In particular, this study extends existing research by structuring teacher competencies based on the interactions among teachers, learners, and the learning environment.

Second, the exploration of the measurement tool through exploratory factor analysis and the examination of its functionality through discriminant analysis suggest that the tool may serve as a useful guideline for designing programs aimed at enhancing pre-service teacher competencies in colleges of education and teacher training institutions.

Despite these contributions, this study has several limitations. Given that factor analysis results are sensitive to sample characteristics, the sample size of 100 participants may not have been sufficient to ensure the stability of the findings. Therefore, the results should be interpreted with caution, taking this limitation into account. The findings of this study should be interpreted as exploratory.

Also, this study has a methodological limitation in that the number of experts involved in the content validity assessment was limited to four. In particular, when the number of experts is small, I-CVI values may be inflated.

Based on the findings, implications, and limitations of this study, several directions for future research are suggested. First, future studies should develop instructional content for 'digital education' teacher professionalism courses based on the competencies and measurement items identified in this study and empirically examine the effectiveness of such programs. Second, future studies are required to revalidate the content validity using a larger panel of experts to further strengthen the robustness of the measurement tool.

Although this study identified the factor structure through exploratory factor analysis, a more rigorous examination of the structural validity of the initial theoretical model requires confirmatory factor analysis (CFA) securing an independent sample. And future research should incorporate multiple variables, such as digital literacy levels, AI usage experience, and learner characteristics, and employ multivariate analysis to more rigorously examine the discriminant validity of the measurement tool.

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Authors

Sung-Wan Kim received a PhD in Instructional Technology(Yonsei Univ.), a BA in English Literature & Linguistics (Yonsei Univ.), and an MA in English Education (Kyunghee Univ.), and Dr. Kim is a professor of Korea Nazarene University. He was a professor of Ajou Univ. His research interests are education service design, AI in education, and diffusion of innovation