

Development of Assessment Tools for Convergent Education of Advanced Technology and Humanities/Social Sciences: Focusing on COSS and HUSS

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ARTICLE INFO

Article history:

Received 24 Oct 2024

Revised 26 Nov 2024

Accepted 29 Nov 2024

Keywords:

Advanced technology,
Competency assessment tools,
Convergent talents
humanities/social sciences,
Convergent thinking skills,
COSS/HUSS

ABSTRACT

This study develops a competency diagnostic tool for fostering individuals who think convergently across advanced technology and the humanities. With growing emphasis on interdisciplinary research and education, systematic assessment tools for such integration are increasingly necessary. Focusing on the COSS (Advanced Convergence) and HUSS (Humanities and Social Science Convergence) initiatives, this study applies the Delphi method to gather expert input and validate identified competencies. Through a literature review, preliminary tool development, and expert feedback collection, customized competency definitions and diagnostic tools were created for both COSS and HUSS. COSS emphasizes understanding advanced technologies and generating convergent value, while HUSS focuses on identifying and addressing future issues from a humanities perspective. This tool evaluates competencies in convergent attitudes, knowledge, learning, and problem-solving, and can be used for self-assessment to support individualized educational planning.

1. Introduction

In the pursuit of sustainable socioeconomic development, interest in the humanities has grown considerably. Since the 1960s, interdisciplinary research has expanded beyond science and technology to include the humanities, social sciences, and the arts, becoming a crucial paradigm for the sustainable development of future societies. Socioeconomic issues are becoming more complex alongside global environmental challenges, prompting developed countries to emphasize interdisciplinary research

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and technological advancement to address these concerns.

Notably, the percentage of science and engineering graduate students recognizing the need for humanities education has risen (JoongAng Daily, 2016), highlighting the importance of humanities in non-humanities fields. This shift underscores the essential nature of a convergent human resources curriculum. Today, university education is transitioning toward competency-based frameworks, reflected in both liberal arts and major courses (Park, 2021). The 2015 revised curriculum emphasizes nurturing creative and convergent talents (Kim et al., 2018) and fostering subject integration (Han et al., 2017). These changes signal a movement away from traditional knowledge-based education toward a focus on individuals' core competencies (So et al., 2013; Jin, 2013).

McClelland (1970s) criticized traditional educational assessment methods and introduced competency assessment as an alternative. Core competencies, defined as essential, non-job-specific abilities critical to life, are increasingly recognized as complex, higher-order skills linked to superior performance and competitive advantage (Lee, 2009; Goddard, 1997; Le Deist & Winterton, 2005). Accordingly, core competencies are gaining prominence in modern education.

A primary driver behind competency-based education in Korean universities is university assessment and national funding programs (Lee et al., 2020), which have spurred discourse on core competencies and educational outcomes. This shift aligns with the Yoon administration's national agenda of "A Learning Revolution that Cultivates Everyone as Talented," emphasizing the need to innovate liberal arts curricula and expand support for convergence research.

The Ministry of Education and the Korea Research Foundation aim to foster convergent talent by dismantling boundaries between disciplines through initiatives like the Convergence University Project for Innovation in High-Tech Fields (COSS) and the Humanities and Society Convergence Talent Development Project (HUSS). Consequently, convergence-oriented curricula are increasingly common, and the demand for convergence competency diagnostics is growing.

This study seeks to develop a diagnostic tool to assess convergence competencies and design an educational program to foster convergent talents. A comprehensive analysis of the vision, goals, and competencies of convergence talent informs the tool's development, contributing to curriculum design and evaluation. By objectively measuring and evaluating the core competencies of convergent talents, this study aims to enhance convergence education and underscores the importance of fostering interdisciplinary skills across diverse fields.

2. Prior Research

The importance of competency-based convergence education and the changes in university education in response to the Fourth Industrial Revolution have recently garnered significant attention in the academic community. Kim, Koo, and Ryu (2021) conducted an empirical analysis on how competency-based convergence education can enhance the quality of university education amidst these transformative changes. Their study, which utilized the SUPERMAN competency diagnosis survey with smart factory convergence majors, demonstrated that students' levels of challenging spirit, sense of social responsibility, and convergence ability significantly improved as their engagement

in convergence majors increased. This suggests that competency-based convergence education has a positive impact on the development of students' core competencies.

In a related study, Kim, Min, and Jeong (2018) developed and validated a diagnostic tool that aligns core competencies with educational philosophy and human resources goals. They identified logical critical thinking, creative convergent thinking, self-management, problem-solving, communication, global competence, and a sense of community as core competencies for university students. These competencies are regarded as essential in the era of the Fourth Industrial Revolution, and the study highlights how core competency diagnosis can be utilized for designing and evaluating educational programs, reinforcing the importance of competency-based education in higher education.

Kim (2016) analyzed the gap between the perceived importance and actual practice of learning competencies, identifying a significant discrepancy between the learning competencies valued by university students and those they actively practice. Specifically, time management and goal management skills were found to require substantial improvement, underscoring the importance of students cultivating the ability to manage their own learning effectively.

Additionally, Kim (2020) examined students' perceptions of multidisciplinary learning competencies, identifying metacognition, memory improvement, and the ability to engage in repetitive learning as crucial factors in the learning process. This study underscores the need for creative and self-directed learning to support the integration of various academic disciplines.

Moreover, Ko (2022) emphasized that in the context of the Fourth Industrial Revolution, the essential qualities for human resources include creativity, convergence, and relational skills, as evidenced by cases of educational innovation in advanced countries. The study advocates for educational reform to strengthen the core competencies necessary to meet these demands.

Collectively, these studies illustrate that competency-based convergence education is becoming an indispensable approach in the era of the Fourth Industrial Revolution. This educational model not only equips students with essential skills in creativity, problem-solving, and critical thinking but also contributes to the cultivation of human resources capable of addressing the complex needs of future societies.

3. Research Method

3.1 Research procedure

This study aimed to develop a systematic diagnostic tool for fostering convergence talent and assessing convergence talent competencies. The research procedure involved reviewing the need for fostering convergence talents and examining related studies through a comprehensive literature analysis. Based on this analysis, a framework of core competencies for convergence talents was constructed. Indicators to measure these competencies were developed through a preliminary assessment tool, and the tool's validity was verified by gathering expert opinions via a Delphi survey. The research process was methodical, and the final convergence competency diagnostic tool was refined based on expert consensus. The study's findings are intended for practical application in education policy and industry, offering suggestions for continuous monitoring and improvement of the tool.

Category	Content		Conducted by
Literature Analysis	Analysis of Convergence Talent Training Project	- Analyze the background, purpose, and curriculum of the COSS and HUSS projects to foster human resources.	Researchers
	Analyzing literature related to convergence human resource capabilities	- Research on the necessity and purpose of diagnosing convergence human resource competencies - Research on the development of convergence talent competency diagnostic test	
Competency Diagnostic Test Development	Derive a framework of basic competencies for convergence talent	- Further analyze the identified competencies to combine or categorize similar competencies - Redefine each competency to develop a convergence talent competency framework	Researchers + Researchers Related fields experts
	Develop a preliminary assessment instrument	- Develop a preliminary assessment instrument to measure the selected convergence competencies. - Include metrics to specifically assess the convergence talent's capabilities	
	Conduct a Delphi survey	- Select about 10 experts in related fields - Conducted three Delphi surveys - Through this process, we review the contents of the convergence competency assessment instrument and make necessary adjustments	
Development of the Convergence Talent Competency Test	Convergence talent	- Final discussion with researchers and experts on the competency diagnostic tool derived from the Delphi survey	Researchers + Researchers Related fields experts
	Confirm	- Finalize the convergence talent competency diagnostic test - Propose to validate it through actual implementation	
Policy Recommendation	<ul style="list-style-type: none"> - Diagnostic name: COSS-HUSS COMPETENCY - Provide the developed competency diagnostic to business units and encourage their utilization - Manage the quality of the convergence curriculum through annual checks of the competency diagnostic test 		Researchers

Fig. 1. Study Organization and Procedures

3.2 Analyzing primary data to derive competencies for convergence talents

This study comprehensively examines the frameworks of convergence competencies proposed by various international organizations and academic research to derive a foundational set of core competencies essential for convergence talents. Convergence education emphasizes the ability to apply knowledge and skills from multiple fields to address complex problems and promote sustainable development. The resulting framework includes human-centered competencies such as creative thinking, critical thinking, problem-solving, communication, collaboration, and social responsibility, aiming to foster problem-solving abilities and value creation through convergent thinking.

In a comparative analysis of core competencies from both domestic and international perspectives, this study systematically reviewed findings from various scholars, identifying each core and sub-competency and summarizing their definitions in a table. By analyzing how core competencies are defined and applied across diverse academic viewpoints, the study offers recommendations for enhanc-

ing convergence education quality worldwide.

Initially, the study reviewed the competencies related to convergence talents as outlined by domestic and international researchers. As detailed in the accompanying table, each study's core competency elements are summarized, revealing variations in the number and types of competencies emphasized. For instance, Kim (2016) identified nine competencies, while Choi (2020) focused on four, reflecting each researcher's unique approach based on their specific assessment goals. Furthermore, the segmentation of competencies characterizes these assessments. Studies like Park (2014) delve deeper, categorizing creative and critical thinking into functional and dispositional components, respectively, suggesting the importance of addressing multiple aspects of competencies in development and evaluation.

The table below provides an integrated view of competency categories and their significance in education by juxtaposing factors from different competency assessments. This comparison clarifies the core competencies prioritized in each study and offers insights into their application and evaluation in educational contexts.

Table 1. Researcher-specific competency evaluation factors

Researcher (Year)	Competency evaluation factors	Number of competencies
Kim, Hyo-Keun (2001)	Cooperation, information technology ability, career exploration, design ability	4
Baek, Yoon-Soo, et al. (2011)	Creative thinking, Convergence knowledge, Communication, Cooperation	4
Choi, Yoo-Hyun (2012)	Creative thinking, Problem solving, Communication, Cooperation	4
Kim (2012)	Diffuse thinking, metaphorical/analogical thinking, collaboration, openness to diversity	4
Park, Ki-Moon et al. (2014)	Creative thinking (creative thinking function, creative thinking disposition), critical thinking (critical thinking, critical thinking disposition), convergence knowledge understanding (understanding the connection between various knowledge, creating new valuable knowledge), convergence performance ability (problem solving, communication, cooperation, utilizing convergence tools), convergence attitude ability (caring, responsibility, positive value attitude)	5(26)
Yang, Hee-Sun, Kang, Sung-Joo (2016)	Creative thinking, critical thinking, problem solving, communication, self-development, responsibility, and ethics	6
Ministry of Education (2015~2023)	Self-management, knowledge information processing, creative convergence thinking, aesthetic sensitivity, communication, community	6
Kim, Hee-Yeon, Min, Kyung-Seok, Jung, Ji-Young (2018)	Logical critical thinking skills, creative convergent thinking skills, self-management skills, problem-solving skills, communication skills, global skills, community awareness skills	7
Myeonghee Lim (2019)	Spirituality, Communication, Self-development, Creative convergence, +Type cooperation	5
Kim (2016)	Learning competencies (personal competencies, basic competencies, and extended competencies) 9 competencies (self-development competency, interpersonal relationship competency, future design competency, basic learning competency, major deepening competency, learning management competency, problem-solving competency, creative convergence competency, information technology competency, creative fusion competency Problem Solving, Creative Convergence, Information Technology)	10
Yonggeum Choi (2020)	Creative ability, Creative personality, Convergent thinking, Convergent value creation	4
Hyunseok Choi (2023)	Pioneering spirit, ethical service spirit, international cultural sensitivity, creative expertise	4
Sangin Kwak, Joonram Jeon (2024)	Dynamic activities of instructors: field trips, experiential activities, and collaboration with industries and companies Active discussion and exchange for knowledge expansion: equal relationship, respect for diverse thinking, and exchange between seniors and juniors Instructor's conditions for fostering convergence talents: communication skills, interest in students and professional knowledge	3(9)
SCANS(The Secretary's Commission (The Secretary's Commission on Achieving Necessary Skills)	Resource utilization ability, Interpersonal relationship ability, Information processing ability, System capability, Eechnical utility ability, Basic ability, Thinking skills, Personal qualities	8

Additionally, this study conducted an extensive literature review to identify and define the core factors of convergence human resource competencies, as summarized in Table 1. The findings revealed that these core competencies can be categorized into three main areas: convergence cognition, convergence performance, and convergence attitude.

Convergence cognition encompasses creative and critical thinking. Creative thinking involves generating innovative ideas to solve problems, while critical thinking focuses on analyzing and evaluating information or problems from diverse perspectives. These sub-competencies are further divided into skills and dispositions, based on definitions provided by Park et al. (2014).

Convergence performance includes problem-solving, communication, and collaboration skills, with each subcomponent addressing aspects such as problem identification and resolution, presentation and conflict management, and interpersonal skills. For instance, Park et al. (2014) define problem-solving skills as the ability to clearly identify issues and design and implement optimal solutions.

Convergence attitude highlights empathy, respect for diversity, and social responsibility, described as the capacity to appreciate and honor the unique characteristics of others and to act responsibly within a societal context. This definition draws on the work of Rychen (2003) and Kyunghee So (2007).

The table provides valuable insights into interdisciplinary competencies and their practical applications in educational settings, reinforcing the academic foundation through various relevant references.

Table 2. Converged talent competencies key factors and definitions

Core	Subcompetency	Definition	References		
Fusion Cognition	Creative Thinking	Creative Thinking Skills	<ul style="list-style-type: none"> - The ability to recognize the facts and values needed to solve a problem and think of different, original, and useful criteria or methods to solve it. - The fluency required to produce creative ideas, flexibility, originality, and sophistication necessary to produce creative ideas. - Suggest original and practical ideas to improve performance. - Always explores new alternatives to solve problems. - Suggests new solutions to solve problems facing the organization. - Establishes useful criteria or plans for creative ideas. 	Park, Ki-Moon et al. (2014) Scott and Bruce (1994) Zhou and George (2001) Baek, Yoon-Soo et al. (2011) Choi, Yoo-Hyun et al. (2012) Kim, Sung-Won (2012)	
		Creative thinking disposition	<ul style="list-style-type: none"> - The sensitivity required to produce creative ideas, defining characteristics such as openness, independence, task focus, spontaneity, etc. 		
	Critical thinking	Critical thinking	<ul style="list-style-type: none"> - Cognitive traits such as interpreting, reasoning, analyzing, evaluating, and explaining stimuli or information given in a problem situation in the context of various solutions. - Thinking comprehensively about a problem from multiple perspectives with accuracy and rationality. - Interpret, reason, analyze, evaluate, and explain stimuli and information from a problem situation analytically. - Adopts an exploratory perspective and viewpoint when approaching problems. 		Park, Ki-Moon (2014) Lee and Olson (2010)
		Critical Thinking Disposition	<ul style="list-style-type: none"> - Defining characteristics such as truth-seeking, openness, exploration, objectivity, systematicity, and self-reliability in the context of multiple solutions to a problem. 		
	Understanding convergent knowledge	Understanding the connections between diverse knowledge	<ul style="list-style-type: none"> - Ability to understand the connections between different pieces of knowledge in the context of a problem situation. - Understanding whether or not knowledge can be acquired 		Kim, Hyo-Keun et al. (2001) O'Dell and Grayson (1998)
		Creating knowledge of new value	<ul style="list-style-type: none"> - Ability to apply and utilize contextual knowledge in a problem situation to create new, valuable perspectives of knowledge. - Understand exactly where existing and new knowledge comes from 		

Table 2. Cont.

Core	Subcompetency	Definition	References		
Convergence performance/ execution skills	Problem solving	Problem recognition	- Ability to insightfully get to the heart of an issue and clearly state the problem - Insightfully identify the core of the problem and clearly redefine the problem.	Kim, Hyo-Keun et al. (2001) O'Dell and Grayson (1998)	
		Design and execute solutions	- Ability to handle and solve problems by designing, implementing, and evaluating the best ideas for solving problems. - Apply and utilize contextual knowledge given in a problem. - Design, implement, and evaluate the best idea to solve a problem.	Park et al. (2014) Luthans et al. (2008)	
	Communication	Listening	- The ability to watch and listen carefully to the words and nonverbal expressions of others to determine their feelings, thoughts, and intentions and respond appropriately.	Kwon, Sangjip (2017) Reece and Brandt (1984)	
		Presentation	- the ability to plan, write, and present materials that effectively express ideas and information through words and nonverbal behaviors.		
	Collaboration	Conflict Management	- The ability to understand the various perspectives and interests of people involved in a conflict situation and guide them toward an amicable resolution. - The skill to assess and reconcile differing viewpoints and interests of those in conflict.	Kim, Hyo Geun et al. (2001) Park, Ki-Moon (2014)	
		Interpersonal Skills	- The ability to form and maintain amicable relationships with a diverse range of people through appropriate interactions. - The ability to engage cooperatively in social interactions and sustain positive interpersonal relationships with others.	Kim, Hyo Geun et al. (2001) Park, Ki-Moon (2014)	
	Utilizing Convergence Tools	Understanding of Various Tools	- The skill to comprehend and compare the characteristics of various tools, such as language, symbols, and digital devices, to select the most optimal tool.		
		Utilization of Various Tools	- The ability to efficiently use various tools, including language, symbols, text, and digital devices.		
	Convergence Attitude Ability	Caring	Understanding Diversity	- The capacity to understand and embrace diversity in others' physical attributes, language, culture, environment, and disciplinary characteristics	Rychen (2003) So (2007)
			Respect for Others	- An attitude of care and respect based on understanding others' emotions and perspectives through empathy	
Responsibility		Practical Ethics	- The attitude of being able to judge what is morally right according to ethical standards and willing to act upon it.		
	Social Responsibility	- An understanding of one's close connection to society or a group and a commitment to fulfill one's duties according to their role.			
Others	Knowledge Accessibility		- A precise understanding of where existing and new knowledge originates. - Awareness of what specific knowledge is needed for particular tasks. - Knowing the possibility and means of acquiring knowledge.	Kim, Hyo-Keun et al. (2001) O'Dell and Grayson (1998)	
		Credibility	- Has confidence in the information and abilities of others. - Has confidence in the judgment of others. - Communicates truthfully when speaking with others. - Does not gossip about others	Hargadon (1998) Krogh (1998)	
	Openness	- Easily solicits information from members. - Is open to sharing information with others. - Favorable to counterarguments from others. - Willingness to share information with others	Choi, Yoo-Hyun et al. (2012) Roos and Roos (1997)		
	Considerate	- Understands and respects diversity in oneself and others. - Understands and respects diversity in self and others. - Empathizes with others' positions. - Always recognizes and embraces diversity	Baek, Yoon-Soo et al. (2011) Organ (1997)		

4. Drafting a diagnostic tool for future talent convergence capabilities

4.1 Drafting a convergence competency diagnostic tool for future human resources

4.1.1 Evaluate the appropriateness of convergence competency definitions

Each definition underscores the capability to generate new value by integrating knowledge and technology. The first definition presents a general perspective on convergence, the second emphasizes applications in advanced technology, and the third highlights a humanistic approach.

Table 3. Future workforce convergence competency name and definition

Competency Name	Definition
[COSS-HUSS Business Integration] Future Human Resources Convergence Competency	The ability to create new convergent values required by future society through understanding of knowledge and technology in various academic fields and convergent thinking
[COSS Specialization] Advanced Convergence Innovation Capability	Ability to create new convergent values in the field of advanced technology through understanding of knowledge and technology in various academic fields and convergent thinking
[HUSS Specialization] Future Convergence Leading Capability	The belief that we must make responsible choices and actions for a sustainable future through convergent thinking and understanding of knowledge and technology in various academic fields based on a humanistic perspective

4.1.2 Evaluate the appropriateness of the structure and definition of future talent convergence competencies

The core competencies for future human resources are systematically outlined, with each competency clearly defined to highlight its relevance in both current and future societies. This approach emphasizes the importance of convergent thinking and collaborative skills across diverse fields, preparing individuals to navigate complex, interdisciplinary challenges.

Table 4. Draft future workforce convergence competency components

Competency families	Subcompetencies	Definition
(Common) Convergent Attitude		Intellectual flexibility to move away from closed thinking, to be open to diverse and new perspectives, information, and knowledge without prejudice, and to continually connect and synthesize with curiosity
	Multidisciplinary inclusion	An attitude toward things and phenomena based on intellectual curiosity about diverse and new perspectives, information, and knowledge
	Convergent Mindset/Will	Willingness to apply diverse and new perspectives, information, and knowledge to view problems and phenomena
((Common) Convergent Knowledge		The ability to build convergent knowledge through a process of analytical and critical learning and experience with diverse and new perspectives, information, and knowledge.
	Understanding Convergent Knowledge	Ability to understand the links between various perspectives, information, and knowledge
	Convergent learning	Ability to understand, analyze, reason, and synthesize diverse perspectives, information, and knowledge
(Common) Convergent Performance		The ability to solve problems or create new knowledge and value based on understanding diverse and new perspectives, information, and knowledge and the connections between them.
	Convergent communication and collaboration	Ability to communicate information, knowledge, etc. with people from various fields of study and collaborate seamlessly
	Convergent problem solving	Ability to examine various perspectives and alternatives to solve problems and propose innovative and leading alternatives from a new perspective.

4.1.3 Evaluate the appropriateness of the Future Talent Convergence Competency Diagnostic Tool

The Future Human Resources Convergence Competency Diagnostic Tool is designed to systematically and comprehensively evaluate the range of convergence competencies essential for future societies. The tool rates each competency on a scale from 1 to 5, enabling a precise assessment of an individual's current competency level. Organized into competency groups and sub-competencies, it includes definitions and targeted statements to help individuals identify their strengths and areas for improvement, making it a valuable resource for designing educational and training programs or personal development plans.

Importantly, this diagnostic tool goes beyond measuring existing knowledge and skills, placing a strong emphasis on convergent thinking and problem-solving skills critical for the future. Competencies such as understanding and applying advanced convergence technologies, recognizing emerging issues, and fostering a sense of efficacy will be vital in an increasingly dynamic environment, preparing learners to adapt to future demands.

The tool also emphasizes the importance of interdisciplinary connections and collaboration, evaluating skills like multidisciplinary integration and interdisciplinary communication that are vital in today's world. The ability to effectively collaborate across disciplines to devise creative, innovative solutions is highly valued in modern workplaces, and strengthening these skills will enhance both individual professional success and organizational progress.

4.2 Validation of the Delphi-based Future Talent Convergence Competency Diagnostic Tool

4.2.1 Validation of Delphi Design and Analysis

This study aims to develop a diagnostic tool to effectively evaluate the convergence competencies essential for future societies. It focuses on assessing the convergence competencies of students who have completed the COSS (Center for Innovation and Convergence University) and HUSS (Humanities and Society Convergence Human Resources Development Project) programs. Based on these assessments, expert opinions are synthesized to develop a reliable and valid competency model and diagnostic tool. Additionally, this study seeks to verify the effectiveness of convergence-focused human resource training programs and identify necessary improvements, ultimately contributing to the cultivation of human resources equipped with creative and convergent thinking skills for the future society.

Delphi Survey Phase

The Delphi Method, a structured decision-making technique, is particularly effective for achieving consensus among experts on specific topics or issues. In this study, a three-stage survey was conducted using the Delphi Method to develop definitions and diagnostic questions for assessing convergence competencies in future talent.

In the first survey, experts provided initial feedback on the definition and detailed competencies of future talent convergence. This phase involved evaluating the appropriateness of specialized com-

petency definitions and components related to each program (COSS, HUSS) and reviewing draft diagnostic questions for each detailed competency.

The second survey served as a re-evaluation phase, where experts reviewed and assessed the revised definitions and questions based on feedback from the first survey, focusing on the appropriateness of the adjustments made to the diagnostic questions.

The third survey aimed to finalize the consensus on definitions, components, and diagnostic questions. In this final step, experts assessed the overall appropriateness of the diagnostic tool, confirming that the established competency definitions and questions are effective for evaluating convergence competencies in future talent.

4.2.2 Study population

The research population for this study comprised experts involved in the convergence curricula of the HUSS and COSS projects. The selection criteria were: (1) active participation in the HUSS or COSS projects, (2) experience in designing these projects, and (3) a minimum of 7 years of experience in curriculum development within relevant fields.

Qualified experts were recommended by departments overseeing the HUSS and COSS projects, as well as by academic societies and associations. Invitations were sent via email, which included the study's purpose and a consent form.

The study population consisted of a 10-member Delphi panel, achieving a 100% response rate. The gender distribution included 4 men (40%) and 6 women (60%). The panel was composed of 8 professors (80%) and 2 researchers or staff members (20%). Age distribution was as follows: 2 members (20%) were under 40, 5 members (50%) were between 40 and 49, and 3 members (30%) were over 50. In terms of experience, 3 members (30%) had less than 10 years, 5 members (50%) had between 10-19 years, and 2 members (20%) had over 20 years of experience.

This detailed composition of the Delphi panel provides a balanced representation of expertise and perspectives within the field of convergence education.

Table 5. Characteristics of study participants

Characteristic	Category	Frequency (Percentage)
Gender	Male	4(40%)
	Female	6(60%)
Occupation	Professor	8(80%)
	Researcher/Staff	2(20%)
Age	Under 40	2(20%)
	40-49	5(50%)
	50 and above	3(30%)
Experience	Less than 10 years	3(30%)
	10-19 years	5(50%)
	20 years or more	2(20%)
Total		10(100%)

4.2.3 Delphi analysis procedure and data analysis

In this study, the Delphi survey was conducted in three rounds, each contributing significantly to the consensus-building process among the expert panel.

The first survey was exploratory and included a mix of unstructured responses along with closed and open-ended questions. This approach enabled the collection of diverse expert opinions, forming the foundation for further analysis. In the second survey, a detailed questionnaire was created based on initial responses, using a 5-point Likert scale and summarizing experts' reasoning to reflect the panel's collective feedback. The third survey involved presenting the results from the second round and analyzing them further to achieve a final consensus.

The questionnaire data collected in each round was analyzed using SPSS and Excel. Content validity ratio (CVR), content validity index (CVI), mean, standard deviation, median, and interquartile range (IQR) were calculated for each of the three questionnaires to assess the level of expert agreement. The interquartile range, in particular, indicates the degree of consensus, with smaller values signifying stronger agreement among expert responses.

4.3 Content Validity, Convergence, and Consensus

This study employs the Delphi technique to develop a diagnostic tool for assessing the convergence competencies of future talent. The Delphi method, typically conducted through iterative surveys, is designed to build consensus among a group of experts; in this study, three rounds of surveys were conducted. The first survey was exploratory, utilizing a combination of open- and closed-ended questions to gather initial expert insights. The second survey refined these insights using a Likert scale, allowing experts to re-evaluate and provide feedback on the revised questions. In the final round, the third survey validated the experts' consensus on the refined items.

For content validity analysis, content validity ratios (CVRs) were used to determine whether each item appropriately represented a specific competency. The CVR threshold for this study was set at 0.62, as recommended by Lawshe (1975), and the Content Validity Index (CVI) for the initial survey was 0.8, reflecting high validity. The interquartile range (IQR) was employed as a measure of response agreement among experts, with narrower ranges indicating greater consensus. In this study, the responses demonstrated fairly consistent expert opinions. Additionally, convergence and consensus were calculated to evaluate the degree of alignment in the Delphi survey results. Convergence was defined as 0.5 or below, and consensus as 0.75 or higher, with an acceptable goal of 80% agreement or more among responses.

4.4 Delphi Survey Analysis

4.4.1 Evaluation of the appropriateness of defining future workforce convergence competencies

As shown in Table 7, this study defines various competencies essential for the future society, drawing on previous studies and presenting them in three main categories. Each competency highlights the capacity to create new value by integrating knowledge and technology from multiple academic fields, with specific characteristics and goals detailed for each competency.

The first category, Future-Oriented Convergence Competency, is applicable across disciplines and involves the ability to address complex problems in future societies through creative and innovative thinking. This competency is based on a convergent understanding of knowledge and skills from diverse fields, emphasizing interdisciplinary cooperation as a core skill needed in an ever-evolving social environment.

The second category, Advanced Convergence Innovation Competency, focuses on the ability to generate new value through convergent thinking and the practical application of knowledge in advanced technology fields. This competency is particularly emphasized in technology-oriented programs such as COSS (College of Advanced Science and Technology), which centers on developing innovative solutions by blending various technological tools and areas of knowledge.

The third category, Future Convergence Leadership Competency, is defined as the ability to guide a sustainable future society through the convergence of diverse academic fields from a humanistic perspective. This competency, which is a key focus of programs like HUSS (Humanities and Society Convergence Talent Training Project), is essential for creating new value by integrating technological and humanistic perspectives to address complex societal issues in the future.

Table 6. Basis data for competency diagnostic tool development

Researcher(s)	Concept	Definition
Seong, E. M., Oh, H. S., & Kim, Y. Y. (2013)	Convergence Talent Competency	The ability to create new and unique values by transcending the boundaries of two or more academic fields, spreading these values to advance the overall development of academia, society, economy, and culture.
Kim, J. Y., & Tae, J. M. (2017)	Creative Convergence Competency	The competency to solve problems creatively by possessing creative abilities, a creative personality, and creative leadership, understanding, analyzing, and reasoning knowledge and skills across various academic fields, and applying them to create new convergent values through integrative thinking.
Lee, G. H., & Lee, K. H. (2020)	Creative Convergence Competency	The capability to address rapidly changing social situations with insight, encompassing knowledge across diverse fields with flexible and original creative thinking, an open-minded and sensitive creative personality, and the ability to handle new and varied problem situations.
Lee, S. M., & Jo, A. M. (2020)	Core Competency in Creative Convergence	Practical activities that enhance problem-solving skills in everyday life through science and technology-based convergent thinking, utilizing various tools and materials to produce personally or socially meaningful results.
Kim, J. Y., Bang, D. M., & Yoon, H. J. (2021)	Convergence Competency	The ability to create new and unique knowledge or values through connections and communication between two or more fields or domains.
Lim, Y. J., et al. (2021)	Creative Convergence Competency	The competency to create new values by approaching complex problems with creative and logical thinking, based on integrative and convergent learning across various fields.
Park, S. M., & Yang, H. K. (2022)	Creative Convergence Competency	The ability to solve problems by combining existing knowledge and information, identifying connections between areas of knowledge, and applying new ideas based on this foundation.
Kim, J. W., & Cho, D. Y. (2023)	Creative Convergence Competency	The competency to integrate knowledge and skills across various fields, generating new and meaningful values or outcomes through creative thinking and convergent thinking.

① Proposed Definition of Future Talent Convergence Competency
The ability to understand knowledge and skills across various academic fields and create new convergent values required by future society through integrative thinking
② Proposed Definition of COSS Competency
The ability to understand knowledge and skills across various academic fields and create new convergent values in advanced technology fields through integrative thinking
③ Proposed Definition of HUSS CompetencyH
The ability to understand knowledge and skills across various academic fields from a humanities-based perspective and create new convergent values for a sustainable future through integrative thinking

Appropriateness of Competency Definitions for Talent Development through COSS-HUSS Projects

The analysis of the appropriateness of defining competencies for talents developed through the COSS and HUSS programs yielded the following results. In the first survey, 50% of respondents indicated that each competency should be defined separately to reflect the distinct characteristics of each program, while 30% preferred a unified competency definition. In the second survey, support for separate definitions rose to 60%, with the preference for a unified competency definition remaining at 30%.

Consequently, although both projects share the overarching goal of “fostering convergent human resources,” it was concluded that defining separate operational competencies for COSS and HUSS would be more effective. This approach allows each program to develop and implement tailored curricula suited to the specific characteristics of its subject area or industry.

Table 7. Appropriateness of competency definitions for talent development through COSS-HUSS projects

Proposed Competency Name	Frequency(N)	
	1st Survey	2nd Survey
Unified Competency Name and Definition	3	3
Definition Considering the Unique Characteristics of Each Project	5	6
Additional Comments	2	1
Total/Average	10	10

In analyzing whether to separate the competency definitions for talents fostered through the COSS and HUSS projects, it was concluded that, although both projects share the core objective of fostering convergence talents, it is appropriate to differentiate the competency definitions based on each project’s unique characteristics. The COSS project requires convergence competencies specialized in high-tech fields, whereas the HUSS project emphasizes convergence competencies grounded in humanistic and social perspectives. Therefore, it was determined that the competency definitions and diagnostic tools should be distinct for each project. This differentiated approach is seen as essential for effectively cultivating human resources aligned with the specific goals and characteristics of each project.

Appropriateness of Competency Names and Definitions

The analysis results demonstrate the appropriateness of each competency definition according to the COSS and HUSS projects. First, the evaluation of the future talent convergence competency indicated high appropriateness, with an average score of 4.0 and an interquartile range (IQR) of 1.5, reflecting relatively strong agreement among experts. With 75% of experts rating it 4 or 5, the competency definition was considered valid, and its content validity ratio (CVR) exceeded the threshold of 0.62.

Next, the advanced convergence innovation competency, a specialized competency for the COSS project, showed similar levels of agreement to the future talent convergence competency, with an average score of 4.0 and an IQR of 1.5. The 4-5 rating percentage was also 75, indicating validity, and although its CVR was slightly below 0.62, it was close enough to be deemed acceptable.

In contrast, the future convergence leadership competency, specific to the HUSS project, showed only moderate agreement, with an average score of 3.0 and an IQR of 2.0, indicating a relatively low consensus among experts. Only 50% of experts rated it 4 or 5, suggesting that the competency definition lacked validity. Additionally, the CVR was below the 0.62 standard, highlighting the need for redefinition.

Table 8. Appropriateness of proposed competency names and definitions

Proposed Competency Name	1st Survey					2nd Survey				
	Mean	STD	IQR	%4-5	CVR	Mean	STD	IQR	%4-5	CVR
[Unified for COSS-HUSS Project]	4.00	1.2247	1.50	75	0.600	4.70	0.4583	0.75	100	1.000
Future Talent Convergence Competency										
[COSS Project Specialization]	4.00	1.2247	1.50	75	0.800	4.50	0.6708	1.00	90	1.000
[HUSS Project Specialization]	3.00	1.0000	2.00	50	0.200	4.60	0.4899	1.00	100	1.000

Based on feedback from the first evaluation round, the names and definitions of competencies for the COSS and HUSS projects were revised. While both competency names initially received an average rating above 4.0, some adjustments were made in response to additional comments—particularly for the HUSS competency name, which was significantly revised due to its lower average rating and CVR value.

The analysis of the second survey showed high average ratings of 4.5 or above for all revised proposals, with COSS displaying a slightly higher standard deviation, while the Integrated and HUSS proposals showed higher consistency. The IQRs remained within an acceptable range across all proposals, with 100% of ratings in the 4-5 range for the Integrated and HUSS proposals. Ultimately, the Integrated proposal received the most consistently positive ratings, with content validity assessed as very high across all proposals.

Based on these findings, the finalized competency names and certain competency definitions are presented as follows.

Table 9. Finalized competency names and definitions

Competency Name	Revised (Results Reflecting 1st/2nd Delphi Analysis)
Future Talent Convergence Competency (Integrated)	The ability to understand knowledge and skills across various academic fields and, through integrative thinking, create new and meaningful values required by future society and industry
Future Talent Convergence Competency (COSS)	The ability to understand knowledge and skills across various academic fields and, through integrative thinking, create new and meaningful values required in the fields of advanced technologies and emerging industries
Future Talent Convergence Competency (HUSS)	The ability to understand knowledge and skills across various academic fields from a humanities-based perspective and, through integrative thinking, create new and meaningful values for a sustainable future

4.4.2 Assessment of the appropriateness of the structure and definitions of the future workforce convergence competencies

The survey results indicate that the statistical validity of the competency names and definitions was rated very high. Notably, some experts suggested that competencies like attitude and willingness, which are suited to self-assessment surveys, were appropriate for inclusion. Additionally, there was a recommendation to add questions to assess respondents' actual understanding through the survey. COSS-specific competencies were defined as "competencies," while HUSS-specific competencies focused on "beliefs/attitudes."

The analysis revealed that all components of the future talent convergence competency were highly rated. In particular, the content validity ratio (CVR) was measured at 1.000, demonstrating that all proposed competency components are highly valid and appropriate. The average scores and percentage of 4-5 ratings were positive, and the overall evaluation showed high consistency. Consequently, the proposed future talent convergence competency components were deemed suitable for use by researchers.

Table 10. Appropriateness of future talent convergence competency components

Future Talent Convergence Competency Components		1st Survey					2nd Survey				
		Mean	STD	IQR	%4-5	CVR	Mean	STD	IQR	%4-5	CVR
(Common) Convergent Attitude	Definition	4.40	0.66	1.00	90	1.000	4.40	0.4899	1.00	100	1.000
	Multidisciplinary Inclusiveness	4.30	0.64	1.00	90	1.000	4.50	0.6708	1.00	90	1.000
	Convergent Mindset/Willingness	4.40	0.66	1.00	90	1.000	4.60	0.4899	1.00	100	1.000
(Common) Convergent Knowledge	Definition	3.90	0.94	1.50	70	0.800	4.60	0.4899	1.00	100	1.000
	Understanding of Convergent Knowledge	4.40	0.49	1.00	100	1.000	4.30	1.1874	1.00	90	0.800
	Convergent Learning	4.50	0.67	1.00	90	1.000	4.60	0.4899	1.00	100	1.000
(Common) Convergent Performance	Definition	4.40	0.49	1.00	100	1.000	4.70	0.4583	0.75	100	1.000
	Convergent Communication and Collaboration	4.30	0.90	1.00	90	0.800	4.80	0.4000	0.00	100	1.000
	Convergent Problem-Solving	4.30	0.64	1.00	90	1.000	4.70	0.4583	0.75	100	1.000
(Specialized) COSS	Definition	4.10	0.94	1.00	80	0.800	4.40	0.6633	1.00	90	1.000
	Understanding of Advanced Convergence Technologies	4.10	1.04	1.75	70	0.800	4.40	0.6633	1.00	90	1.000
	Utilization of Advanced Convergence Technologies	4.10	1.04	1.75	70	0.800	4.30	0.7810	1.00	80	1.000
(Specialized) HUSS	Definition	3.60	0.80	1.00	60	0.800	4.50	0.5000	1.00	100	1.000
	Awareness of Future Issues	4.30	0.90	1.75	70	1.000	4.50	0.5000	1.00	100	1.000
	Future Efficacy	3.80	0.98	1.75	60	0.800	4.70	0.4583	0.75	100	1.000

4.4.3 Assessing the appropriateness of the Future Talent Convergence Competency Diagnostic Tool

Results of the first Delphi analysis

The statistical validation of the diagnostic tool for future talent convergence competencies confirmed a Content Validity Index (CVI) of 0.8 in the first round and 0.948 in the second round among 10 experts. This high level of agreement underscores the validity of the proposed competency components and affirms their suitability as a foundation for designing educational programs. The findings strongly support that the program aimed at cultivating future talents aligns well with educational objectives and is effectively applicable in real educational settings (Appendix 1).

The results from the first round of Delphi analysis demonstrated overall positive validity in the experts' evaluation of the Future Talent Convergence Competency Diagnostic Tool. Most items had high mean scores, between 3.0 and 4.0 or above, with relatively low standard deviation and IQR values, indicating high consistency among expert responses. This consistency suggests that the items are well-aligned with the topic, and that experts share a common understanding of each competency.

Furthermore, 60-90% of experts rated items between 4 and 5, and most items had CVR values above 0.6, confirming good content validity. These ratings indicate that the items accurately capture the core of each competency. Notably, the diagnostic tool effectively reflects the educational goals and definitions of convergence competencies, suggesting it will be a valuable resource in future educational applications.

The findings indicate that the proposed diagnostic tool can serve as a reliable benchmark for future talent training programs and offer a robust foundation for the design and implementation of future education programs. Consequently, the convergence competency diagnostic tool developed in this study has demonstrated substantial feasibility and validity for educational use. Further research and ongoing refinement based on these results are recommended to enhance its effectiveness.

Results of the 2nd Delphi Analysis

The statistical validation from the second round of Delphi feedback for the Future Talent Convergence Competency Diagnostic Tool showed a CVI value of 0.948, indicating strong statistical validity. A CVI of 0.9 or higher reflects a very high level of expert agreement on the proposed convergence competency components for the future workforce, suggesting that these components can serve as a highly reliable foundation for training program design. The results also strongly support that the Future Workforce Competencies program aligns well with its educational objectives and is likely to be effectively implemented in classroom settings (Appendix 2).

The table below presents the findings from the second round of Delphi analysis. The mean values for each competency ranged from 4.0 to 4.6, reflecting high adequacy, while standard deviations ranged from 0.66 to 1.16, indicating a relatively stable response distribution. Additionally, the IQR values were generally below 1.0, signaling a high level of agreement among experts. Notably, most CVR values were 1.000, demonstrating exceptionally high content validity.

Overall, the proposed competencies and diagnostic items received very positive evaluations from experts. These findings indicate that the tool has sufficient validity to be effectively used for diagnosing future human resource convergence competencies.

The overall conclusions from the statistical analysis in the table above are as follows. First, there was a very high level of agreement among the expert group. The Content Validity Index (CVI) increased from 0.800 in the first survey to 0.948 in the second, indicating consistent expert agreement across both rounds. This positive evaluation by experts suggests that the Future Talent Convergence Competency Diagnostic Tool is a reliable assessment instrument. Second, the statistical assessment of each competency definition and component was also highly positive. The interquartile ranges (IQRs) were generally below 1.00, indicating strong consistency in responses with minimal divergence in expert opinions. Additionally, over 70% of items scored in the 4-5 range, indicating that the components are highly valid and appropriate for assessing convergence competencies. Third, the analysis of specialized competencies for the HUSS and COSS projects indicated that, although both pursue similar convergence competencies, the competencies should be differentiated according to the unique focus of each project. For the HUSS-specific competencies, certain items showed lower mean values and CVRs, signaling a need for redefinition. In contrast, the COSS-specific and common competencies received consistently high ratings, confirming the adequacy of their current definitions.

In summary, this analysis supports the use of the proposed convergence competency diagnostic tool as a reliable resource in educational settings. It also confirms that the tool can provide a sound foundation for designing programs that align with educational goals and practical learning environments.

5. Finalize the final convergence competency diagnostic tool

5.1 Competency Name and Competency Definition

In this study, specific competency definitions for the human resources to be developed through the COSS and HUSS projects were presented, with structural analysis conducted accordingly. As COSS and HUSS are convergence talent training programs with distinct characteristics, their competency names and definitions were differentiated to reflect these unique focuses.

First, future human resources fostered through the COSS program are defined as possessing advanced convergence innovation capabilities. This competency emphasizes convergent thinking and problem-solving skills that drive new value creation in advanced technology fields. For instance, a convergent attitude entails maintaining an open and integrative mindset across various disciplines, while convergent knowledge involves understanding the interconnections among fields and generating new knowledge.

In contrast, the HUSS project focuses on developing future convergence leadership capabilities from a humanistic perspective, centered on creating new convergent values for a sustainable future. This includes specialized competencies such as future problem recognition, defined as the ability to anticipate and address moral and social issues.

A shared competency between the two projects, convergence capability, is defined as the ability to generate new value through creative and convergent thinking across diverse academic backgrounds, serving as a fundamental value uniting both programs.

Tables 16 and 17 provide detailed structures and definitions of the competencies as defined by the COSS and HUSS projects, respectively, clarifying the goals and directions for fostering future talent in alignment with each program’s objectives.

Table 10. Competency names for talent development through COSS and HUSS projects

Competency Name	Competency Definition
Future Talent Convergence Competency	The ability to understand knowledge and skills across various academic fields and, through integrative thinking, create new and meaningful values required by future society and industry

Table 11. Structure and definition of future talent convergence competency (COSS)

Competency Group	Sub-competency	Definition
Convergent Attitude	Intellectual flexibility based on open-minded thinking, characterized by an unbiased and open understanding and curiosity about various academic fields, new perspectives, information, and knowledge, enabling continuous connection and synthesis	
	Multidisciplinary Inclusiveness	An attitude of viewing things and phenomena with an open mind and curiosity toward various academic fields, new perspectives, information, and knowledge
	Convergent Mindset/Willingness	The willingness to view problems and phenomena through convergent thinking, integrating diverse and new perspectives, information, and knowledge
Convergent Knowledge	The competency to acquire convergent knowledge through an analytical and critical process of learning and experience across various academic fields and new perspectives, information, and knowledge.	
	Understanding of Convergent Knowledge	The competency to understand various academic fields and new perspectives, information, and knowledge from a convergent perspective.
	Convergent Learning	The competency to synthesize diverse academic fields and new perspectives, information, and knowledge through analysis and reasoning based on comprehensive understanding
Convergent Practice	The competency to solve problems or create new convergent knowledge and value by understanding various academic fields, new perspectives, information, knowledge, and the connections between them.	
	Convergent Communication and Collaboration	The competency to communicate and collaborate smoothly with individuals from various fields, based on shared information and knowledge
	Convergent Problem Solving	The competency to examine diverse perspectives and alternatives to propose solutions from a convergent perspective
(Specialized) COSS Advanced Convergence Innovation	The ability to create new convergent value in advanced technology and emerging industry fields by understanding knowledge and skills across various academic domains and employing integrative thinking	
	Understanding Advanced Convergence Technology	The competency to understand the convergent characteristics, latest trends, and development directions of advanced technologies and emerging industries
	Utilizing Advanced Convergence Technology	The competency to leverage the convergent aspects of advanced technologies and emerging industries to create new convergent value

Table 12. Structure and definition of future talent convergence competency (HUSS)

Competency Group	Sub-competency	Definition
Convergent Attitude	Intellectual flexibility based on open-minded thinking, characterized by an unbiased, open understanding and curiosity toward various academic fields, new perspectives, information, and knowledge, enabling continuous connection and synthesis	
	Multidisciplinary Inclusiveness	An attitude of viewing things and phenomena with an open mind and curiosity toward various academic fields, new perspectives, information, and knowledge.
	Convergent Mindset/Willingness	The willingness to approach problems and phenomena through convergent thinking that integrates diverse and new perspectives, information, and knowledge.
Convergent Knowledge	The competency to acquire convergent knowledge through an analytical and critical process of learning and experience across various academic fields, new perspectives, information, and knowledge.	
	Understanding of Convergent Knowledge	The competency to understand various academic fields and new perspectives, information, and knowledge from a convergent perspective.
	Convergent Learning	The competency to synthesize diverse academic fields and new perspectives, information, and knowledge through analysis and reasoning based on comprehensive understanding
Convergent Practice	The competency to solve problems or create new convergent knowledge and value by understanding various academic fields, new perspectives, information, knowledge, and the connections between them.	
	Convergent Communication and Collaboration	The competency to communicate and collaborate smoothly with individuals from various fields, based on shared information and knowledge
	Convergent Problem Solving	The competency to examine diverse perspectives and alternatives to propose solutions from a convergent perspective
(Specialized) HUSS Future Convergence Leadership	The competency to make responsible decisions and create or enhance social and public values for a sustainable future by understanding knowledge and skills across various academic fields from a humanities-based perspective and applying convergent thinking.	
	Future Problem Recognition	The competency to specifically recognize future issues, exploring, identifying, and defining goals that need to be addressed or achieved.
	Future Efficacy	The ability to acknowledge the ambiguity and uncertainty of the future and to make choices and take actions that can have a meaningful impact on oneself, one's organization, and our shared future.

5.2 Self-Diagnostic Tool for Future Talent Convergence Competencies

This section introduces a self-diagnostic tool for assessing future talent convergence competencies within the COSS and HUSS projects. Each tool includes items targeting specific sub-competencies, enabling respondents to evaluate their competency levels accurately.

Firstly, the convergence competency diagnostic tools developed for COSS and HUSS are customized to align with each project's distinct goals and characteristics. Specifically, the COSS tool emphasizes understanding and applying advanced convergence technologies, while the HUSS tool focuses on fostering future problem awareness from a humanities perspective.

Secondly, the self-assessment items are crafted to allow respondents to evaluate themselves based on personal experiences and knowledge, enhancing the tool's effectiveness in helping individuals identify and strengthen their competencies.

Thirdly, the item structure supports learners in becoming more self-aware of their competency levels, providing a basis for developing personalized education and growth plans.

In conclusion, this self-diagnostic tool is essential for assessing and improving individual convergence competencies and serves as a foundational resource for designing future educational programs.

Table 13. Self-diagnostic tool for convergence competencies of future talent (COSS)

Competency Group	ID	Question Item
(Common) Multidisciplinary inclusion	1	I believe that differences in environment or culture can lead to different perspectives.
	2	I acknowledge the viewpoints of colleagues with perspectives different from my own.
	3	I actively embrace various situations and information to solve problems.
	4	I think it is important to learn about diverse topics and academic fields.
	5	I enjoy asking questions about diverse topics and academic fields.
	6	I am curious about new knowledge related to various topics and academic fields.
(Common) Convergent Mindset/Will	1	I strive to use knowledge from diverse fields to explain complex situations.
	2	I try to utilize content from various fields when creating new outcomes.
	3	I seek to solve problems by applying knowledge from multiple fields.
	4	I make efforts to apply knowledge from various fields to solve problems.
	5	I have a mindset of considering perspectives from fields outside my own major.
	6	I am interested in participating in collaborative projects with students majoring in fields different from mine, such as engineering, humanities, and the arts.
(Common) Understanding of convergent knowledge	1	when solving problems, I tend to utilize diverse knowledge and experiences.
	2	I make an effort to understand unfamiliar fields of knowledge when necessary.
	3	I believe it's important to understand knowledge from various fields based on the problem context.
	4	I think real-world problems are interconnected with knowledge from various fields.
	5	I can generate new ideas by combining related knowledge.
	6	I strive to learn new knowledge from different fields.
(Common) Convergent Learning	1	I can identify connections between different fields of study.
	2	I can find connections between unrelated objects or phenomena and integrate them appropriately.
	3	I try to identify connections between my field and others.
	4	I can understand and assimilate new knowledge and apply it to different areas.
	5	I work to integrate newly acquired knowledge and information with my existing knowledge.
	6	I think about how to merge my field of expertise with others.
(Common) Convergent Communication - Collaboration	1	I respect diverse perspectives and can work cooperatively with people holding various viewpoints.
	2	I can construct and expand new knowledge and understanding through interactions with others.
	3	I am open to accepting information, knowledge, and perspectives from fields other than my own.
	4	I can openly accept things that are different from my own ideas.
	5	I can communicate and collaborate with people from different majors or perspectives.
	6	I enjoy learning through mutual communication between my field and others.
(Common) Convergent Problem Solving	1	I can gather relevant information to derive a reasonable solution.
	2	I apply various perspectives to solve problems and identify success factors.
	3	I look for solutions from multiple perspectives.
	4	I can prioritize and choose the most effective and suitable method for problem-solving.
	5	I can find necessary information for problem-solving in various ways.
	6	I can set criteria to select among different problem-solving approaches.
(COSS-specific) Understanding Advanced Convergence Technologies	1	I am well-informed about the characteristics of advanced technologies emphasized in emerging fields.
	2	I can identify and select the necessary advanced technologies depending on the situation.
	3	I can explain the characteristics of advanced technologies required for problem-solving by comparing them.
	4	I can utilize two or more advanced technologies to solve problems when necessary.
	5	I assess my skill level in advanced technology and work to improve it continually.
	6	I can determine appropriate application areas for advanced technologies.
	7	I can critically propose ways to utilize advanced technologies.
(COSS Specialization) Utilizing Advanced Convergence Technology	1	I can integrate knowledge and information in advanced technology fields to apply in problem-solving.
	2	I can solve problems using advanced technologies.
	3	I can restructure knowledge in advanced technology fields into new knowledge.
	4	I enjoy creating new solutions by combining knowledge in advanced technology fields.
	5	I can apply previous experiences to advanced technology fields to create new knowledge and value.
	6	I can create innovative ideas or values based on advanced convergence technologies.

Table 14. Self-diagnostic tool for convergence competencies of future talent(HUSS)

Competency Group	ID	Question Item
(Common) Multidisciplinary inclusion	1	I believe that differences in environment or culture can lead to different perspectives.
	2	I acknowledge the viewpoints of colleagues with perspectives different from my own.
	3	I actively embrace various situations and information to solve problems.
	4	I think it is important to learn about diverse topics and academic fields.
	5	I enjoy asking questions about diverse topics and academic fields.
	6	I am curious about new knowledge related to various topics and academic fields.
(Common) Convergent Mindset/Will	1	I strive to use knowledge from diverse fields to explain complex situations.
	2	I try to utilize content from various fields when creating new outcomes.
	3	I seek to solve problems by applying knowledge from multiple fields.
	4	I make efforts to apply knowledge from various fields to solve problems.
	5	I have a mindset of considering perspectives from fields outside my own major.
	6	I am interested in participating in collaborative projects with students majoring in fields different from mine, such as engineering, humanities, and the arts.
(Common) Understanding of convergent knowledge	1	when solving problems, I tend to utilize diverse knowledge and experiences.
	2	I make an effort to understand unfamiliar fields of knowledge when necessary.
	3	I believe it's important to understand knowledge from various fields based on the problem context.
	4	I think real-world problems are interconnected with knowledge from various fields.
	5	I can generate new ideas by combining related knowledge.
	6	I strive to learn new knowledge from different fields.
(Common) Convergent Learning	1	I can identify connections between different fields of study.
	2	I can find connections between unrelated objects or phenomena and integrate them appropriately.
	3	I try to identify connections between my field and others.
	4	I can understand and assimilate new knowledge and apply it to different areas.
	5	I work to integrate newly acquired knowledge and information with my existing knowledge.
	6	I think about how to merge my field of expertise with others.
(Common) Convergent Communication - Collaboration	1	I respect diverse perspectives and can work cooperatively with people holding various viewpoints.
	2	I can construct and expand new knowledge and understanding through interactions with others.
	3	I am open to accepting information, knowledge, and perspectives from fields other than my own.
	4	I can openly accept things that are different from my own ideas.
	5	I can communicate and collaborate with people from different majors or perspectives.
	6	I enjoy learning through mutual communication between my field and others.
(Common) Convergent Problem Solving	1	I can gather relevant information to derive a reasonable solution.
	2	I apply various perspectives to solve problems and identify success factors.
	3	I look for solutions from multiple perspectives.
	4	I can prioritize and choose the most effective and suitable method for problem-solving.
	5	I can find necessary information for problem-solving in various ways.
	6	I can set criteria to select among different problem-solving approaches.
(HUSS Specialization) Recognize future issues	1	I become interested when I hear discussions about future technologies or societal changes.
	2	I enjoy talking about future technologies and societal changes.
	3	I can identify and analyze errors or hidden intentions in information related to the future.
	4	I am able to compare and analyze various pieces of information to understand diverse perspectives on the future.
	5	Based on future-related information, I can recognize and predict new patterns of change.
	6	I can synthesize past and present data to draw insights about the future.
(HUSS Specialization) Future Efficacy	1	I believe that our current choices and actions can change our future.
	2	I believe that today's decisions can shape the future.
	3	I think it is important to take actions that bring about positive changes in the future.
	4	Even when facing an uncertain future, I am willing to adapt and respond with a determination to change.
	5	Even when others are pessimistic about the future, I believe in our ability to work together to prepare responses.
	6	I am confident in my ability to overcome difficulties that may arise while preparing for the future.

6. Discussion and Conclusion

This study centers on developing a diagnostic tool to assess convergence competencies and applying it to educational programs within the COSS and HUSS projects, underscoring the increasing importance of convergence education in modern society. Convergence competencies—characterized by intellectual flexibility and cross-disciplinary problem-solving skills—have become essential in the era of the Fourth Industrial Revolution. This study yields several important implications.

Firstly, the development of this convergence competency diagnostic tool enables a systematic approach to evaluating convergence education and designing effective curricula. The COSS and HUSS projects, which focus on advanced technology and humanities-social science integration respectively, highlight curricula that foster convergent thinking and problem-solving skills. This tool provides foundational data, helping students understand their competency levels while offering valuable feedback for curriculum development.

Secondly, the self-diagnostic tool's practicality is emphasized. By allowing learners to self-assess, it enables personalized education, helping individuals identify areas for improvement. This approach maximizes learning effectiveness and increases the real-world impact of educational programs.

Thirdly, the differentiated approach between the COSS and HUSS projects aligns with the distinct talent profiles each aims to cultivate. The COSS project emphasizes the understanding and application of advanced technologies, while the HUSS project focuses on problem recognition and resolution from a humanities perspective. This differentiation suggests a need for specialized diagnostic tools that reinforce the unique competencies each project seeks to develop.

In conclusion, the convergence competency diagnostic tool developed in this study is a valuable educational resource for nurturing the talent required by future society. Future studies should aim to refine and apply this tool in educational settings to enhance its reliability and validity. Ongoing efforts to foster creative and innovative problem-solving skills through interdisciplinary convergence will also be essential.

While this tool provides a solid foundation for fostering convergence talent, additional research is needed for practical application and validation in educational contexts, with particular attention to reliability and validity. Although this study confirmed validity through the Delphi method, further research should address potential issues encountered by students and educators using the tool in diverse settings, with a focus on improving reliability and validity across various contexts.

Research should also explore integration with additional fields. While initially designed for advanced technology (COSS) and humanities-social science (HUSS), further studies are needed to adapt the tool for other fields, such as the arts, economics, and medicine, as required competencies may differ across disciplines. Developing and validating field-specific diagnostic tools would enhance precision in these areas.

Furthermore, examining connections with teaching methods and educational programs is recommended. Research should investigate how educational programs can be tailored to students' competency levels based on diagnostic results, as well as optimal teaching methods and strategies to foster convergence competencies in practice.

Long-term tracking of students' learning outcomes is also essential. Studies that analyze the impact

of convergence competencies on academic performance, creativity, and problem-solving abilities over time can offer insight into the long-term benefits of convergence education.

Lastly, international comparative studies are proposed to explore how convergence competencies and diagnostic tools are implemented globally. Comparative research could help to develop a model that considers different educational systems and cultural contexts, enriching the understanding of convergence competencies worldwide.

These follow-up studies will enhance the tool's effectiveness and contribute to cultivating the convergence talents required for the future.

Notes

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Conflicts of Interest

No author has any other conflict of interest to declare.

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〈Appendix 1〉 Evaluation of the Appropriateness of the Diagnostic Tool for Future Talent Convergence Competencies (Results of the First Delphi Analysis)

Competency Group	Question Item	Mean	STD	IQR	%4-5	CVR
(Common) Multidisciplinary inclusion	Competency Definition	4.10	0.83	0.75	90	0.800
	1	3.80	1.25	2.00	60	0.800
	2	3.60	1.50	2.00	60	0.600
	3	4.30	0.90	1.00	90	0.800
	4	3.30	0.90	1.75	60	0.400
	5	3.50	1.12	1.75	40	0.600
	6	2.60	1.02	1.00	20	0.200
	7	3.00	1.10	1.50	30	0.400
	8	2.90	0.94	1.50	30	0.400
	9	3.40	1.36	2.50	50	0.400
	10	3.30	1.01	1.00	40	0.800
11	3.60	1.20	1.75	50	0.800	
(Common) Convergent Mindset/Will	Competency Definition	4.00	1.00	1.75	70	0.800
	1	3.70	1.42	0.75	80	0.600
	2	4.00	1.18	1.00	80	0.800
	3	3.40	1.28	1.75	60	0.400
	4	4.00	0.89	0.75	80	0.800
	5	3.30	1.35	2.50	40	0.400
	6	3.20	1.25	1.75	40	0.400
	7	3.50	1.43	2.75	50	0.400
	8	3.10	1.30	2.00	40	0.200
9	3.10	1.30	2.00	40	0.200	
(Common) Understanding of convergent knowledge	Competency Definition	4.20	0.87	1.00	90	0.800
	1	3.70	0.78	0.75	70	0.800
	2	3.80	1.33	1.75	70	0.600
	3	3.70	1.27	1.50	70	0.600
	4	4.10	0.94	1.00	80	0.800
	5	3.70	1.27	1.50	70	0.600
	6	3.10	1.30	2.00	40	0.200
	7	3.50	1.36	2.50	60	0.400
	8	3.70	1.01	0.75	70	0.600
	9	3.80	1.17	2.00	60	0.600
	10	3.70	1.19	0.00	80	0.600
	11	3.10	1.04	0.75	30	0.600
12	3.10	1.30	2.00	40	0.200	
(Common) Convergent Learning	Competency Definition	4.20	0.98	1.00	80	0.800
	1	2.80	1.17	1.75	30	0.000
	2	3.00	1.34	2.00	50	0.200
	3	3.30	1.35	2.50	40	0.400

Competency Group	Question Item	Mean	STD	IQR	%4-5	CVR
	4	3.40	1.20	1.00	50	0.600
	5	3.60	1.28	1.75	60	0.600
	6	3.80	1.33	1.75	70	0.600
	7	3.20	1.40	1.50	30	0.600
	8	4.00	1.18	1.00	80	0.800
	9	3.80	1.17	1.50	70	0.800
	10	3.60	1.20	1.75	50	0.800
(Common) Convergent Communication - Collaboration	Competency Definition	4.20	0.98	1.00	80	0.800
	1	4.20	0.87	1.00	90	0.800
	2	3.60	1.02	1.00	60	0.600
	3	4.10	0.94	1.00	80	0.800
	4	4.30	1.01	1.00	80	0.800
	5	3.70	0.90	1.00	60	0.800
	6	4.30	0.90	1.00	90	0.800
	7	3.40	1.20	1.50	30	0.800
	8	3.30	1.10	0.75	30	0.800
	9	3.50	1.36	2.00	40	0.600
	10	3.80	1.17	1.50	70	0.800
(Common) Convergent Problem Solving	Competency Definition	3.70	1.10	1.75	60	0.600
	1	3.80	1.17	2.00	60	0.600
	2	3.40	1.11	1.75	50	0.400
	3	3.60	1.11	1.75	50	0.600
	4	3.50	1.43	2.75	50	0.400
	5	3.00	0.89	0.75	20	0.400
	6	3.20	0.98	1.75	40	0.400
	7	3.50	1.02	1.00	50	0.600
	8	3.50	1.02	1.00	50	0.600
	9	3.40	1.02	1.00	40	0.600
	10	3.70	1.35	2.75	50	0.400
	11	4.00	0.89	0.75	80	0.800
	12	3.60	1.11	1.75	50	0.600
(COSS-specific) Understanding Advanced Convergence Technologies	Competency Definition	4.00	1.00	1.75	70	0.800
	1	3.80	0.87	0.75	70	0.800
	2	3.90	0.83	0.00	80	0.800
	3	3.70	1.10	1.75	60	0.600
	4	3.50	1.02	1.00	50	0.600
	5	3.80	0.98	1.75	60	0.800
	6	3.80	0.98	1.75	60	0.800
	7	3.90	1.14	1.75	70	0.600
	8	3.80	0.98	1.75	60	0.800
	9	3.80	1.17	1.50	70	0.800
	10	3.00	1.18	2.00	40	0.200
	11	4.20	0.98	1.00	80	0.800
	12	3.90	1.04	2.00	60	0.800

Competency Group	Question Item	Mean	STD	IQR	%4-5	CVR
(COSS Specialization) Utilizing Advanced Convergence Technology	Competency Definition	3.50	1.20	2.50	50	0.400
	1	3.80	1.17	2.00	60	0.600
	2	4.10	1.22	1.75	70	0.600
	3	3.70	1.10	1.75	60	0.600
	4	3.30	1.27	1.75	50	0.400
	5	4.10	1.14	1.00	80	0.600
	6	3.10	1.04	0.75	30	0.600
	7	3.60	1.28	1.75	60	0.600
	8	3.60	1.28	1.75	60	0.600
	9	3.80	1.17	2.00	60	0.600
	10	3.30	1.10	1.75	40	0.400
	11	3.10	1.30	2.00	40	0.200
	12	2.70	1.01	1.00	10	0.200
(HUSS Specialization) Recognize future issues	Competency Definition	4.20	1.08	1.75	70	0.800
	1	3.50	0.92	1.00	60	0.600
	2	3.10	1.14	1.75	40	0.400
	3	3.20	1.33	2.25	30	0.400
	4	4.20	0.98	1.00	80	0.800
	5	3.60	1.11	1.75	50	0.600
	6	3.30	1.27	1.75	50	0.400
	7	3.60	1.11	1.75	50	0.600
	8	3.60	1.11	1.75	50	0.600
	9	3.70	1.10	1.75	60	0.600
	10	4.10	0.94	1.00	80	0.800
	11	4.00	1.00	1.75	70	0.800
	12	3.90	1.04	2.00	60	0.800
(HUSS Specialization) Future Efficacy	Competency Definition	4.30	0.90	1.75	70	1.000
	1	3.90	0.94	1.50	70	0.800
	2	3.60	1.28	1.75	60	0.600
	3	4.10	0.94	1.00	80	0.800
	4	3.30	1.49	2.50	50	0.400
	5	3.70	1.01	0.75	70	0.600
	6	3.70	1.27	1.50	70	0.600

〈Appendix 2〉 Evaluation of the Appropriateness of the Diagnostic Tool for Future Talent Convergence Competencies (Results of the 2nd Delphi Analysis)

Competency Group	Question Item	Mean	STD	IQR	%4-5	CVR
(Common) Multidisciplinary inclusion	1	4.50	0.67	1.00	90	1.000
	2	4.80	0.40	0.00	100	1.000
	3	4.70	0.46	0.75	100	1.000
	4	4.40	0.66	1.00	90	1.000
	5	4.50	0.50	1.00	100	1.000
	6	4.20	0.87	1.75	70	1.000
	7	4.50	0.67	1.00	90	1.000
(Common) Convergent Mindset/Will	1	4.70	0.46	0.75	100	1.000
	2	4.50	0.67	1.00	90	1.000
	3	4.30	0.78	1.00	80	1.000
	4	4.40	0.66	1.00	90	1.000
	5	4.00	0.77	0.00	90	0.800
(Common) Understanding of convergent knowledge	1	4.30	0.64	1.00	90	1.000
	2	4.10	1.04	1.75	70	0.800
	3	4.00	1.18	1.75	70	0.600
	4	4.60	0.92	0.00	90	0.800
	5	4.40	1.02	0.75	80	0.800
	6	4.50	0.67	1.00	90	1.000
	7	3.90	1.04	2.00	60	0.800
	8	4.10	1.22	1.75	70	0.600
(Common) Convergent Learning	1	4.20	0.75	1.00	80	1.000
	2	4.40	0.66	1.00	90	1.000
	3	4.30	0.90	1.00	90	0.800
	4	4.40	0.49	1.00	100	1.000
	5	4.40	0.92	1.00	90	0.800
	6	4.00	1.00	1.75	70	0.800
(Common) Convergent Communication - Collaboration	1	4.50	0.50	1.00	100	1.000
	2	4.70	0.46	0.75	100	1.000
	3	4.50	0.67	1.00	90	1.000
	4	4.60	0.49	1.00	100	1.000
	5	4.70	0.46	0.75	100	1.000
	6	4.50	0.50	1.00	100	1.000
(Common) Convergent Problem Solving	1	4.50	0.67	1.00	90	1.000
	2	4.00	0.89	0.75	80	0.800
	3	4.70	0.46	0.75	100	1.000
	4	4.20	0.98	1.00	80	0.800
	5	4.50	0.50	1.00	100	1.000
	6	4.10	1.04	1.75	70	0.800
(COSS-specific) Understanding	1	4.50	0.50	1.00	100	1.000
	2	4.20	0.98	1.00	80	0.800

Competency Group	Question Item	Mean	STD	IQR	%4-5	CVR
Advanced Convergence Technologies	3	4.10	0.70	0.75	80	1.000
	4	4.20	0.98	1.00	80	0.800
	5	4.50	0.67	1.00	90	1.000
	6	4.30	0.78	1.00	80	1.000
	7	4.50	0.67	1.00	90	1.000
(COSS Specialization) Utilizing Advanced Convergence Technology	1	4.60	0.66	0.75	90	1.000
	2	4.50	0.67	1.00	90	1.000
	3	4.60	0.49	1.00	100	1.000
	4	4.40	0.66	1.00	90	1.000
	5	4.40	0.66	1.00	90	1.000
	6	4.40	0.66	1.00	90	1.000
(HUSS Specialization) Recognize future issues	1	4.40	0.66	1.00	90	1.000
	2	4.40	0.80	1.00	80	1.000
	3	4.20	0.87	1.75	70	1.000
	4	4.60	0.49	1.00	100	1.000
	5	4.40	0.66	1.00	90	1.000
	6	4.60	0.49	1.00	100	1.000
(HUSS Specialization) Future Efficacy	1	4.60	0.66	0.75	90	1.000
	2	4.50	0.67	1.00	90	1.000
	3	4.60	0.66	0.75	90	1.000
	4	4.20	1.17	1.00	90	0.800
	5	4.20	1.25	1.00	80	0.800
	6	4.20	1.17	1.00	90	0.800
Mean/CVI		4.40	0.74	1.01	88	0.948