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Development of Creative Convergence Talent in the era of the 4th Industrial Revolution through Self-Directed Mathematical Competency

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Abstract

To combine the science and technology creativity necessary in the era of the 4th Industrial Revolution, it is necessary to cultivate talents who can discover new knowledge and create new values by combining various knowledge with self-directed mathematical competencies. This research attempted to lay the foundation for the curriculum for fostering future creative convergence talent by preparing, executing, and reflecting on the learning plan after learners themselves understand their level and status through self-directed learning. Firstly, We would like to present a teaching-learning plan based on the essential capabilities of the future society, where the development of a curriculum based on mathematics curriculum and intelligent informatization are accelerated. Secondly, an educational design model system diagram was presented to strengthen the self-directed learning ability of mathematics subjects in the electronic engineering curriculum. Consequently, through a survey, we would like to propose the establishment of an educational system necessary for the 4th industry by analyzing learning ability through self-directed learning teaching methods of subjects related to mathematics, probability, and statistics.

Keywords: *Competence, Creative Convergence, Mathematics, Self-Directedness, Talent Development*

1. INTRODUCTION

The future society, characterized by uncertainty and ambiguity, is at a time when talent is needed to recognize problems in various situations, create ideas with completely new ideas, or combine information from machines with human wisdom to create efficient alternatives and values. In the 2015 revised curriculum, core competencies were presented as characteristics along with the human image pursued by the 4th Industrial Revolution [1]. The core competencies were presented by subject, along with 6 competencies of self-management, knowledge information processing, creative thinking, aesthetic sensibility, communication, and community to develop practical skills in the student's actual life throughout the subject, creative experience activities, and school life. Through the core competencies presented in the 2015 revised curriculum, independent people, cultured people, people living together, and creative people who create new things with various ideas and challenges on the basis of basic skills were presented. In other words, in order to prepare and adapt to the AI(Artificial Intelligence) era, the creative competency presented in the 2015

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revised curriculum should cultivate self-directed learning and integrated thinking skills to actively discover and solve problems in a changing society such as the 4th Industrial Revolution [2]. Self-directed learning is a learning method and ability development method that sets and executes goals on its own without learning from someone. As a learning method in which learners voluntarily lead the overall learning process, it is an educational plan in which learners are primarily responsible for planning, implementing, and evaluating learning experiences. To implement the 2015 revised curriculum, education must be improved in both directions between instructors and learners. A creative convergence curriculum that focuses on actual use through the convergence of various knowledge rather than fragmentary knowledge acquisition should be realized. In order to pursue this, firstly, the curriculum that reflects core competencies should be emphasized. In the past, we focused on how much knowledge we know, but in recent years, we will focus on self-directed learning rather than cramming, and experience-oriented education rather than outcome-oriented education. Secondly, the curriculum based on the 4th industry reflecting convergence should be emphasized. That is to say, the demands of the times that demand academic convergence should be reflected, and the direction of education should be changed based on the ability to fuse various knowledge.

2. TEACHING-LEARNING PLAN BASED ON MATH SUBJECT COMPETENCY

2.1 Development of a Curriculum based on Mathematics Competency

Table 1. Simulation Parameters

Curriculum competence	Achievement standards
Troubleshooting	Ability to use math's knowledge and skills to explore solution strategies and choose the best solution to solve a given problem in a problem situation where you do not know how to solve it
Inference	Ability to guess mathematical facts, analyze them logically, justify them, and reflect on the process
Creativity & convergence	Ability to produce and refine new and meaningful ideas in a variety of ways based on the knowledge and functions of mathematics, to create new knowledge by connecting and converging various knowledge with mathematics, and to handle various problems logically
Communication	Ability to express mathematical knowledge or ideas, results of mathematical activities, problem-solving processes, beliefs and attitudes, etc. in words, writings, pictures, and symbols, and to understand other people's ideas
Information processing	Ability to collect, organize, analyze, and utilize various materials and information and to effectively process data and information by selecting and utilizing appropriate engineering tools and teaching tools
Attitudes & practices	Ability to recognize the value of mathematics and to practice it with an independent mathematical learning attitude and democratic citizenship

The mathematics department is a subject that develops the ability and attitude to mathematically observe and interpret various phenomena around it, think logically, and solve problems rationally by understanding concepts, principles, and laws of mathematics. Mathematics is the basis for learning natural science, engineering, medicine, as well as social science, humanities, arts and physical education, including economics and business administration, and further provides a foundation for growing into a convergence talent with creative capabilities. To this end, students must develop six math curriculum competencies:

problem-solving, reasoning, creativity and convergence, communication, information processing, attitude, and practice, as well as understanding math knowledge and acquiring skills. The six math curriculum competencies are presented in Table 1 [2].

Through academic learning, students can grasp the regularity and structure of mathematics, use their knowledge and skills to creatively solve math problems as well as problems in real life and other subjects, and cultivate rational decision-making and democratic communication skills. By cultivating mathematics curriculum competence, students can successfully play the role of members of society in a complex and specialized future society, express individual potential and talents, understand the need and usefulness of mathematics, and foster interest and confidence in mathematics [3]. Table 2 presents a system chart for fostering talent based on the 4th industry through the cultivation of mathematics subject competency.

Table 2. Human resource development system based on the 4th industry by cultivating mathematics subject competency

Mathematical curriculum competence					
Troubleshooting	Inference	Creativity & convergence	Communication	Information processing	Attitudes & practices
⇩					
Effects of fostering competency in mathematics subjects based on the 4th industry					
- Convergence major & interdisciplinary development - Establishment of a major-linked education system - Development of interdisciplinary creative convergence curriculum - Study on the convergence curriculum	⇨	- Practical use of major education - The revitalization of convergence education - Expansion of convergence programs - Strengthening the capacity of interdisciplinary creativity			
⇩					
Future talent award through mathematics curriculum competency					
Strengthen capabilities related to IoT (Internet of Things), Bigdata, Smart Robots (VA/AR), Virtual & Augmented Reality (VA/AR), Cloud computing, Mobile computing, Embedded system, and Fintech (Fintech) in the future					

2.2 Teaching-Learning Objectives and Plans based on Mathematical Subject Competency

The goal of the mathematics department based on mathematics and competency presented in 2.1 above is to understand concepts, principles, laws, and relationships related to mathematics through the experience of mathematically observing, analyzing, organizing, and expressing social and natural phenomena. And then, it infers and communicates mathematically, understands social and natural phenomena mathematically based on creative and convergent thinking and information processing ability, and solves problems reasonably and creatively. Learners have an interest and confidence in mathematics, understand the role and value of mathematics, and develop desirable attitudes and practical skills as [4, 5]. A teaching-learning plan based on mathematics subject competency is presented in Table 3.

Table 3. Teaching-learning plans based on math subject competences

Curriculum competence	Achievement standards
Troubleshooting	- Understanding problems, explore resolution strategies, execute resolution processes, validate and reflect on them - Improving mathematical modeling by exploring and generalizing mathematical concepts, principles, and laws while solving problems identified in social and natural phenomena
Inference	- Guessing mathematical facts using induction, analogy, etc. in observational and exploratory situations and justify them based on evidence - Deriving concepts, principles, and laws of mathematics and the mathematical procedure are logically carried out
Creativity & convergence	- Promoting students' creative thinking by providing mathematical tasks to produce diverse and rich new ideas - Connecting various mathematical knowledge, functions, and experiences or connecting and converging math, other subjects, real-life knowledge, functions, and experiences to create new knowledge, skills, and experience and solve problems
Communication	- Understanding other people's thoughts, express mathematical ideas efficiently, and discuss them while respecting different perspectives Information processing - Exploring and collecting appropriate data in real life and mathematical problem situations, organizing, analyzing, evaluating, and utilizing analyzed information appropriately for problem situations - Understanding the concepts and principles of mathematics through manipulation and exploration activities using appropriate teaching tools
Information processing	- Exploring and collecting appropriate data in real life and mathematical problem situations, organizing, analyzing, evaluating, and utilizing analyzed information appropriately for problem situations - Understanding the concepts and principles of mathematics through manipulation and exploration activities using appropriate teaching tools
Attitudes & practices	- Recognizing the necessity and usefulness of mathematics, and recognize the role and value of mathematics - With interest, interest, curiosity, and confidence in mathematics, actively participating in math learning to induce a spirit of challenge, motivation, and motivation to learn - Developing independent learning habits and attitudes that set goals, carry out learning, and evaluate learning outcomes on their own - Providing opinions based on logical grounds and practice with a rational decision-making attitude

3. STRENGTHENING THE SELF-DIRECTED LEARNING ABILITY OF MATHEMATICS SUBJECTS

3.1 Elements of Self-Directed Learning Ability

As the definition of the concept of self-directed learning varies by scholars, the constituent of self-directed learning also shows slightly different views. As a component of self-directed learning, Guglielmino (1977) defined it as openness to learning opportunities, self-concept as an effective learner, initiative and independence in learning, acceptance of responsibility for one's own learning, love for learning, creativity, ability to use basic learning and problem-solving functions, and positive orientation for the future. Garrison (1997) defined it as self-management, self-evaluation, and motivation. Stolk et al. (2008) defined it as a cognitive domain, a motivational domain, a behavioral domain, and a contextual domain [6].

3.2 Educational Design for Self-Directed Learning Ability Development

Table 4. Educational design model system diagram for self-directed learning ability development

Learning process	Learning element	Learning factor	Self-directed learning ability factor
Preparation	Synchronous	- Openness to learning opportunities - Love for learning - Recognizing the internal and external value of mathematics - Self-concept of mathematics	- Preparation for Pre-learning
⇩	⇩	⇩	⇩
Practice	Learning strategic (voluntary plan)	- Learning strategies to refine, organize, regenerate and utilize knowledge - Need to strategize how learners learn math - Leadership and independence in learning - Learners themselves accept responsibility for learning - Learner's belief - Creativity and investigative characteristics	- Troubleshooting - Inference - Creativity and convergence - Communication - Processing information
⇩	⇩	⇩	⇩
Self-reflection	Metacognitive (Self-evaluation, self-regulation, self-reflection)	- Cognitive strategy - Learning plan - Learning check (Assessment and Control, Response and Reflection) - Self-efficacy and intrinsic motivation - Positive orientation for the future	- Attitudes and practices
⇩	⇩	⇩	⇩
Creative convergence	Creative self-directed learning ability	- Major education for creative competency development - Practical major education centered on consumers - Customized convergence major track operation	- Practical major knowledge - Major link - Interdisciplinary convergence

Based on the skills that learners have under the guidance of instructors, this study first sought to design self-directed learning-related education through reflection by recognizing the value of mathematics and preparing for learning with positive self-concept, secondly grasping math concepts, focusing on learning speed, and thirdly implementing plans and implementing learning. Since self-directedness can be improved through the guidance of others, it is necessary to prepare to start self-directed learning with the help of a professor, and to reflect on the learning process and results. However, preparation, execution, and reflection are not in a temporal order in self-directed learning, and you can reflect on yourself while performing and go back to the preparation stage while reflecting. The educational design model system diagram for self-directed learning ability development is presented in Table 4.

4. IMPROVEMENT OF SELF-DIRECTED LEARNING ABILITY IN MATHEMATICS SUBJECTS

4.1 Research Methods

In this study, a self-directed learning teaching method was developed to strengthen self-directed learning ability as a teaching method for major subjects related to probability and statistics based on mathematics in the electronic engineering curriculum, and case education was conducted. The purpose of the self-directed learning method is to identify that mathematics, probability, and statistics are important subjects in electronic engineering as well as university mathematics, engineering mathematics, probability, statistics, statistical data analysis, random signals, and electronic engineering. And then, converting math-related subjects into self-directed learning methods, we want to select topics that learners can integrate themselves, not knowledge-oriented memorization education, and develop creative thinking skills through learners' ability to solve problems themselves. In addition, by establishing an electronic engineering education system necessary for the 4th industry based on the self-directed learning ability of mathematics-related subjects, we intend to actively respond to smart technologies or acquire intelligent information technology based on the generated knowledge. As a result, we intend to foster professional manpower related to the 4th industry by strengthening our self-directed learning ability so that systematic research can proceed by predicting and responding to future industrial changes. For this study, 40 students from each grade who wanted to voluntarily participate in the study were selected as department E of electronic engineering at S University in Seoul, and a survey was conducted from December 14 to 28, 2020.

4.2 Research Results

The analysis of the results of the questionnaire on the satisfaction of self-directed learning teaching methods related to mathematics and probability/statistics of electronic engineering majors is presented in Table 5 and Table 6, respectively. Electronic engineering majors were found to have improved their ability to discover, utilize, and create knowledge through self-directed learning teaching methods using self-directed learning as a tool, and were effective in statistical and data analysis subjects by strengthening information exchange, perception, reasoning, and decision-making skills. In particular, self-directed learning is a learner-centered education based on autonomy and creativity, away from knowledge-oriented memorization education, and aims to cultivate creative convergence talent necessary in the 4th industry.

Table 5. Analysis of satisfaction results of self-directed teaching methods related to mathematics (units: frequency (%))

College mathematics curriculum contents	Teaching methods	N	Engineering mathematics curriculum contents	Teaching methods
Limits and continuity	30 (75.0%)	40	Ordinary differential equations	32 (80.0%)
Derivatives	31 (77.5%)	40	Linear ordinary differential equations	33 (82.5%)
Applications of derivatives	33 (82.5%)	40	Laplace transforms	32 (80.0%)
Integration	32 (80.0%)	40	Linear algebra	31 (77.5%)
Applications of integrals	30 (75.0%)	40	Vector differential calculus	32 (80.0%)
Transcendental function	33 (82.5%)	40	Vector integral calculus	34 (85.0%)
Infinite series	31 (77.5%)	40	Fourier analysis	35 (87.5%)
Polar coordinates	32 (80.0%)	40	Partial differential equations	31 (77.5%)
Vectors	30 (75.0%)	40	Complex differentiation	33 (82.5%)
Vector-valued functions	33 (82.5%)	40	Complex integration	35 (87.5%)
Partial derivatives	32 (80.0%)	40	Complex analysis	31 (77.5%)
Multiple integrals	34 (85.0%)	40	Numeric analysis	33 (82.5%)
Integration in vector fields	26 (65.0%)	40	Optimization, graphs	25 (62.5%)

Table 6. Self-directed teaching method satisfaction results analysis related to probability/statistics and data analysis (units: frequency (%))

Probability/statistics curriculum contents	Teaching methods	N	Data structure curriculum contents	Teaching methods
Probability	32 (80.0%)	40	Categorical Data	28 (70.0%)
Conditional Probability	33 (82.5%)	40	Nonparametric Methods	27 (67.5%)
Random Variables	34 (85.0%)	40	Factor Analysis	30 (75.0%)
Distributions	32 (80.0%)	40	Discrimination	32 (80.0%)
Expectation	34 (85.0%)	40	Classification	30 (75.0%)
Special Distributions	26 (65.0%)	40	Clustering	27 (67.5%)
Estimation	30 (75.0%)	40	Maximum likelihood estimation	25 (62.5%)
Sampling Distributions of Estimations	31 (77.5%)	40	Goodness of Fit Tests	24 (60.0%)
Testing Hypotheses	29 (72.5%)	40	Distance Methods and Ordination	23 (57.5%)
Discrete Data analysis	30 (75.0%)	40	Smoothing	33 (82.5%)
Analysis of Variance	29 (72.5%)	40	Random Processes.	28 (70.0%)
Correlation Analysis	34 (85.0%)	40	Random Signals	30 (75.0%)
Linear Regression	33 (82.5%)	40	Reliability	22 (55.0%)

5. CONCLUSION

This study aims to foster creative convergence talent to lead the future society by strengthening the self-directed learning ability required for probability and statistics education, including mathematics, a basic core subject in the electronic engineering curriculum to prepare for changes in the industrial environment caused by the 4th Industrial Revolution. In the electronic engineering curriculum, the self-directed learning ability in which majors prepare, execute, and reflect on their own learning is an important factor for fostering

creative convergence talent. Learners should construct knowledge through active and active learning participation, use that knowledge in communication and intellectual activities, and discover new mathematical relationships based on their mathematical knowledge. In other words, for electronic engineering majors, self-directed learning is essential to adapt to the major subject. The significance of this study is, firstly, the basic direction of probability and statistical education, including mathematics in the electronic engineering curriculum, and it should be adjusted to cultivate mathematical literacy, mathematical knowledge, mathematical creativity, problem-solving skills, and computing thinking skills. Secondly, an educational environment should be created to foster creative talents through convergence of two or more subjects, including probability, statistics, data analysis, and random signals. Thirdly, it is expected that the effectiveness of electronic engineering education that requires creativity and problem-solving skills can be maximized by strengthening teaching-learning strategies for self-directed learning ability development in the era of the 4th industrial revolution.

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