

코로나19 팬데믹 전후 컴퓨터 및 소프트웨어 관련 전공의 제4차 산업혁명중심 교과과정 변화 분석

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Analyzes the Changes in the Curricula of Computer and Software-Related Majors in Line with the Fourth Industrial Revolution, Comparing the Periods Before and After the COVID-19 Pandemic in KOREA.

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요약

본 논문은 4차 산업 혁명에 필요한 핵심 ICT 관련 기술을 교육하는 컴퓨터 및 소프트웨어 관련 전공의 코로나19 팬데믹 전후의 교과과정 변화를 분석하였다. 대학교육 편제단위 표준분류에 따라 응용소프트웨어공학, 전산학·컴퓨터공학, 그리고 인공지능공학으로 분류된 172개 전공을 대상으로, 2023학년도와 2019학년도 교과과정을 비교 분석하였다. 제4차 산업혁명 대응을 위해 도입된 사물인터넷과 모바일, 클라우드와 빅데이터, 인공지능, 그리고 정보보안의 분야의 교과과정 변화를 분석하였다. 분석결과 각 교육과정 군에 대해 코로나19 팬데믹 전후로 관련 교과과정 도입이 약2.6%p 증가(2023 84.2%, 2019 81.6%)하였으며, 교육영역별 가중치를 부여하여 계산한 4차산업혁명 대응지수(100점 만점)는 9.5점 상승(2023 37.0점, 2019 27.5점)하였으며, 이는 인공지능과 클라우드 및 빅데이터 분야의 교과 개설 증가에 기인한 것으로 분석되었다.

ABSTRACT

This paper analyzed the changes in the curriculum of computer and software-related majors that educate the core ICT technologies needed for the 4th Industrial Revolution, before and after the COVID-19 pandemic. According to the standard classification of university education units, 172 majors classified into Applied Software Engineering, Computer Science-Computer Engineering, and Artificial Intelligence Engineering were targeted, and the curricula of 2023 and 2019 were compared and analyzed. As a result of the analysis, the introduction of the related curriculum for each curriculum group increased by about 2.6%p before and after the COVID-19 pandemic (2023 84.2%, 2019 81.6%). and the 4th Industrial Revolution response index increased by 9.5 points (37.0 in 2023, 27.5 in 2019)

키워드

COVID-19, The 4th Industrial Revolution, Standard Classification, Curriculum, IoT, Big Data, AI
코로나19, 4차 산업혁명, 표준분류, 교육과정, 사물인터넷, 빅데이터, 인공지능

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I. Introduction

With the declaration of the end of the COVID-19 pandemic that started in 2019, many studies are being published on the changes in the educational environment, such as the shift to online-centered classes, triggered by this social phenomenon. According to research, due to the impact of online classes conducted during the COVID-19 period, it was found that the level of professor-student interaction has generally decreased compared to before, and it is a fact that it has brought about many changes in computer and software-related education[1-2].

The COVID-19 pandemic is accelerating the era of Information and Communication Technology (ICT) in countries both domestically and internationally, bringing about innovative changes in university curricula, educational content, and teaching methods. Artificial Intelligence(AI), the core of the Fourth Industrial Revolution, is at the center of this educational paradigm shift[3].

In the era of the Fourth Industrial Revolution(4thIR), the use of ICT technologies such as the Internet of Things(IoT), Artificial Intelligence(AI), and Big Data is essential. Especially, experts say that ICT personnel in the era of the 4th Industrial Revolution must have adaptability to technological changes and coding skills[4, 5].

As we usher in the era of the 4th Industrial Revolution in its full swing, the significance of software education is escalating. This form of education, which fosters the development of innovative knowledge through collaboration and communication underpinned by critical thinking, is becoming an indispensable element in our rapidly evolving society[6].

The software education curriculum, which is responsive to the 4th Industrial Revolution, is closely linked to the cultivation of key professionals

in the field of intelligent information technology. This is a domain where technologies such as Artificial Intelligence (AI), Internet of Things (IoT), Cloud Computing, Big Data, and Mobile converge to create new value(Table 1)[7-10].

This paper aims to present the implications for the direction of changes in the curriculum of computer and software-related majors in the post-COVID era, through the analysis of curriculum changes before and after COVID-19, amidst these societal changes.

Table 1. Classification of the 4th Industrial Revolution-oriented Curriculum

Curriculum		Keyword
IoT & Mobile	Technology that collects data from all machines and humans	<ul style="list-style-type: none"> • Data creation of all things • Real-time reaction • Autonomous evolution • Unmanned decision making
Cloud & Big data	Technology to accumulate and analyze data through advanced information processing	
AI	Technology for judging and deciding by cognition, learning and reasoning	
Information Security	Technology that protects systems and data through protection, detection, and response	

II. Comparative Analysis of Curriculum Implementation Before and After the COVID-19 Pandemic

The status analysis was conducted based on the standard classification of educational units organized by the Korean Council for University Education. Data analysis was conducted on 172 computer and software-related majors with engineering category, divisions in electricity, electronics and computers, and subdivisions classified as applied software, computer science and computer engineering, and AI engineering (added in 2022). Out of the 489 related majors listed in the standard classification, majors in the field of games and media content, majors without enrolled

students, and majors where the curriculum could not be confirmed, were excluded from the analysis [11–13].

The distribution of related majors was examined based on the subcategories of the standard classification. In 2019, there were 120 majors (75.9%) in the category of Computer Science(CS) and Computer Engineering(CE), and 38 majors (24.1%) were classified under the Applied Software Engineering category. And in 2023, there were 112 majors (65.1%) in the category of Computer Science and Computer Engineering, 39 majors (22.7%) were classified under the Applied Software Engineering category, and 21 majors (12.2%) were in the Artificial Intelligence Engineering category(Table 2).

Table 2. Status of Established Majors Related to Computer and Software

majors	Standard Classification			Total		
	C.S & C.E	Applied SW Eng.	AI Eng.	Num of Majors	ratio (%)	
2023	Computer engineering(CE.)	62	1	0	63	36.6
	Software(applied-, convergence- etc)	17	22	0	39	22.7
	Computer science(CS)	10	1	0	11	6.4
	Specialization for the 4 th IR	23	15	21	59	34.3
Total	112	39	21	172	100.0	
2019	Computer engineering(CE)	77	0	-	77	48.7
	Software(applied-, convergence- etc)	22	28	-	50	31.7
	Computer science(CS)	10	0	-	10	6.3
	Specialization for the 4 th IR	11	10	-	15	13.3
Total	112	39	-	172	100.0	

* Excluding majors classified as information and communication engineering

When observing the changes in the names of specific departments, in 2019, out of the 158 majors, the Computer Engineering major accounted for 77, making up 48.7% of the total, thus forming the majority. In 2023, the Computer Engineering major still made up the majority with 36.6%, however, the number decreased to 62. This decrease is due to a significant increase of over 20 percentage points in the proportion of specialized departments that use terms such as artificial intelligence, big data,

information security, and the Internet of Things in response to the Fourth Industrial Revolution, which now account for 34.3%.

In 2019, a total of 21 specialized majors were established, with 2 each in the fields of Internet of Things, Artificial Intelligence, and Big Data, and 6 in the field of Information Security. The distribution of specialized majors for the 2023, which increased to 59, is as follows: 2 majors related to the Internet of Things, 38 majors related to artificial intelligence, 11 majors related to big data, 4 majors related to information security, 1 major related to mobile, and 3 other majors. During the COVID-19 pandemic, it was observed that there were numerous new establishments or changes in the majors of specialized departments, particularly in the fields of artificial intelligence and big data.

Table 3. Education fields and major education contents in the standard classification

S.C.	Education fields	Education contents
C.S & C.E	To adapt to the information society, learn computer- related skills, such as computer systems, and apply them to each field.	Basic computing, Computer application, Hardware system, Database, Multimedia, Computer communication, Programming language, Computer structure, Computer AI, Software engineering, Computer graphics, etc.
Applied SW Eng.	Various technologies required in computer science and computer engineering are developed and applied to software-related industries.	Basic Computer science, Software design and development, Various programming languages, Discrete mathematics, Computer structure, Information management, Computer systems and networks, etc.
AI Eng.	The development and operation of systems that can precisely analyze, infer, and predict various societal problems by acquiring abilities such as language intelligence, visual intelligence, voice intelligence, interaction, and performance, which mimic human learning ability, inference ability, perception ability, etc., through machine learning.	Computer Basics, Computer Applications, Hardware Systems, Database, Multimedia, Computer Communications, Programming Language, Computer Architecture, Software Engineering, Neural Network Theory, Machine Learning, Deep Learning, Computer Vision, Data Mining, Natural Language Processing, Detection and Estimation, Speech Recognition, Linear Algebra, Data Analysis, Neuroengineering

Major subjects according to the existing standard classification are as follows, and basic subjects traditionally trained in existing majors, such as basic programming, software design, network, and basic computer hardware, were excluded from the analysis (Table 3) [14].

The analysis was conducted targeting 158 majors established in the 2019 academic year with secured curriculums and 172 majors established in the 2023 academic year. The curriculum status analysis was conducted based on the subjects shown in Table 4. The classification of subjects was divided into the Internet of Things, mobile, cloud and big data, artificial intelligence, and information security [8–10].

Table 4. Example of Subjects by Area for Analysis

Classification	subjects
IoT & Mobile	Internet of Things, IoT communication systems, intelligent IoT systems, ICT convergence, robot software (drone, robotics, etc.) embedded systems and programming, sensors and interfaces, VR and AR systems, mobile systems and programming, human-computer interaction (HCI), etc.
Cloud & Big data	Cloud (computing) systems, data science, big data and machine learning, big data and deep learning, big data (computing, programming, platform, analysis), big data mining (text mining, search mining, data science), data center programming, etc.
AI	AI Overview, Artificial Intelligence, Artificial Intelligence System, Artificial Intelligence and Robot, Virtual Reality and Augmented Reality, Machine Learning (Mechanical Learning), Deep Learning, Human-Computer Interaction (HCI), Artificial Intelligence, Computer Vision, etc.
Information Security	Information protection overview, information protection system, computer system security, network/Internet security, blockchain, etc.

* The classification of some subjects may vary depending on the curriculum contents, etc. of each major.

Table 5 shows the results of an analysis of the changes in the curriculum before and after the COVID-19 pandemic in each field of computer and software-related majors classified according to the standard classification. The status of the operation of the 4th Industrial Revolution-related curriculum in the respective departments was analyzed using the data submitted by each department to the University Education Council and the information available on each university’s website. The

determination of whether to introduce a curriculum for each field was made based on the operation track and related subjects in the curriculum of each department [11–13].

Table 5. Current Status of Subjects for Response to the 4thIR by Standard Classification

Field	CS & CE		Applied SW Eng.		AI Eng.		Total	
	Num of Majors	ratio (%)	Num of Majors	ratio (%)	Num of Majors	ratio (%)	Num of Majors	ratio (%)
Total	112	100.0	39	100.0	21	100.0	172	100.0
IoT & Mobile	104	92.9	36	92.3	14	66.7	154	89.5
Cloud & Big data	84	75.0	36	92.3	20	95.2	140	81.4
AI	104	92.9	36	92.3	21	100.0	161	93.6
Information Security	86	76.8	31	79.5	7	33.3	124	72.1
Total	120	100.0	38	100.0	-	-	158	100.0
IoT & Mobile	108	90.0	36	94.7	-	-	144	91.1
Cloud & Big data	81	67.5	28	73.7	-	-	109	69.0
AI	103	85.8	33	86.8	-	-	136	86.1
Information Security	94	78.3	33	86.8	-	-	127	80.3

As of 2023, the proportion of curriculum introduction by major showed that the field of artificial intelligence had the highest establishment rate of 93.6%, with 161 out of 172 target majors introducing related subjects. Compared to the survey in 2019, before the COVID-19 pandemic, the field with the largest increase in the number of established majors was the cloud and big data field, showing an increase of 20.5 percentage points in the establishment ratio compared to 2019.

In the 2022 curriculum standard classification, Artificial Intelligence Engineering was added as a subcategory. As of 2023, 21 of the majors analyzed were classified under Artificial Intelligence Engineering. It was found that these majors were relatively focused on the establishment of courses in the fields of Artificial Intelligence and Cloud and Big Data.

III. Analysis of 4thIR-oriented curriculum

In this paper, the 'Curriculum Response Index for the 4thIR (CRL_{4th})' was introduced to quantify the degree of response to the 4thIR by each major.

The calculation of the Response Index, denoted as 'CRL_{4th}', is based on a weighted scheme that encapsulates the progression of course introduction across various domains pertinent to the Fourth Industrial Revolution[6].

The index 'CRL_{4th}' was calculated according to formula (1).

$$CRL_{4th} = \frac{(1 \times N_{IP}) + (3 \times N_{EP}) + (5 \times N_{AP})}{N_T} \dots (1)$$

In this formula, N_{IP}, N_{EP}, and N_{AP} are defined as follows.

- **N_{IP}** : The number of majors in the Initial Phase, which are operating 1-2 subjects in each course area. (Weight of 1)
- **N_{EP}** : The number of majors in the Expansion Phase, which are operating 3-4 subjects in each course area. (Weight of 3)
- **N_{AP}** : The number of majors in the Active Phase that organize a track and operate more than 5 subjects over more than 3 semesters. (Weight 5)
- **N_T** : Total number of majors by year for analysis.

Table 6. Analysis Results of CRL_{4th}

CRL _{4th}		Number of Majors in Each Area				Total
		IoT & Mobile	Cloud & Big data	AI	Information Security	
2023	N _{IP}	77	76	68	107	172 Majors
	N _{EP}	55	41	49	10	
	N _{AP}	22	23	44	7	
	CRL _{4th}	40.9	36.5	50.6	20.0	
2019	N _{IP}	67	89	104	111	158 Majors
	N _{EP}	59	16	29	9	
	N _{AP}	18	4	3	7	
	CRL _{4th}	42.3	19.9	26.1	21.9	

The response index(CRL_{4th}), based on the majors surveyed in 2023, was analyzed to be an average

of 37.0 points, an increase of 9.5 points compared to the 27.5 points shown in the 2019 survey results. The response index(CRL_{4th}) was highest in the field of artificial intelligence, and the increase in the response index(CRL_{4th}) was highest in the fields of 'Artificial Intelligence' and 'Cloud and Big Data', respectively(Table 6).

Table 7. Status of Course Subject Establishment in Response to the 4thIR.

Courses Area	Number of Majors Offering Courses in Each Area		Number of Subjects Offered in Each Area		
	Num. of Majors	Establishment ratio(%)*	Avg. Num. of Estavishments	SD	
2023	IoT & Mobile	154	89.5	2.49	1.539
	Cloud & Big data	140	81.4	2.40	2.314
	AI	161	93.6	3.58	3.030
	Information Security	124	72.1	1.35	1.940
Total		172 Majors		9.82 Subjects/major	
2019	IoT & Mobile	144	91.1	2.59	1.569
	Cloud & Big data	109	69.0	1.18	1.218
	AI	136	86.1	1.67	1.164
	Information Security	127	80.4	1.48	1.805
	Total		158 Majors		6.92 Subjects/major

*The course establishment ratio for the year 2023 was calculated based on a total of 172 target majors, and the course establishment ratio for the year 2019 was calculated based on a total of 158 target majors.

The analysis results showed that as of 2023, the average number of subjects established across 172 majors in response to the 4th Industrial Revolution was 9.82 . This represents an increase of 2.90 compared to the 6.92 established across 158 majors in 2019. By field, artificial intelligence showed the highest average with 3.58 in 2023(Table 7).

According to the analysis results based on the characteristics of each university's establishment type, both in 2023 and 2019, private universities showed a higher response index than national and public universities in all fields except for the field of artificial intelligence. Based on the 2023 analysis results, the overall response index of private

universities was 38.1, which is 4.9 points higher than the 33.2 of national and public universities. This is similar to the deviation of 5.1 points in 2019(Table 8).

Table 8. CRI_{4th} by University's establishment type

Courses Area		University's establishment type		
		Private(A)	public(B)	(A-B)
2023				
Number of Majors		134	38	-
CRI _{4th}	IoT& Mobile	42.2	36.3	5.9
	Cloud& Big data	39.3	26.8	12.4
	AI	50.1	52.1	-2.0
	Information Security	20.7	17.4	3.4
	Total	38.1	33.2	4.9
2019				
Number of Majors		125	33	-
CRI _{4th}	IoT& Mobile	43.8	36.4	7.4
	Cloud& Big data	21.3	14.5	6.8
	AI	25.9	26.7	-0.8
	Information Security	23.4	16.4	7.0
	Total	28.6	23.5	5.1

Table 9. CRI_{4th} by Location of Universities

Courses Area		Location of Universities		
		Seoul Metropolitan area(A)	Local (B)	(A-B)
2023				
Number of Majors		88	84	-
CRI _{4th}	IoT& Mobile	42.3	39.5	2.7
	Cloud& Big data	43.0	29.8	13.2
	AI	51.8	49.3	2.5
	Information Security	18.2	21.9	-3.7
	Total	38.8	35.1	3.7
2019				
Number of Majors		66	92	-
CRI _{4th}	IoT& Mobile	43.9	41.1	2.8
	Cloud& Big data	23.6	17.2	6.4
	AI	29.4	23.7	5.7
	Information Security	30.1	25.7	4.4
	Total	31.8	26.9	4.8

The response index(CRI_{4th}), according to the location of the university was found to be 38.8

points in the Seoul metropolitan area and 35.1 points in the Local, indicating that the response index of universities located in the metropolitan area was 3.7 points higher. This is somewhat reduced compared to the deviation of 4.8 points in the 2019 survey(Table 9).

Table 10. CRI_{4th} by the Selection Status of the Government Project

Courses Area		Selection status of the project (National Program of Excellence in Software)		
		selected (A)	non-selected (B)	(A-B)
2023				
Number of Majors		92	80	-
CRI _{4th}	IoT& Mobile	47.6	33.3	14.4
	Cloud& Big data	43.5	28.5	15.0
	AI	57.0	43.3	13.7
	Information Security	22.2	17.5	4.7
	Total	42.6	30.6	11.9
2019				
Number of Majors		45	113	-
CRI _{4th}	IoT& Mobile	54.7	37.3	17.4
	Cloud& Big data	27.6	16.8	10.8
	AI	32.9	23.4	26.1
	Information Security	20.4	22.5	-2.1
	Total	33.9	25.0	8.9

Lastly, based on the analysis of whether a university was selected for the government's university project(National Program of Excellence in Software), universities that were selected for the project scored an average of 11.9 points higher (42.6 points for selected universities, 30.6 points for non-selected universities) than those not selected. This is 3 points higher than the deviation of 8.9 points in the 2019 survey, and it was found to be significantly larger than the deviation depending on the location of the university(Table 10).

IV. Conclusion

This paper analyzes the changes in the curriculum of computer and software-related majors that educate the core ICT technologies needed for the Fourth Industrial Revolution, before and after the COVID-19 pandemic. The analysis was conducted on 172 majors classified as ‘Applied Software Engineering’, ‘Computer Science and Engineering’, and ‘Artificial Intelligence Engineering’ according to the subcategory items of the standard classification of university education unit by the Standard Classification Committee of the University Education Council.

The curriculum of the major in the 2023 academic year was compared with the previously researched curriculum analysis data of the 2019 academic year, and the changes in the curriculum divided into the fields of Internet of Things and Mobile, Cloud and Big Data, Artificial Intelligence, and Information Security, which were introduced to respond to the Fourth Industrial Revolution, were analyzed.

The analysis results showed that on average 84.2% of the majors have arranged related subjects in the 2023 curriculum for each given curriculum group, which is a 2.6 percentage point increase compared to 2019(81.6%). The ‘Curriculum Response Index for the Fourth Industrial Revolution (CRL_{4th}) by major, calculated by assigning weights to the operation of tracks by education field, etc., increased by 9.5 points from 27.5 points in 2019 to an average of 37.0 points on a 100-point scale. Among the related fields, the field of Artificial Intelligence showed the highest increase of 26.1 points to 50.6 points, and it was analyzed that the establishment of courses centered on the field of Artificial Intelligence significantly increased before and after the COVID-19 pandemic.

The analysis results of the characteristics by type of university showed that in both the 2019

and 2023 survey results, universities located in the Seoul metropolitan area, national-public universities, and universities selected for the government’s university project (National Program of Excellence in Software) were relatively excellent in curriculum organization. When comparing before and after the COVID-19 pandemic, it can be seen that many universities have increased the proportion of curriculum organization in the fields of Artificial Intelligence, and Cloud and Big Data after the pandemic compared to before.

The increase in the proportion of curriculum composition in fields such as artificial intelligence and big data can be said to reflect the emergence of new paradigms, such as generative artificial intelligence like ChatGPT, which have become a hot topic recently[15].

However, considering the recent concerns that the emergence of the fourth-generation GPT-4 is threatening professional jobs, including programmers, it is thought that universities, particularly those with computer and software-related majors, need to seriously consider how to reflect this in their education. Furthermore, looking at the results of MIT’s research, which suggests that proficient use of artificial intelligence improves work efficiency, it is believed that the establishment of curricula aimed at continuously enhancing students’ ability to utilize the increasingly sophisticated artificial intelligence will be essential in future computer and software education[16].

감사의 글

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