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Investigating Job Mismatch in Software Industry through News Big Data

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ABSTRACT

The purpose of this study is to identify issues related to software manpower, which became more important in the era of the Fourth Industrial Revolution in Korea. The results of this study can provide guidelines for those who establish software manpower training policies for solving the software industry's human resource paradox. As for the research method, the quantitative text network and qualitative analyses from industry experts were used to interpret the results. A total of 14,752 news data mentioning software manpower were extracted, and data pre-processing for the synonyms and negative words were performed. The network was non-directional and consisted of 14,074 words (nodes) and 1,542,383 word combinations (edges). In addition, the network was clustered based on Modularity, and the degree of connection and eigenvector centrality were used to determine the importance of nodes. The analysis of the results showed that the government's efforts through the Korean Ministry of Science and ICT were vital in creating jobs that fueled software innovation growth, and that software education was actively promoted to develop software talent. This study had the following implications. It was confirmed that software is making a high contribution to the expansion of business opportunities and job creation in the fields of new technology and software convergence technology. To resolve the software manpower supply-demand mismatch, it is necessary to cultivate high-quality software talent and provide mid- to long-term activities to attract competent human resources. In addition, it is necessary to develop and expand programs that link education and recruitment in terms of public-private cooperation along with government-led investment to strengthen national software competitiveness.

Keywords: News big data, network analysis, software manpower, human resource development.

INTRODUCTION

The role of software (hereafter, SW) manpower has become more important in the advent of the Fourth Industrial Revolution (hereafter, 4IR), which brought about the use of SW technologies, such as artificial intelligence (hereafter, AI), cloud, big data, and the Internet of Things (hereafter, IoT) (Schwab, 2016). Now, big data is being used across industries at an increasing rate. AI technology is now being used to provide advanced, customized services to customers in convergence with various domains based on big data (Kim, 2020). These core technologies of the 4IR have established themselves as essential requirements for strengthening the future competitiveness of businesses and individuals.

However, the shortage of SW manpower in new technology and convergence fields, such as AI and cloud, has not been easily resolved. According to the '2021 Software Industry Survey' (Software Policy and Research Institute (SPRI), 2022), the number of employees in the new SW business field was 7,700, 6,600 and 5,100 in the cloud, AI, and big data industries, respectively. The shortage of manpower in the SW industry was 600 people for cloud, 600 people for AI, and 400 people for big data. About 9 percent of the total workforce in the field is unfilled. In addition, 59 percent of SW companies end up reassigning existing employees to fill these jobs instead of hiring SW professionals, indicating that there are difficulties in supplying new manpower. There continues to be a mismatch between the available SW manpower and the demand for their services (Lee et al., 2018), causing the SW industry human resource paradox. While graduates majoring in Applied SW continued to grow at an average annual rate of 11.6 percent from 2014 to 2018, the increase is still not enough to cover the demand caused by the rapid growth of the SW industry (SPRI, 2019). According to a survey conducted by the Software Policy and Research Institute (SPRI) (2018), the shortage of manpower in the promising field of SW will reach a total of 31,833 by 2022 (Lee et al., 2018). As it is difficult to secure SW professionals in the industrial field, it is predicted that the SW industry human resource paradox will continue unless preventive actions are taken.

Existing research on the mismatch of manpower is either quantitative, statistical surveys of human resource supply and demand, or qualitative, investigative studies by experts focusing on the causes of, and problems caused by, supply and demand differences. These prior studies concentrate on presenting implications for numerical interpretation and resolving supply-demand differences rather than approaching the underlying problem of manpower mismatch. Jung (2011) emphasized the need to secure SW competitiveness to lead the future global information technology (IT) market. In addition, the shortage of intermediate and advanced SW manpower reached 45 percent and 52 percent, respectively, indicating the seriousness of the shortage of professional manpower. To nurture these SW talents, SW job performance standards are developed and SW education is being strengthened. While researchers suggest solutions to the problem, analysis of the social phenomenon and cause of manpower mismatch is yet to be conducted. According to Cha (2014), the non-recruitment rate of SW development experts has reached 28.9 percent. The SW industry's poor working environment and low pay are cited as the cause of the SW manpower shortage. The study compared Korea's SW manpower ecosystem with excellent global IT companies in the United States (US) and explained that in Korea, the job of a programmer is not considered ideal and is avoided. These studies mainly focus on expert opinions and interpretations by using data from corporate surveys concerning mismatches in SW personnel.

Because of this, the study at hand seeks to explore the phenomena of the SW human resource paradox and major issues regarding SW personnel through big data collection and analysis. The research team aims to shed light on the fundamental problems of SW personnel presented in the background and derive related implications. The research results suggest the ideal approach and possible direction for training SW personnel who are the main players in the era of the 4IR.

REVIEW OF RELATED LITERATURE

Software Manpower

Who is considered SW manpower? According to the Korean Software Promotion Act, SW personnel and SW technicians are those who have obtained national technical qualifications in the IT field, or those with educational backgrounds or experience prescribed by the Presidential Decree in the field of SW technology. Here, "academic background" means a person majoring in SW technology, and "experience" refers to involvement in planning, analysis, design, development, testing, operation, maintenance, supervision, and/or education in the SW field for at least 30 days. It also includes those who have completed courses on SW technology at government-recognized educational institutions. The definition and scope of this SW personnel are more general than professional, and it is difficult to guarantee whether they have the professional capabilities for AI and big data required in the the 4IR era.

SW manpower, as defined by Korean law, was set decades ago, and there is a gap between that and the manpower required in today's SW industries. Because the professional competency required in the era of the 4IR goes beyond technology education, it takes a long time for manpower to be nurtured through the regular curriculum. To prepare for the 4IR, Korea has emphasized a need for SW education. As a result, SW education was organized in the elementary, middle, and high school curriculums. In addition, there are increased efforts to expand the base and create an environment familiar with SW, by requiring universities selected through a government-supported project called 'SW-centered universities' to provide SW education regardless of major. However, there is a limit to cultivating highcomplexity SW technologies, such as AI and big data. Most of these advanced SW skills are acquired only by computer engineering majors through bachelor's, master's, and doctoral degree courses. There is some limit to supplying a large amount of professional competency in a short period of time, both quantitatively and qualitatively, the 4IR era. For this reason, the task of cultivating professional competency mostly falls upon the research community or some private sectors with research and development capabilities.

Compared to existing traditional industries, the specialized skills and manpower required by the 4IR lack market data imperative to predicting supply and demand. For the past ten years, the Ministry of Employment and Labor of the Republic of Korea has developed National Competency Standards through analysis and arrangement of job competencies that correspond to the qualitative part of manpower required in the industrial field. These standards analyze job competencies for traditional industries and the newly emerging 4IR and use them for education and training. While the standards excel at analyzing competencies for well-known traditional occupations in Korea, there is a need to refer to job competency analysis data from the United States or the United Kingdom since AI or big data-related experts are required to analyze the newly emerging 4IR. Because of this, actual experience is somewhat insufficient for AI or big data experts.

Furthermore, it is difficult to use the job competency definition alone in the SW field. It must be accompanied by an evaluation of whether actual SW personnel have AI or big data-related capabilities. With the advancement of AI and big data technologies, as well as the rapid growth of the application market, the demand for manpower in the SW field increases rapidly while the slow supply of manpower with related technologies causes a human resource supply-demand paradox and hinders potential growth (SPRI, 2019). For this reason, an exploratory analysis of various perspectives, phenomena, and issues related to SW personnel is needed before defining the supply and demand of SW-specialized technology in preparation for the 4IR.

Text Network Analysis

Text network analysis is utilized across multiple disciplines as it is useful for analyzing specific topics under a wide range of text material and big data (Scott, 1991; Ali et al., 2020; Choi, 2019; Lee & Kwon, 2019; Blondel et al., 2008; Kim et al., 2022). Text network analysis also employs natural language processing techniques to examine extracted texts from a quantitative perspective and allows researchers to qualitatively recombine the extracted keywords (Jiapei et al., 2017). These characteristics compensate for the shortcomings of traditional quantitative and qualitative analyses, thus bringing attention to text network analysis as an alternative methodology. Network analysis identifies the characteristics of the network being analyzed through various analysis metrics. Analysis indicators include centrality, degree of connection, and modularity, which represent the characteristics of the network and are used as key concepts and representative indicators (Scott, 1991).

Centrality is a measure of what nodes are important in the network (Li, 2018; Lee et al., 2021). This study quantifies whether a node is relatively important in the network using Eigenvector centrality and is expressed as a value between the centrality indices (0.0–1.0). The degree indicates how many current nodes are directly connected to other nodes (Driskell & Mullen, 2004). Modularity is an index that shows how close a particular node is to a certain cluster and how far that node is from other clusters. It is used as an indicator to distinguish clusters on the network (Brandes et al., 2007). The modularity value of a cluster is a measure of link density within a cluster with scalar values between -1 and 1 (Park et al., 2017). The formula for calculating the modularity of a weighted network between links is defined as the following Equation 1 (Newman & Girvan, 2004; Newman, 2004):

$$Q = \frac{1}{2m} \sum_{ij} \left(A_{ij} - \frac{k_i k_j}{2m} \right) \delta(c_i, c_j)$$

where,
A_{ij} denotes the edge weight between i and j.
k_i is the sum of the weights of links connected to vertex i,
and c_i is the cluster to which vertex i is assigned.
The function δ (u, v) is 1 if u = v, otherwise m = 1/2∑ijAij.

A network graph is a graph that visualizes the characteristics of a network, and the size of a node represents the value of the relative Eigenvector centrality in that network. The edge connecting the nodes expresses the relationship between words appearing at the same time. The thicker it is, the higher the degree of connection.

Research using such big data analysis techniques is widely used to study the latest technology, industry, and human resources trends. This is very useful for identifying trends in a specific field and is vastly used in practice. Studies related to text network analysis using big data generated from news or SNS are as follows. Choi et al. (2019) performed unstructured data analysis using news big data on the 4IR. The topic modeling technique was applied to the study on 19,187 news data. Differences in topics according to media type and major period were explored. The overall trends related to the 4IR including 5G were presented, but the trends of 5G were not directly included. Lee and Song (2021) performed text network analysis using 36,693 news data from the Korean media on big data manpower from January to December 2019. Through this research, they pointed out the limitations of utilization due to the institutional problems of the big data industry in Korea. To foster human resources, they emphasized the need for education that combines domain and AI technology. Lee and Kwon (2019) used news network analysis techniques to examine trends in smart cities. From December 1, 2017 to December 1, 2018, 7,882 cases of 'smart city'-related unconventional news data were analyzed. As a result, it was confirmed that 5G technology, along with AI, is viewed as the core technology of a 'smart city', and telecommunications operators such as Korea's SK Telecom and Korea Telecom are spearheading the global move toward 5G coverage.

In the above studies, major trends related to industry and manpower brought about by the emergence of new technologies are analyzed in a timely manner. These studies determine the limitations of the current state of development of technology and industry, and suggest implications and alternatives. In addition, implications were derived from case-oriented trend analyses or from a study that mixed expert-based qualitative predictions. In particular, the research on manpower mismatch in the SW field, which is the subject of this study and forms the basis of new technologies, covers a wider range than the trends of individual technologies in previous studies. This is significant in suggesting implications for human resource training at a macro level. Therefore, this study goes beyond the limitations that can appear only with expert qualitative research to identify trends. The current study would thereby provide significant results in that it can present a more objective trend analysis by quantitatively grasping the characteristics of the connection state and connection structure between entities through an examination of keywords.

RESEARCH METHODOLOGY

Data Collection

The study at hand makes use of the 'BigKinds' database, which holds news data from 54 major media companies in Korea. News data were extracted under the "software manpower (Combination of {SW or software} and {manpower or human resource or job})" keyword. The keyword search period was limited to two years after the inauguration of the Moon Jae-in government, from May 10, 2017 to May 9, 2019. As a result, a total of 14,752 articles, which were news data, containing the keyword "software manpower" had been collected.

Data Analysis

The analysis process comprised (1) text pre-processing, (2) text keyword frequency analysis, (3) text cluster analysis, and (4) content analysis. In pre-processing the collected data, a word dictionary was created from the data provided by 'BigKinds'. Using Excel and Visual Basic, the team combined synonyms (Korean/English equivalent words, abbreviations of official organization names, etc.) and excluded words (meaningless dates, advertising words, etc.) (Ali et al., 2020; Maylawati & Saptawati, 2017; Tissera et al., 2020). Furthermore, the undirected characteristic of news-based networks, where no directionality exists between nodes, was considered.

This study utilized Gephi 0.9.2, one of the network analysis tools that is being used universally for network analysis and visualization, to construct a network of words (node) and word combinations (edge) on the pre-processed materials. It can be visualized as a network graph based on the Eigenvector centrality, degree, and modularity that characterize the network. These network graphs became the basis for content analysis performed by a group of SW industry and human resource experts.

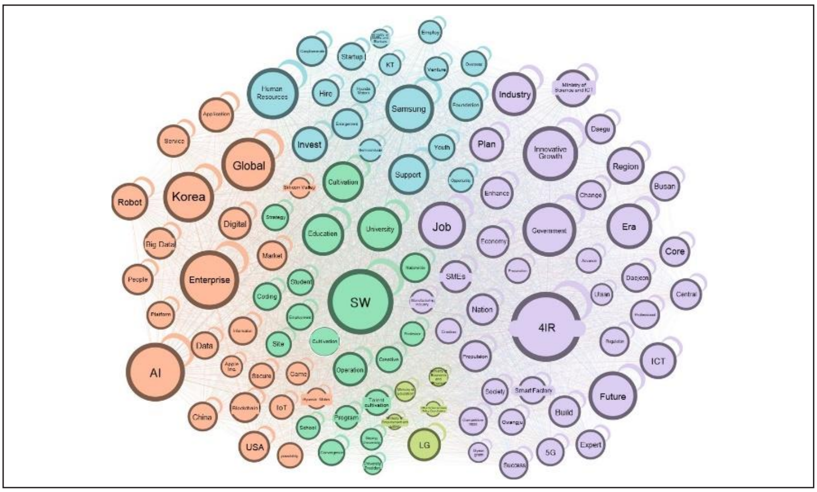
RESULTS AND ANALYSIS

Due to the nature of the news, a wide variety of words could be combined. Moreover, it was determined that connections with a relatively very low degree of word connection (degree) did not have much meaning in the network, so data with a word connection degree of less than 2,000 were excluded from further analysis.

A network of 194,074 words and 1,542,383 word combinations was constructed based on the Eigenvector centrality, degree, and modularity representing the characteristics of the network. The number of final aggregated groups was determined through modularity. Modularity is an indicator of a cohesive group, and the number of groups is determined at the point where modularity increases and then suddenly decreases (Scott, 1991). The entire network was classified into a total of 11 clusters based on modularity. An additional content analysis was performed on the top five clusters, excluding six minor clusters with less than 5 percent of the total network. The results are shown in Figure 1. "SW manpower", "4IR", "Company", "AI", "Innovative Growth", "Government", "Global", "Humanities", "Korea", "Future", and "Job" showed high Eigenvector centrality.

Figure 1

'SW Manpower' Network Graph



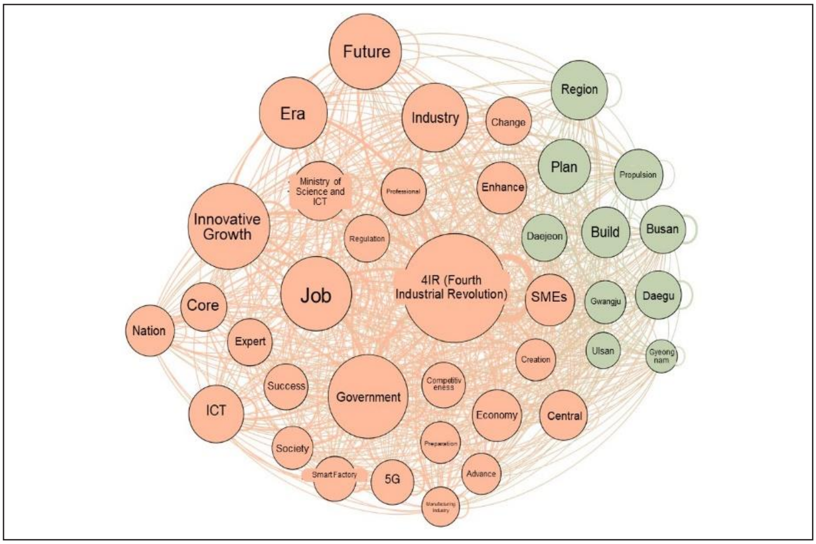
Cluster 1: 'Innovative Growth of 4IR Era'

The first cluster comprised a total of 38 nodes. "4IR (connection: 14,731)", "Government (8,770)", "Innovative Growth (7,860)", "Job (6,551)", "Future (6,285)", in that order, showed high Eigenvector centrality. Eigenvector centrality means that nodes connected to critical nodes are more important (Bonacich, 1972; Bonacich, 1987; Lee, 2010). In the case of the cluster, it is difficult to grasp the contents of the cluster, consisting of a total of 38 nodes at once. For this reason, a hierarchical cluster analysis was performed by using the modular clustering algorithm for more detailed content analysis.

The hierarchical analysis classified two subgroups as shown in Figure 2: subgroup 1 (innovative Growth of 4IR Era) and subgroup 2 (regional hub-centered construction plan). In the case of subgroup 1, the government, led by the Ministry of Science and ICT, seemed to be pushing for policies to grow SW innovation and create related jobs in the 4IR era. Specifically, policies for fostering 40,000 working-level SW personnel and 4,000 core talents, creating jobs through developing SW high-growth companies, and improving the system to innovate the SW industry ecosystem are being pursued. There is an effort to foster new industries through temporary deregulation policies in the form of regulatory sandboxes to promote the development of new SW convergence technologies and new services. In addition, ICT, 5G, smart factories, and manufacturing industries are at the center, leading economic and social development and job creation. On the other hand, subgroup 2 appeared to be related to a regional hub-centered construction plan. It can be inferred that the government planned and promoted the expansion of core capabilities centered on regional hubs for growth engines and intelligence to support the 4IR.

Figure 1

'Innovative Growth of 4IR Era' Subgroup Network Graph

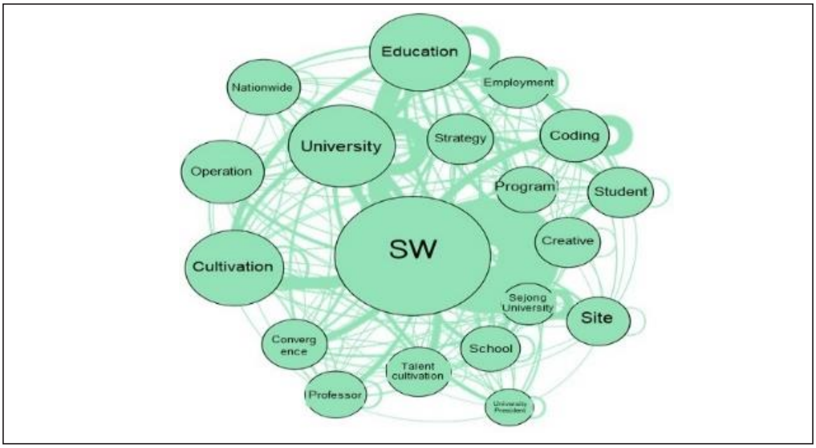


Cluster 2: 'SW Talent Development'

The second cluster encompassed a total of 20 nodes as presented in Figure 3. The Eigenvector centralities from highest to lowest were: "SW (connection: 10,198)", "University (6,257)", "Education (4,685)", "Training (4,450)", "Operations (3,141)", "National (3,191)", "Coding (3,063)", "Employment (2,768)", "Strategy (2,259)", "Student (2,474)", "Convergence (2,273)", "Creativity (2,604)", and "Talent Development (2,208)". Analysis of the SW Talent Development cluster suggested that SW talent training promotes coding education to foster long-term SW talent centered on universities and schools. The use of information through SW and the development of creative thinking are becoming increasingly important. In the case of universities, 35 higher education institutions around Korea were selected as SW-centered universities, led by Sejong University, Chung-Ang University, and Jeju National University. Through innovations in the curriculum centered on SW, universities are cultivating talent for SW convergence that meets the needs of the field. SW major courses aim to develop working-level talent that has global competitiveness. SW training for non-majors, on the other hand, aims to cultivate convergence talent that combines knowledge of other majors with SW literacy. Aside from this, elementary, middle, and high schools have expanded their educational programs to foster future talent through mandatory SW education based on SW literacy since 2018.

Figure 2

'SW Talent Development' Network Graph



Cluster 3: 'Utilizing New Digital Technology Companies'

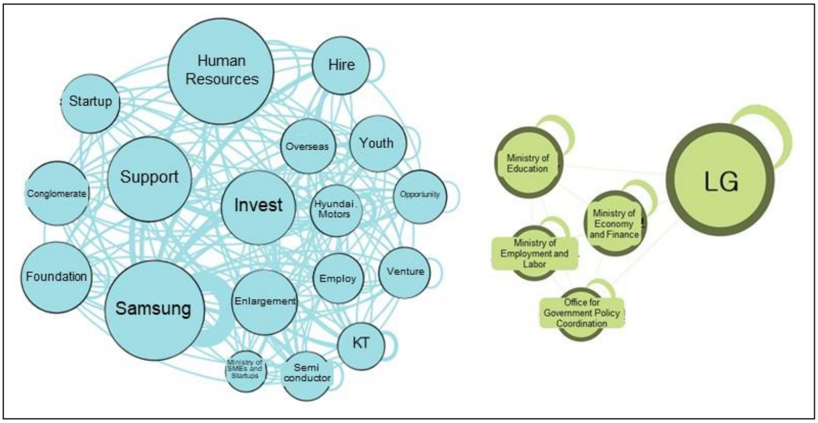
The third cluster consisted of 24 nodes shown in Figure 4. The Eigenvector centralities were as follows: "AI (connection: 10,755)", "Company (9,301)", "Korea (7,721)", "Global (7,695)", "Robot (4,752)", "Digital (3,754)", "Blockchain (3,747)", "Big Data (3,227)", "Use (3,211)", "China (3,201)", and "United States (3,137)". As a result of analyzing the third cluster, it could be surmised that companies are focusing on expanding the use of new digital technologies, such as AI, big data, robots, and IoT, which are core SW technologies of the 4IR. In addition, it can be seen that efforts are being made toward utilizing SW for product and service improvement, platform development, and market creation. The US has eight of the world's top 10 AI companies, while China has two. This has boosted the soft power of the two countries. In the US, Silicon Valley companies like Apple have been focusing on digital transformation. China, on the other hand, has become prominent in the AI and data sectors. In Korea, Hyundai Mobis is prominent in using AI; applying AI technology to research and development, production, and logistics sites, and autonomous vehicles.

Cluster 4: 'Expanding the Recruitment of SW Talent for Korean Companies'

The fourth cluster comprised a total of 18 nodes as displayed in Figure 4. The Eigenvector centralities were as follows: "Samsung (connection: 8,815)", "Talents (6,294)", "Support (4,010)", "Investment (3,928)", "Starting a Business (3,514)", "Large Companies (3,159)", "Recruitment (2,862)", "Expansion (2,824)", "Start-up (2,756)", "Hyundai Motors (2,669)", "Youth (2,569)", "Venture (2,218)", "KT (2,213)", and "Employment (2,208)". Analyzing the fourth cluster, it can be deduced that SW talent recruitment will increase, especially for large companies. In addition, it showed that the Ministry of SMEs and Start-ups supports venture start-ups and start-up investments to expand recruitment and employment. Recruitment is expanding due to the high demand for SW talent, mainly in large domestic companies, such as Samsung, Hyundai Motors, and KT, all of which are private companies. As the importance of cores in developing flash chips has increased in semiconductor businesses, the importance of SW algorithms has grown even more. Because of this, Samsung is making efforts to strengthen its competitive edge in SW, secure related technologies, and nurture talented people. Start-ups are also working hard to secure SW personnel that are directly related to their services. Despite the overall drop in employment rate, recruitment of SW development personnel is on the rise. The company's future competitiveness depends on whether competent SW personnel are secured for its mobile and global services.

Figure 3

'Expanding the Recruitment of SW Talent for Korean Companies' Network Graph (left) and 'SW Education Public-Private Cooperation' Network Graph (right)



Cluster 5: 'SW Education Public-Private Cooperation'

The fifth cluster encompassed five nodes as shown in Figure 4. The Eigenvector centralities from the highest to lowest were as follows: "LG (connection: 5,357)", "Ministry of Education (2,492)", "Ministry of Economy and Finance (3,709)", "Ministry of Employment and Labor (3,097)", and "Office of Government Policy Coordination (3,859)". Analysis of the fifth cluster revealed that the Ministry of Strategy and Finance and the Office of Government Policy Coordination, as well as government agencies such as the Ministry of Education and the Ministry of Employment and Labor, have many related references to SW and manpower. In particular, LG, in cooperation with government agencies, operates free IT and new technology education and coding curricula for elementary, middle, and high school students and is actively engaged in social contribution activities. Aside from LG, Naver and Samsung are also supporting SW training and education due in part to the mandatory SW education programs for elementary, middle, and high schools. Private companies' social contribution activities related to SW education also serve as a good indicator for the development of the SW industry and human resource training.

CONCLUSION

This study conducted a big data network analysis focusing on two years of news data that mentioned "software manpower" in relation to the 4IR. It investigated and analyzed the issues and direction of fostering SW personnel and its evolution in this new era. Data were collected from the time of Korea's 2017 presidential election, which marked a new phase in the government's policy stance on the SW industry.

According to the analysis of the news big data network, demand for the use of new technologies and convergence SW, such as AI, big data, blockchain, and IoT, continued to increase in industrial sites due to the arrival of the 4IR. This has resulted in increased demand for related personnel and new job creation. In particular, it has been confirmed that the demand for SW talent is very high in large companies and start-ups in new technology fields. Securing excellent SW manpower has become an essential factor in strengthening the competitiveness of companies in most industrial fields. Despite a general downturn in the employment market, demand and employment for SW talents, such as in AI and big data, continue to increase, as shown in Cluster 4: 'Expanding the Recruitment of SW Talent for Korean Companies'.

In responding to the rapidly increasing demand for manpower, regional governments are making continuous efforts, as shown in Cluster 2: 'SW Talent Development'. Despite their efforts to strengthen the SW manpower, the supply of SW manpower is still insufficient. Therefore, it is urgent to establish a national strategy for nurturing SW manpower at the central government level and establish a policy that can be linked with regional governments. In addition, the problem of the human resource paradox presented in the background is not due to the lack of supply in reality but rather a disparity in the quality of manpower. SW competency should no longer be viewed as a competency that exists alone, but as a capability that creates a synergistic effect by convergence with other capabilities.

It has been confirmed that securing human resources with excellent SW-based convergence capabilities is becoming an essential factor in strengthening corporate competitiveness in most industrial fields. Fortunately, long-term investments in SW talent development are being made through elementary, middle, and high school SW education, as well as SW-centered universities. In nurturing talents with SW-based convergence capabilities, it is expected that cooperation between industry-university councils for nurturing convergence SW talents between industries is necessary. Currently, as shown in Cluster 5: 'SW Education Public-Private Cooperation', it is confirmed that the SW manpower nurturing policy is mainly focused on public-private cooperation. However, it is difficult for the government to respond directly to the needs of the industry. It is necessary to establish an SW manpower nurturing policy focusing on industry-university cooperation rather than public-private cooperation. The central government must urgently establish a policy to promote an industry-university council.

This study has several limitations. Since data collection was based on news articles made by media reporters, it showed its limitation in grasping practical technology and industry trends. Therefore, considering this limitation, it is necessary to proceed with similar studies again after a certain period and to collect multiple data sources. Furthermore, due to the inherent nature of news data, the wide distribution of non-directionality between nodes and the degree of edge connection compared to the number of nodes presents itself as another limitation. To address the limitations of this study, long-term data could be collected and, in addition to news data, SW manpower training and job-related research data could be used.

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