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Research trend analysis on convergence and joint research of Korea using scientific papers

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Abstract Recently, convergence has been presented as one of the technical innovations in many industrial sectors and diffusion has been discussed as providing the main influence on convergence. The present study used the VOSviewer to analyze convergence trends and the current state of joint research, complemented by quantitative analysis using information from scientific papers published in 2015 obtained through the Scopus database. The results of this study illustrate that convergence of research occurring in Korea is evident in a variety of sectors, e.g. chemistry, material science, mechanics and the electrical and electronics sectors. We discovered that a sector performing research characterized by convergence also was actively involved in joint research. We also discovered that institutions conducting many studies were doing so as partners within joint research with other institutions. There are two important applications: The present study identified important information that can be used to monitor convergence and diffusion appears to provide the most influence on convergence.

Keywords Convergence · Joint research · VOSviewer · Gini index

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1 Introduction

In recent innovation trend, emerging sectors are characterized by rapid development of technologies based on combining various field and increased necessity of interdisciplinary research, which is called convergence. Definition's difference between convergence and fusion is defined by curren et al. By that definition, Convergence is defined as the process where the science, technology, and industry move to the different branch and it is combined. And convergence is defined as the process where two technologies is combined at least one branch [1]. Curran [2] explained convergence as a concept of at least two distinguishable items, e.g. hardware devices or entire industries migrating to one distinct technology. According to Curran, as convergence progresses, the distance between technologies exhibits a strictly monotonic-decreasing behavior. As shown in Fig. 1, when the distance between technologies becomes closer, the boundaries between A and B become blurred, leading to convergence. In contrast, if the distances between A and C and B and C are large, the technical boundaries are distinct and easily identifiable, demonstrating no convergence. As a method for measuring the distance between technologies, various studies using co-citation, co-author, co-publication, and co-word analyses between technologies are in progress (Fig. 1). Bores [3] defined convergence as the process of combining communication, broadcast, and IT sectors into a single market. The OECD [4] provided a definition of convergence from two perspectives. One perspective viewed convergence as the process of increasing the intersection of technology, service, and corporate activities accompanied by the increase in gray boundaries ("blurring" of the boundaries) between all technologies that affect the economics of the institution. This convergence is being studied with most of the focus on continuity and type, as they influence convergence. We believe

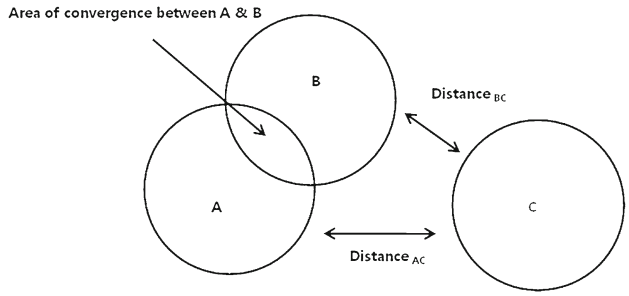

Fig. 1 Convergence measurement method demonstrating the measurement of distance between areas

that the primary influence on convergence is diffusion and that the primary influence on diffusion is joint research [5].

Convergence has attracted growing interest among many researchers. So far, the emerging discussion on convergence has tended to focus on developments within the information technology, communications and media industries. Most of studies around convergence has centered on topologies, consequences and drivers. While knowledge diffusion is one of the most important drivers of convergence, various factors, including changing market environments and customer behavior, regulation absolutely. Also, diffusion is affected by joint research network in terms of researcher level and network level. Despite the fact that diffusion seems to a major driver of convergence and it is affected by joint research network, these phenomena remain largely unexplored in the academic field. Although a number of prior studies on convergence, diffusion and joint research network can be identified, the academic discussion on relationships between convergence and joint research so far must be considered as still emerging, meaning that the topic remains relatively uncharted empirically [6–8]. Also, Despite such important aspects of convergence, studies on convergence monitoring using patent information are still lacking; moreover, studies on joint research that can facilitate diffusion, a driving force behind convergence, are still insufficient.

The purpose of this study is to monitor trend of convergence and joint research in Korea and find their implications. For this study, the convergence trend in Korea was analyzed using VOSviewer, Gini index and network analysis. Using VOSviewer, we implemented ASJC code mapping in scopus data to monitor trend of convergence in Korea. Also, We used the Gini index which used determined diversity index as determining the degree of convergence. Convergence is the concept that two or more different technology combine to new technology, which has the same meaning as the diversity index. Therefore, in this study, we used the Gini index to determine the degree of convergence in major research areas. This study provides important information that can be used to monitoring convergence and joint research. Futhermore, it can be promote convergence in Korea.

2 Literature review

2.1 Joint research network and diffusion

Joint research network has always been implied, often without elaboration, in the diffusion literature: diffusion through a social system has usually been studied as a process of communication between connected researchers [9,10]. Diffusion researchers employing the joint research network perspective have sought to explicate the actual structure of relationships that shape and constrain the communication, thus throwing further light on the diffusion process. The core idea in joint research network tradition is that social structure influences the spread of new ideas and practices by shaping patterns of interaction within joint research network [11]. The fundamental intuition of joint research network theory of diffusion is that structural patterns determine whom a given researchers will choose as a "model". While joint research networks are composed of relationships between a set of researchers, there are two broad approaches to the study of how relationships influence diffusion: relational and structural models of diffusion [12]. Relational models consider the focal researcher's adoption or non-adoption in light of the behavior of those to whom the former is directly connected. Thus, for a given researcher, direct contact with an influential "opinion leader" might be seen as impelling adoption. Structural models, in contrast, consider all relationships in joint research network, rather than only the direct ties that a given researcher may have. Founded on the key assumptions of joint research network analysis [13], structural joint research network models acknowledge that the overall structure of the joint research network, as well as a given researcher's position in it, influence that researcher's behavior and subsequent performance. In modeling the effect of the overall Joint Research network structure on diffusion, we adhere to the structural model. The history of joint researchnetwork model of diffusion may be traced from opinion leadership formulations [14], to the strength of weak ties formulation [15], to the communication joint research network formulation [16] and finally to the structural equivalence formulation. Joint research network analysts refer to the specific process of diffusion; thus, the chief concern of joint research network model of diffusion is the variety of network mechanisms through which diffusion operates [11].

In the Researcher level (with primary reference to the position of researcher in the IJR network), Firstly, Diffusion is positively associated with the researcher's prominence in the joint research network (a crude measure of which is the number of an researcher's contacts), which may be viewed as indicative of opinion leadership [9] or, in a related manner, as a measure of how well integrated the researcher is [14]. Secondly, Highly central researchers are more likely to be early adopters [14,17–19]. Potential adopters who are highly cen-

tral tend to have higher reputations that they are less willing to risk by adopting unproven or contra-normative innovations; peripheral players have less at stake and may be more willing to take such risks [9,20]. Thirdly, Isolates, i.e. researchers who are not connected to anybody else, tend to show considerably later adoption times [16]. Fourthly, Weak ties, i.e. researchers that serve as bridges between unconnected groups, are important links in the knowledge process [11,15]. Lastly, Diffusion is positively associated with structural centrality, i.e. how significant a position the researcher has in the network. For example, betweenness centrality measures the degree to which are searcher lies between other researchers (corresponding to potential control), while closeness centrality measures the degree to which a researcher is close to others (corresponding to potential access). Researchers who are highly central in these respects are more likely to receive related information and influence early, and hence more likely to adopt early [18].

In joint research network-level (with primary reference to overall patterns of relationships), Mainly, Highly centralized Joint Research networks (with a small number of highly central researchers) should demonstrate a higher rate of diffusion; once adopted by the central researchers, the diffusion will spread rapidly through the joint research network [12]. Secondly, Diffusion will be more rapid in Joint Research networks that are densely interconnected [21]. Thirdly, Diffusion operates through cohesive ties, i.e. through strong connections with close contacts [14]. Lastly, An alternative hypothesis to diffusion through cohesion is that it operates through structural equivalence, i.e. researchers may take their cues from others that they consider to be similar to themselves, even in the absence of direct ties between them [11].

2.2 Diffusion as driving factor of convergence

The underlying causes and drivers of convergence are diverse. A First set of causes has been identified in changing market environments and customer behavior. The phenomenon of one stop shopping, i.e. customers seeking the full of multiple needs within only one transaction, leads to a convergence of formerly distinct markets [7]. A second set of causes for convergence comprises political, legal and regulatory aspects which encompass regulation as well as deregulation, standardization, legislature, government funding and the way governmental authorities deal with debated issues [5,22–26]. As the example of the NFF sector shows, it is especially regulation that plays an essential role in regard to the question whether Functional Foods will compete with conventional foods and/or pharmaceutical industry drugs in the future [27]. In the ICT sector, the role of regulation in the process of science convergence is also subject of an interesting discussion. On the one hand, regulation is considered a mere barrier to convergence due to the monopoligopolization of the telecommunication sector in the past [28]. On the other hand, it is also regarded as an important driver for convergence in this area. For instance, Nystroem [25,26] concludes that regulation may also aim at fostering convergence developments, e.g. in regard to internet services or multi-purpose devices. Deregulation of a given industry is often a result of policy makers' desire to induce competition by lowering entry barriers for new competitors that bring alternative technologies or business models into an industry [6,29]. Deregulation has predominantly been a driving factor in the telecom industry [28] leading to convergence such as that between data communications and traditional fixed telephony, i.e. 'Voice over IP' [30]. The next area ripe for deregulation would likely be the mobile telephony sector [31]. A third set of convergence cause, which has attracted most interest in literature on convergence so far, is diffusion [32]. Diffusion is undoubtedly the principal driver behind convergence that is discussed in existing literature. Diffusion is integral in many cases of convergence, and thus also central as a driver for convergence. This holds especially true for science and technologies intense industries like the ICT sector [30].

3 Methodology

3.1 Extraction of papers and making joing research network

In this study, information from papers regarding the renewable energy field was extracted using the Scopus database (www.scopus.com), and a search was executed using keywords in the Scopus database. The information from 43,710 papers was extracted with this search (Table 1).

A diagram of joint research networks was drawn by creating a simultaneous occurrence matrix table using the paper information, extracting the organizations involved in joint research, ASJC code and keyword. Finally, we created a diagram based on the resulting information (Fig. 2).

3.2 Measurement of convergence

In this study, we measured convergence using VOSviewer and Gini index. VOSviewer is a computer program developed by Eck and Waltman [19] for the primary purpose of producing network maps. VOSviewer can produce author information, identify citation relationships, keywords, and

Table 1 Search query

Search query	No. of search results
CU = (KOR) PY = (2015)	43,710

Paper	Information of Instutution	Information of AJSC Code	Information of keyword
Paper1	Instutution 1 ; Instutution 2	Code 1;Code 2	Keyword 1; Keyword 2
Paper2	Instutution 1 ; Instutution 3	Code 1;Code 3	Keyword 1; Keyword 3
Paper3	Instutution 2 ; Instutution 4	Code 2;Code 4	Keyword 2; Keyword 4
Paper4	Instutution 2 ; Instutution 3	Code 2;Code 3	Keyword 2; Keyword 3
...	...	...	...

Making Co-occurence

	Institution or AJSC code or Keyword 1	Institution or AJSC code or Keyword 2	Institution or AJSC code or Keyword 3	Institution or AJSC code or Keyword 4
Institution or AJSC code or Keyword 1	3	1	1	1
Institution or AJSC code or Keyword 2	1	2	1	0
Institution or AJSC code or Keyword 3	1	1	2	0
Institution or AJSC code or Keyword 4	1	0	0	1

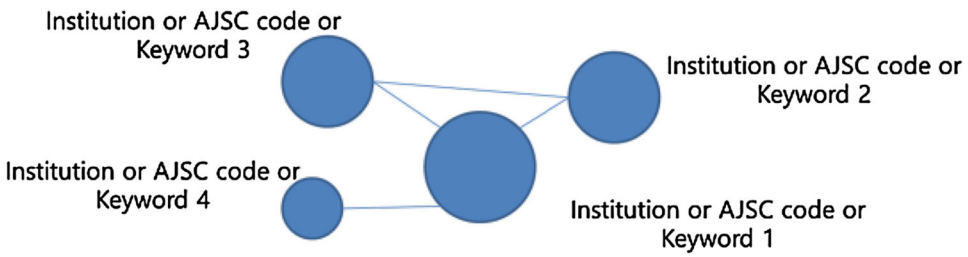

Fig. 2 An example of method of creating an joint research network diagram (example)

subject category information and aggregate this data within the format of a map based on aco-occurrence matrix. Generally, the methods for producing a map largely involve analysis of distance-based and graph-based maps. The distance-based map uses a method that considers the strength of association between items in measuring the distance, unlike the graph-based map, which draws the map by determining whether a simple relationship exists or not. VOSviewer, as used in the present study produced the map based on the distance method. In general, VOSviewer undergoes a 3-step process. The first step calculates the similarity between categories based on a given co-occurrence matrix. This computation requires a variable, the Association Strength, which is computed as follows:

$$\text{Association Strength} = \frac{C_{ij}}{w_i w_j} \tag{1}$$

where c_{ij} denotes the number of co-occurrences of items i and j and where w_i and w_j denote either the total number of occurrences of items i and j or the total number of co-occurrences of these items. In the second step, a 2-dimensional map is produced, based on the similarity calculated in the first step. In other words, associations with higher similarity are located in closer proximity and those with lower similarity are located further apart. In the final step, the variables are clustered and the density of each variable is marked according to its occurrence frequency [33]. Since VOSviewer is a program that can display the associations between variables based on distances between technology sectors, it can be used to monitor convergence trends between sectors. That is, the relation with a high similarity is positioned closely while the relation with low similarity is positioned with distance. On the last stage, parameters are clustered, and the density of the parameter is indicated depending on the frequency of incidence. VOSviewer is a program that indicates the relation between the parameters based on the distance between the fields of technology. Therefore, we can monitor the trend of convergence between fields through this program.

Many studies have been conducted regarding convergence index and proposed network index (based on degree centrality), journal index (Shannon Entropy and Gini Index), and recently, Rao-Stirling measures.

Gini Index used in this study is a barometer to measure the level of impurity or diversity of each node and defined as follows:

$$G = 1 - \sum_{j=1}^{c} \left(\frac{n_j}{n}\right)^2 \quad (2)$$

n_j means that number of particular ASJC code and n means that number of total ASJC.

3.3 Measurement of joint research

Network can be expressed as a relation network in which persons are related. Establishing relationships is the most important aspect of people's life, with some relationships being intentional, and others inevitable. Network is established based on the social relation between people, and normally, social relation includes relation based on role, cognitive/emotional relation, and relation based on action [34].

Network theory is based on graph theory, and graph theory is a mathematic model that expresses relation between element pairs of specific group. It is expressed by nodes and links that link the nodes. By analyzing the form of node or link, overall structure of the network, and characteristics of link, the influence relation of nodes can be understood. Network analysis is one of the analysis methods based on the network theory like this, and it is used throughout various areas like R&D evaluation, Big data and etc [35–37].

In network analysis method, relation between social beings like individual, organization and country is sought by network, and the form and contents of the network structure are studied. Network is a quantitative method that analyzes interaction between nodes through visual expression of graph technique. Especially, materialized concepts introduced in network analysis like density, centrality and structural equivalence are quantitatively analyzed and suggested by social network researchers who used to study social ties, connection relation, and network connectivity. Social network analysis (SNA) or network theory have been used in organization theory and policy network study. In this study, analysis element at microscopic level is mainly studied, and network theory was applied to for analysis with focus on the index of degree centrality. The degree centrality used in this study measures the level of connection between one point that consists of the network and other points directly connected to the point, and how central each point is located on the network can be analyzed. With a higher value of degree centrality, it is considered to play a role of connector between nodes or a hub [38,39].

Network centrality analysis is divided into degree centrality and betweeness centrality between nodes. Degree centrality measures how central a node is located in a network and the degree of connection between one node and other nodes that are directly connected to the original node. The number of connected node is an absolute criterion. That is to find how central a node is located in a network, and it is divided into in-degree centrality analysis out-degree centrality, depending on the connecting direction of two nodes. By formulating this, in a random node p_k, degree centrality Dc (p_k) can be calculated by sum of other nodes nearing p_k. Where, (p_i, p_k) = 1 means that p_i and p_k are connected and (p_i,p_k) = 0 means that they are not.[1]

$$\text{Degree Centrality} = \frac{\sum_{i=1}^{n} p_i \cdot p_k}{n(n-1)} \quad (3)$$

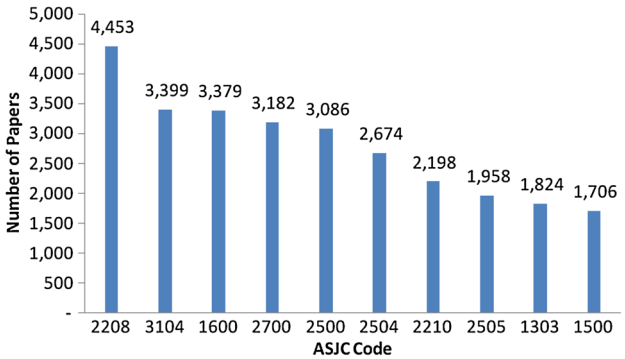

Fig. 3 Frequency of ASJC code

Table 2 Description of the ASJC codes

ASJC code	Detail
2208	Electrical & electronic engineering
3104	Condensed matter physics
1600	Chemical
2700	Medicine
2500	Material science
2504	Electronic, optical & magnetic materials
2210	Mechanical engineering
2505	Materials chemistry
1303	Biochemistry
1500	Chemical engineering

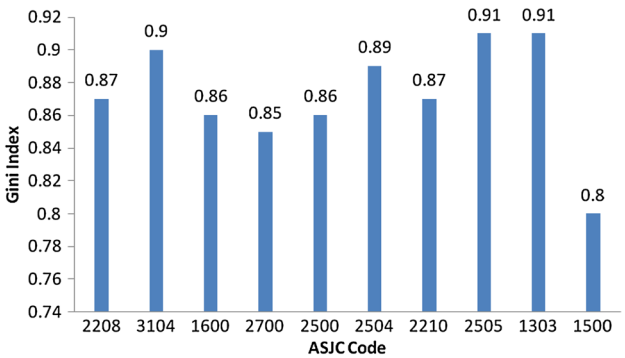

Fig. 4 Gini index of ASJC code

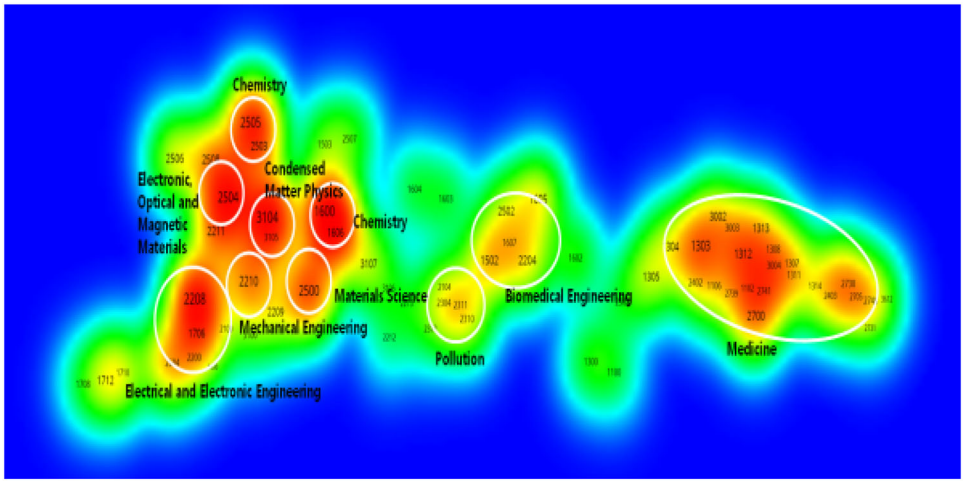

Fig. 5 Map of the relationships between the ASJC codes

4 Results

After analyzing the all science journal classification (ASJC) codes from the extracted database, it was determined that the largest number of studies had been carried out for the 2208 sector, followed by the 3104, 1600, and 2700 sectors (Fig. 3; Table 2).

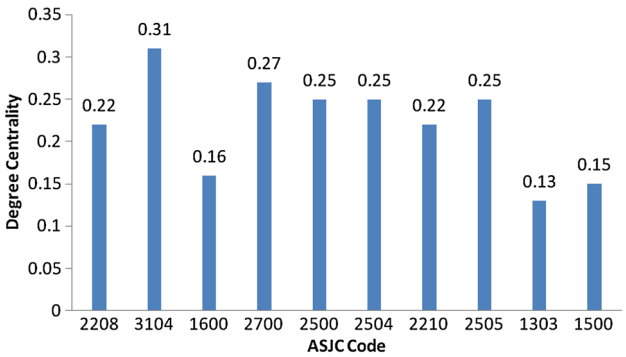

Fig. 6 Degree centrality of ASJC code

The Gini index analysis for the ASJC codes appeared to have high sector scores of 2505 (Materials Chemistry), 1303 (Biochemistry), and 3104 (Condensed Matter Physics), indicating that those sectors have active convergence with other technologies. The materials chemistry sector converged mostly with the electrical and electronic engineering sector, as well as the condensed matter physics sector for technology development. By contrast, the biochemistry sector conducted research and development in convergence with the technologies of the medicine sector (Fig. 4).

After creating the map based on the ASJC codes, as shown in Fig. 1, it was observed that various studies had been executed through the convergence of the chemistry, electrical and electronics, mechanical, and materials sectors. More-

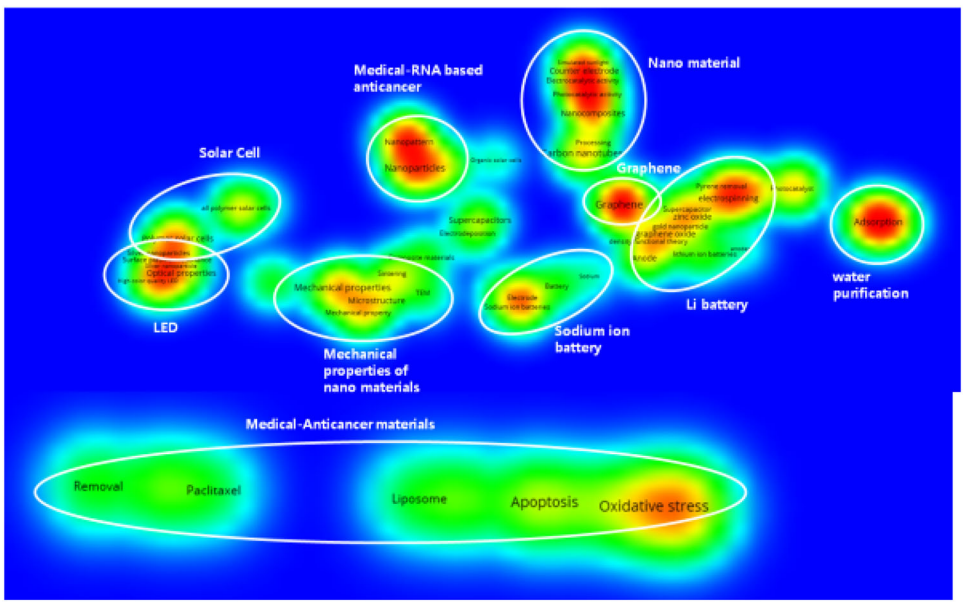

Fig. 7 Map of the relationships between the keywords

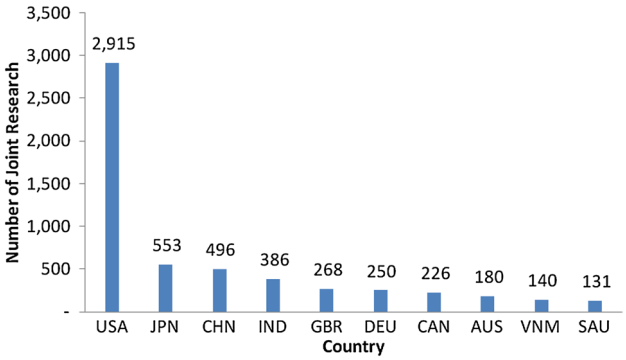

Fig. 8 Number of joint research cases by country

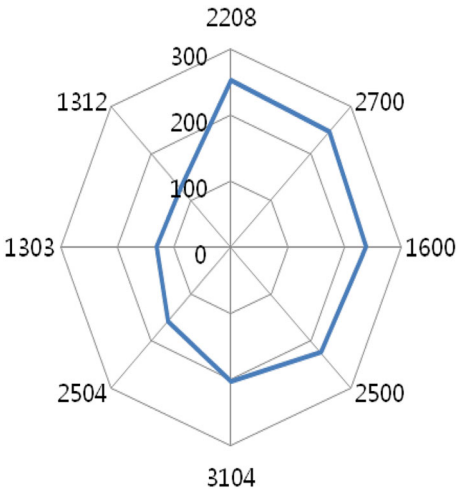

Fig. 9 Number of joint research cases with the US by sectors

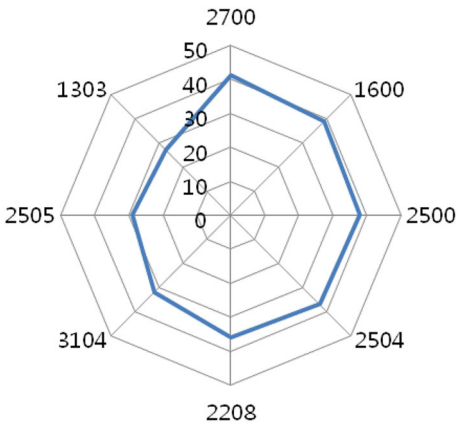

Fig. 10 Number of joint research cases with China by sectors

over, separate studies had been conducted in the medical and environmental sectors. However, although the research in some areas of the medical sector had been conducted in convergence with the bio-related sectors, the proportion of such research was relatively small (Fig. 5).

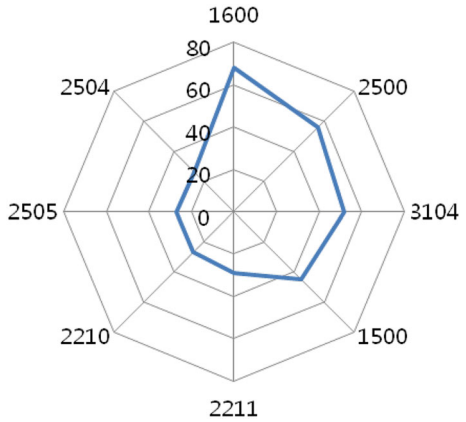

Fig. 11 Number of joint research cases with India by sectors

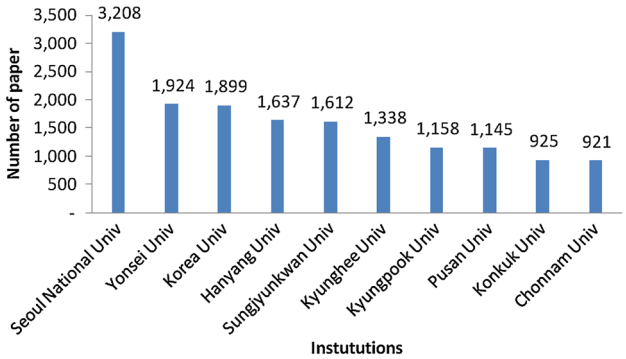

Fig. 12 Number of scientific paper publishing institutions

When the degree of centrality of the ASJC codes was analyzed, sector 3104 was found to have the highest centrality, indicating that this sector played the most important role in the total convergence studies (Fig. 6).

Figure 7 showed the map created using the keywords information from papers to analyze the details of the map of the ASJC codes above. As shown in Fig. 7, the main areas of the research involved the photovoltaic technology, LED application techniques, mechanical characteristics of nano materials, anticancer technology in the medical sector, nano materials synthesis, energy systems, and water quality management sectors (Fig. 7).

As shown in Fig. 8, analysis of the state of joint research between countries showed that the United States was conducting most joint research studies, while Japan, China, and India were also conducting many such studies (Fig. 8).

The results also indicate that the sectors that were included within joint research studies with the US occurred in the electrical &electronic engineering, medicine, and chemical sectors, while joint research with Japan appeared as 3379, 3399, and 3086. On-going joint research with China was found to involve medicine and chemical and material sciences sectors, while joint research with India was found to

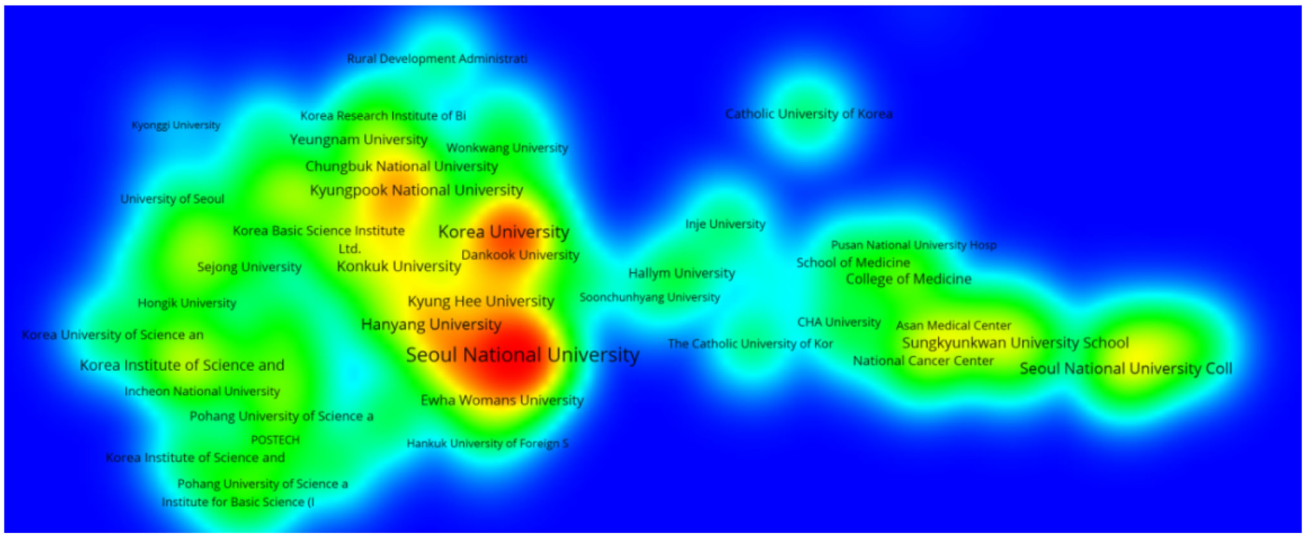

Fig. 13 Status of joint research between institutions publishing scientific papers

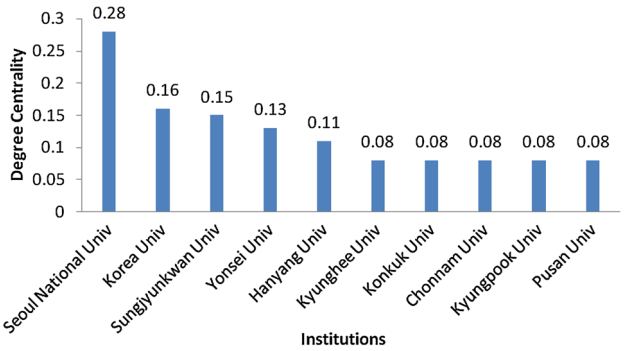

Fig. 14 Degree centrality of joint research between institutions publishing scientific papers

involve the chemical, material sciences and chemical, and engineering sectors (in Figs. 9, 10, 11).

As shown in the figure below, an analysis of the number of published scientific papers by research institutions in Korea showed that Seoul National University published the highest number of scientific papers, followed in order by Yonsei University, Korea University, and Hanyang University (Fig. 12). A review of joint research between institutions showed that Seoul National University was actively involved in joint research with Hanyang University, Ehwa Womans University, and Kyung Hee University, while Korea University was actively involved in joint research with Dankook University and Konkuk University (Fig. 13).

When the degree of centrality of major institutions was analyzed in the joint research network, Seoul National University scored 0.28, which corresponded to the highest value. This indicated that it led joint research studies among the major institutions in South Korea (Fig. 14).

5 Conclusions

Convergence is being presented as a major technical innovation, while diffusion is being presented as a significant influence to create convergence. The present study analyzed major research trends in Korea for examination of the current state of convergence and joint research, the primary factor that causes diffusion. Convergence trends and the current state of joint research were analyzed using information from scientific papers published in 2015 in journals that are at the Scopus level or above.

As a result, convergence studies in Korea have been led by the Electrical and Electronic Engineering sector as well as the Chemistry, Materials Science, and Mechanical Engineering sectors. There were high convergences with the Materials Chemistry, Condensed Matter Physics, and Biochemistry sectors. With the exception of the biomedical sector, independent studies were pursued. In particular, convergence studies were actively pursued between solar technology and LED application technology, as well as within the nano material and energy storage system sectors. In the network of technology sectors, the Condensed Matter Physics sector showed the highest degree of centrality, suggesting that this sector is the core technology in all research. Examination of the current state of joint research indicated that Korea was actively involved in joint research with the US, China, and India. The sectors in which joint research with the US was pursued included the electrical and electronics, medical, and chemical sectors, whereas joint research with China involved the medical, chemical, and material sciences sectors and joint research with India involved the chemical and material sciences sectors. In other words, it was found that Korea was conducting joint research in the chemical, electrical and electronics,

and material sciences sectors with other major countries, and based on this observation, it was determined that joint research was being pursued in sectors in which convergence was occurring within Korea. With respect to joint research between institutions, it was found that joint research was being pursued actively between institutions that were conducting many individual studies. In particular, it was found that institutions conducting the highest number of studies (such as Seoul National University and Korea University) had also been performing active joint research studies in Korea. Based on these results, it seems that Korea has put efforts into creating new growth engines in the renewable energy and biosectors through convergence, which is required when creating new markets and innovating new concepts. As a part of this effort, joint research has been promoted in various countries. In addition, the institutions that have been conducting active research in Korea pursue joint research as well. In other words, the analysis showed that the number of participants in corresponding research increased through joint research, and that the studies were being expanded and convergence was being promoted.

As a results, First, in terms of convergence trends, it had been taking place in the fields of electronics and electronics in Korea, which were being applied to renewable energy and biotechnology. It was in line with the convergence strategy that Korea is focusing on [40]. Therefore, it was expected that it would provide useful information when establishing related strategy of convergence. Second, joint research with the United States had been actively conducted in the field of materials and electric and electronic fields where joint research was active. This showed that convergence had been actively carried out in areas where joint research was active. This meant that activation of joint research was one factor that promotes convergence. Third, in order to revitalize joint research, it was necessary to induce the joint research of major universities. This is because, if universities that many outstanding researchers possess were pursuing a joint research, it could promote efficiently joint research with other researchers.

The present study used information from scientific papers for analysis of convergence trends through production of maps created from research of keywords and the researched sectors. The value of this study can be found in the fact that the findings can provide important information to monitor convergence and enable leadership within new convergence fields. Future study will be necessary to analyze how the convergence progresses and the pattern of joint research changes in these fields according to time, through analysis of convergence trends and joint research.

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