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Original Article

Analysis and Examination of Trends in Research on Medical Learning Support Tools: Focus on Problem-based Learning (PBL) and Medical Simulations

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Objectives: By grasping trends in research, technology, and general characteristics of learning support tools, this study was conducted to present a model for research on Korean Medicine (KM) to make use of information technology to support teaching and learning. The purpose is to improve the future clinical competence of medical personnel, which is directly linked to national health.
Methods: With papers and patents published up to 2011 as the objects, 438 papers were extracted from "Web of Science" and 313 patents were extracted from the WIPS database (DB). Descriptive analysis and network analysis were conducted on the annual developments, academic journals, and research fields of the papers, patents searched were subjected to quantitative analysis per application year, nation, and technology, and an activity index (AI) was calculated.
Results: First, research on medical learning support tools has continued to increase and is active in the fields of computer engineering, education research, and surgery. Second, the largest number of patent applications on medical learning support tools were made in the United States, South Korea, and Japan in this order, and the securement of remediation technology-centered patents, rather than basic/essential patents, seemed possible. Third, when the results of the analysis of research trends were comprehensively analyzed, international research on e-PBL- and medical simulation-centered medical learning support tools was seen to expand continuously to improve the clinical competence of medical personnel, which is directly linked to national health.
Conclusions: The KM learning support tool model proposed in the present study is expected to be applicable to computer-based tests at KM schools and to be able to replace certain functions of national KM doctor license examinations once its problem DB, e-PBL, and TKM simulator have been constructed. This learning support tool will undergo a standardization process in the future.

Key Words : Medical learning, TKM learning, PBL, medical simulation, IT

Introduction

In a knowledge- and information-based society, physicians are expected to be equipped with the ability to treat patients by analyzing and integrating an increasing medical knowledge and making appropriate situational judgments[1]. This is expected to accelerate further in the future because of changes in the health and medical service environment and the development of medical theory, which in turn demands qualitative changes in KM education[2]. Because of changes in the medical education

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Table 1. Expression Used for Paper and Patent Search

TS = (A and B) or (B and C) or (C and A)
A = (((clinic or diagno* or treat* or acup* or herb*) NEAR (support* or train* or educat* or learn*) NEAR system*))
B = ((PBL OR e-PBL) OR ((problem OR computer* OR case* OR electron*) NEAR (based OR assisted) NEAR (train* OR educat* OR learn*)))
C = (((medic OR educat* OR train*) NEAR simulat) OR "simulation in healthcare" OR "simulation in health" OR "virtual reality" OR "virtual realities" OR "haptic device" OR "haptic devices")

paradigm, medical schools began to introduce PBL in 1990. Currently, most medical schools now implement PBL[3], which, with the combination of telecommunication technology, has developed in the form of e-PBL. However, while certain KM schools have introduced PBL education, the discrepancy between KM education and medical education is considerable. PBL was originally begun in the mid-1970’s to improve medical school education and was systematized by Barrows. The purpose of PBL is to enable the knowledge acquired from medical education through knowledge-based deduction and self-directed learning to be appropriately used in the examination and treatment of patients in the clinical field[4].

Yet another change in the medical education paradigm is the fostering of medical personnel with a wealth of clinical experience, and this stems from the demands of medical consumers regarding patients’ safety and improved services[5]. With an aim at promoting the qualitative improvement of learning by virtually providing medical circumstances identical to actual ones in controlled environments, medical simulations have been used in medical education since 1990 through the use of mannequins[6]. While more intricate medical simulation education has been offered in diverse fields in recent years with the development of virtual reality (VR) technology and 3D technology, there is nearly no research on the application of medical simulations to KM education. Consequently, the present study was conducted to present a model for future research on KM learning support tools by analyzing research papers published in SIC(E)-registered academic journals and patents registered in patent DB. This study focused on grasping trends in research on medical learning support tools, technological trends, and general characteristics.

Methods

1. Objects of Analysis

The search equations used in the present study were constructed as unions with respect to intersections of A, B, and C, as shown in <Table 1>. A represents medical learning support tools, B represents PBL support tools, and C represents simulation support tools, respectively. With papers and patents published up to 2011 as the objects, papers were searched on "Web of Science"[7] and regularized by using the search equations in <Table 1>, thus extracting 438 SCI(E) papers, while 313 patents on related technology were extracted from the WIPS DB[8].

2. Methods of Analysis

As shown in <Table 2>, descriptive analysis was conducted on the frequency and number of citations of the papers searched above per annual development, academic journal, research field, research organ, nation, and keyword. The networks among the research organs, nations, and keywords were analyzed, thus grasping the correlation among the research fields in question. In addition, the patents searched were classified per application year, nation, technology, and

Table 2. Paper and Patent Analysis Tools

	Descriptive statistical analysis	Network analysis
Paper	- Publication trend by year - Publication trend by journal - Publication trend by category - Publication/citation trend by nation/institute - Frequency/citation trend by keyword	- Network between institutes - Network between nations - Network between keyword
Patent	- Publication trend by nation - Publication trend by inventor - Publication trend by IPC	- Activity index per nation

Table 3. The Number of Papers by Journal

Journal	Paper	Journal	Paper
ACADEMIC MEDICINE	15	SURGICAL ENDOSCOPY AND OTHER INTERVENTIONAL TECHNIQUES	9
MEDICAL TEACHER	12	JOURNAL OF THE AMERICAN MEDICAL INFORMATICS ASSOCIATION	8
ARTIFICIAL INTELLIGENCE IN MEDICINE	9	MEDICAL EDUCATION	7
COMPUTERS & EDUCATION	9	ANATOMICAL SCIENCES EDUCATION	6
COMPUTERS & EDUCATION	9	CYBER PSYCHOLOGY & BEHAVIOR	6
SURGICAL ENDOSCOPY AND OTHER INTERVENTIONAL TECHNIQUES	9	JOURNAL OF DENTAL EDUCATION	6

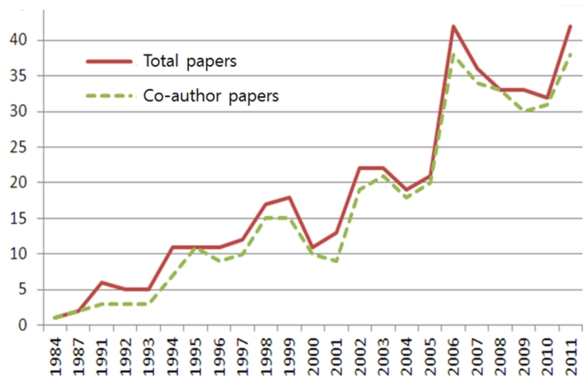

Fig. 1. The number of papers by year

applicant. Patent trends were grasped through quantitative analysis of the number of patents, share, and increase rate per field, and the relationships among the applicants' nationalities and the applying nations were analyzed to calculate the AI.

Results

1. Results of Paper Analysis

Research papers related to medical learning support tools have continued to increase in number, from one in 1984 to 42 in 2011. Most of these papers were analyzed to have been authored through joint research and published the most in

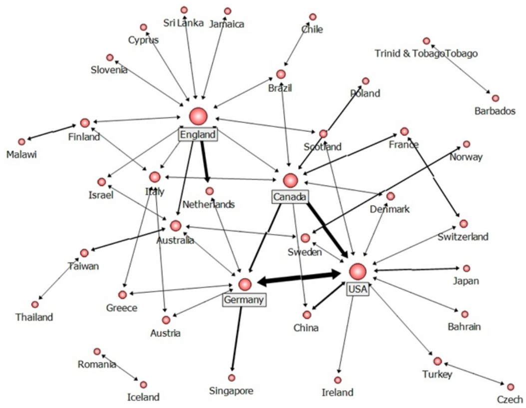

Fig. 2. Network analysis between nations

※ Node size means the degree of centrality and link size means the frequency of joint research

Table 4. The Number and Citation Index of Papers by Institute

Institute	Paper	Citation Index	Institute	Paper	Citation Index
Harvard University	9	1.9	University of Western Ontario	6	2.2
Indiana University	7	0.7	Arizona State University	5	0.8
University of Illinois	7	0.7	Cornell University	5	1.0
University of Toronto	7	1.9	Dartmouth College School of Medicine	5	1.0
Johns Hopkins University	6	1.7	Emory University	5	1.4
University of Iowa	6	1.2	National Cheng Kung University	5	1.2
University of New Mexico	6	1.2	National Taiwan University	5	1.0
University of Ottawa	6	1.2	Thomas Jefferson University	5	1.4
			University of Western Australia	5	1.0

Academic Medicine and Medical Teacher. In addition, when the academic journal classification of "Web of Science" was applied, the largest number of papers were presented in the area of computer engineering (41 cases), followed in order by educational research (38 cases) and surgery (34 cases).

When the number of papers per nation was analyzed, the United States ranked the highest with 165 cases, followed by Canada (28 cases) and the United Kingdom (26 cases). However, the impact factors of the papers differed: in order, 35.0 for Israel; 26.6 for the Netherlands; and 23.4 for Greece. In addition, when international research networks were analyzed, as shown in <Fig. 2>, the United States formed strong links with Canada and Germany, constructing research cooperation systems stronger than those of the United Kingdom. While Taiwan and China exhibited networks weaker than the number of papers, Australia was linked to relatively more countries.

When the number of papers per research organ was analyzed, American research organs, including Harvard University, Indiana University Bloomington, University of Illinois at Urbana-Champaign, and Johns Hopkins University ranked high, and, in Asia, two universities in Taiwan were very active. On the other hand, from the perspective of the quality of research, the

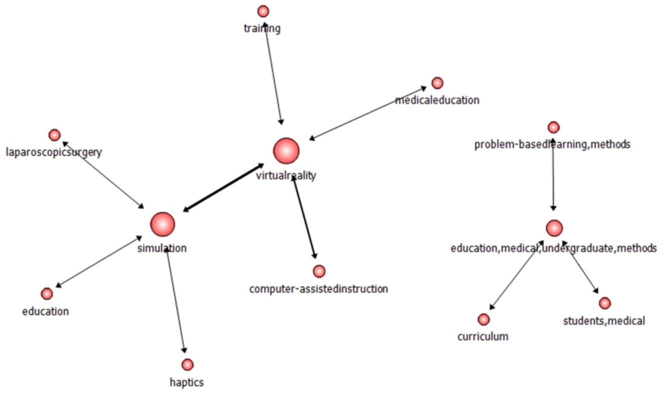

Fig. 3. Network analysis between keywords

※ Node size means the degree of centrality and link size means the frequency of joint research

ranking order was University of Western Ontario in Canada, Harvard University and Johns Hopkins University in the United States.

When the number of papers per keyword was analyzed, “virtual reality” exhibited the greatest frequency. Other important keywords included “computer-assisted instruction” and “medical education.” <Fig. 3> expresses networks among keywords, “simulation” and “virtual reality,” which exhibited great frequency. These networks were strongly linked and analyzed to be connected in turn to keywords such as “education.” In addition, PBL-related keywords were connected to separate networks.

2. Results of Patent Analysis

Counting patents on medical learning support tools, the United States took up 60% recording the largest number, with 188 cases, while South Korea took up the next 20% (62 cases). The patent application ratio also consisted of Japan, China, and Europe, in this order, thus showing that a large number of patents were applied for in the United States and South Korea where education and IT are well developed. <Fig. 4> shows the number of patents per year and the applicant’s nationality. In the United States, related patents were actively applied for around 1999, decreasing in number afterwards and

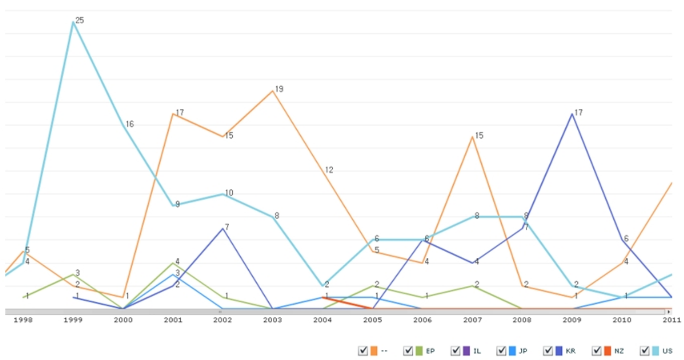

Fig. 4. The number of patents by year and nation

Table 5. The Number of Patents by IPC (Subclass)

IPC	Explanation	Patent	IPC	Explanation	Patent
G06F	Electric digital data processing	104	A61H	Physical therapy apparatus	7
G09B	Educational or demonstration appliances	64	G06N	Computer systems based on specific computational models	7
G06Q	Data processing systems or methods, specially adapted for administrative, commercial, ...	45	G06T	Image data processing or generation	7
A61B	Diagnosis, surgery, identification	31	A61N	Electrotherapy, magnetotherapy, radiation therapy, ultrasound therapy	5
G09G	Arrangements or circuits for control of indication devices using static means to present variable information	12	A63B	Apparatus for physical training, gymnastics, swimming, climbing, or fencing	5

Table 6. The Number of Patents by IPC (MainGroup)

IPC	Explanation	Patent
G06F-017	Digital computing or data processing equipment or methods, specially adapted for specific functions	55
G06F-015	Digital computers in general	15
G06F-009	Arrangements for programme control	12
G06F-019	Digital computing or data processing equipment or methods, specially adapted for specific applications	8
G06F-011	Error detection; Error correction; Monitoring	7

increasing once again since 2007. In South Korea, related patents were applied for in a moderate number around 2002 and have been more actively applied for since 2006. In addition, when the major applicants around the world were examined, subsidiaries of Accenture in the United States applied for 40 cases, thus exhibiting the greatest activity, followed in order by the Seoul National University (SNU) Research and Database Foundation in South Korea (21 cases), Wicab in the United States (7 cases), and Takatoshi Yanase in Japan (5 cases).

<Table 5> and <Table 6> show the number of applications for patents based on the IPC classification, and applications for G06F, G09B, G06Q, and A61B were analyzed to be active. Patents for G06F, which concerns electrical digital data processing, amounted to 104 cases, taking up 33% of the total. In particular, those for G06F-017, which concerns digital computing or data processing equipment or methods which are specially adapted for specific functions, were applied for the most (55 cases). The fact that valid cases are concentratedly detected for certain IPC can be seen as the failure to secure remediation technology. When interpreted as the technological development stage, because patents on source technology exist, it may be said that investment and interest in remediation technology development are necessary.

The equation below represents the AI, which analyzed the relationships among the applicants' nationalities and nations applied in and expresses the relative concentration of patent activities in specific technological fields by the nation or corporation in question. When the AI is 1 or below, patent activities are inactive; when it is 1-2, patent activities are comparatively active; and when it is 2 or above, patent activities are relatively active. Through the AI, patent activities in the major countries (KR, US, JP, EP) of patents in South Korea, United States, Japan, and Europe were examined. According to the results, the degree of patent concentration was high domestically in all four nations. This means that applicants with a South Korean nationality were

Equation 1. Expression for activity index

$$AI = \frac{\frac{N(\text{nations and classification})}{N(\text{classification})}}{\frac{N(\text{nations})}{N}}$$

, N is total number of patents and N(x) is N by x.

inactive in patent activities abroad, while United States and Europe were inactive in patent activities in South Korea, with the exception of Japan.

Discussion

Through an analysis of papers published in SIC(E)-registered academic journals, it was possible to confirm the continuous expansion of research on medical learning support tools. The joint research ratio was analyzed to be especially high in this field so that network analysis was conducted on research cooperation. Because international research cooperation was analyzed to be high according to network analysis, it will be advisable to conduct joint research with United States, Canada, and United Kingdom through the pursuit of cooperative partners in the future. In particular, in the cases of the United States and Canada, which were located in the center of the networks, cooperation with Harvard University and the University of Toronto is indicated. In addition, cooperation with the Netherlands and Greece, which conduct qualitatively outstanding research despite their relative isolation from the networks, was analyzed to be indicated as well.

In addition, academic journals with large numbers of papers in this field were those on computer engineering, educational research, and surgery. Additional analysis of the research results through literature analysis that can grasp the in-depth contents of the research is necessary in the future, and the securement of a pool of related experts is urgent. Examining research keywords regarding medical learning support tools, “virtual reality,” “simulation,” and “education” were important in frequency and the networks and were important methodological and conceptual elements of this field.

When patents related to medical learning support tools were analyzed, the securement of remediation technology-centered patents rather than basic/essential patents seemed possible and can be used as an index for establishing the direction of future research. When the top 20 major applying organs were analyzed, the United States (10 organs) and Japan (5 organs) exhibited active patent activities, followed by South Korea (3 organs), and each of these organs was analyzed to focus on fields related to IT, medicine, and education.

When applications for patents on medical learning support tool technology according to the IPC classification were examined, patents on G06F, G09B, G06Q, and A61B, which concern

Table 7. Activity Index by Nation

	in Korea	in the USA	in Japan	in the EU
KR	5.0484	0.0326	0.1364	0.8768
US	0.3127	1.5176	0.1231	0.3957
JP	1.2621	1.0406	36.5167	5.5893
EP	0.3606	1.0703	0.4968	12.7755

digital data processing technology, were actively applied for. Those on G06F amounted to 104 cases, taking up 33% of the total. In particular, patents on G06F-017, which concerns digital computing or data processing equipment or methods specially adapted for specific functions amounted to 55 cases. Thus, they were analyzed to be logging the greatest number of applications. In addition, when patent activities per technological field in the major countries (KR, US, JP, EP) of patents in South Korea, United States, Japan, and Europe were examined through the AI, the degree of patent concentration was the highest domestically in all four nations.

When the results of the analysis of research trends were synthesized to improve the clinical competence of medical personnel, which is directly linked to national health, international research on e-PBL- and medical simulation-centered medical learning support tools that can support teaching and learning by using IT technology was seen to be expanding continuously. Consequently, research on KM learning support tools is urgent. Therefore, it is necessary to avoid overlapping research on basic technology through international joint research and to conduct research on remediation technology that is appropriate to KM contents.

According to the examination above, a research model based on KM contents that converges e-PBL and medical simulation technology was analyzed to be feasible, thus making it possible to consider the KM learning support tool model. Because the KM learning support tool model can be used to learn and evaluate not only KM knowledge accumulated over a long time, but also the latest research results by constructing the DB of the learning contents developed by KM schools and the research contents produced by the Korea Institute of Oriental Medicine (KIOM), its appropriateness to the clinical field is expected to increase.

Conclusions

The present study analyzed trends in research on medical learning support tools and papers published in SCI(E)-registered academic journals, as well as related patents, to present a model for future KM learning support tool research. The study arrived at the following results:

First, research on medical learning support tools has continued to increase and has been active in the fields of computer engineering, education research, and surgery. In addition, as for individual nations, large numbers of papers on the field have been published in the United States, Canada, and United Kingdom in this order. Harvard University, Indiana University Bloomington, and the University of University of Illinois at Urbana-Champaign were analyzed to be actively conducting research. The keywords in these papers were analyzed to be “virtual reality,” “computer-assisted instruction,” and “medical education.”

Second, the largest number of patents on medical learning support tools were applied for in order in the United States, South Korea, and Japan. As for the United States, related patents were actively applied for around 1999, decreased in number afterwards and increased once again since 2007. In addition, when the major applicants worldwide were examined, they were in order Accenture, SNU, Wicab, and Takatoshi Yanase. As for applications for patents according to the IPC classification, patents on G06F, G09B, G06Q, and A61B were analyzed to be actively applied for. Through AI analysis, patent activities per technological field in the four major countries were seen to be the highest domestically.

Third, when the results of the analysis of research trends were analyzed comprehensively, international research on e-PBL- and medical simulations-centered medical learning support tools to improve the clinical competence of medical personnel, which is directly linked to national health, was seen to expand continuously. Therefore, research on KM learning support tools is urgent. In addition, it is necessary to avoid overlapping research on basic technology through international joint research and to conduct research on remediation technology appropriate to KM contents.

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