Artificial Intelligence in Education (AIED)

Artificial Intelligence in Education (AIED) has 3 meanings : The first is "education for understanding AI," which aims to develop the ability to understand and handle AI. The second is "education using AI," which applies AI to effective teaching and learning in each subject. The third is "AI expert training," which cultivates experts who develop AI and teachers who teach AI.

1. Introduction

Today, we live in an artificial intelligence (AI) society, in which people can easily experience AI anytime and anywhere. AI has become commonplace and ubiquitous, ranging from AI speakers to high-performance robots. It has become a key driver of transformation in almost all areas, including personalized online education systems, medical services (health care, prescription/treatment), automobiles (autonomous vehicles, transportation services), manufacturing (process optimization, smart factory), finance (investment, trading, credit evaluation), media (content, advertisement), agriculture (weather data, farm management), energy (energy management), communication (communication resource distribution), and distribution (omnichannel platform) [1] (pp. 47–80).

Humanity has long been striving to create an automated and intelligent workforce that humans can freely utilize. The "automated and intelligent workforce" created by humans evolved into "AI." This means "the engineering and science of making intelligent machines," as proposed by McCarthy at the Dartmouth Conference in 1956 [2]. The Oxford English Dictionary defines AI as "computer systems able to perform tasks that normally require human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages" [3].

The rapid development of AI technology is universalizing the application and use of "AI in education (AIED)" [4][5][6]. AI has a fundamental and far-reaching impact on education. The problem-solving knowledge transfer type of education is being converted into a creative convergence type of education. The collective-type public education, based on the industrialization era, is being transformed into personalized education based on the AI era. The purpose, content and method of education are changing all at once. Furthermore, AI is changing the paradigm of education [7].

Currently, an in-depth exploration of education in the AI era is urgently needed. Thus, the impact of AI on education needs to be identified and the ways in which AI affects education needs to be closely examined. In particular, as the number of published AIED research papers increases, it is necessary and essential to systematically clarify and discuss related issues. There are several studies that explore the issues associated with the application of AI in the context of education [8][9][10][11][12]. However, these studies approach bibliometrics analysis from a partial perspective, such as higher education [8] and special education [9]. Thus, there is still a lack of systematic research to comprehensively grasp the research trends of AIED in the context of training as a whole.

2. Background

The key to identifying the impact of AI on education lies in a system that can use AI for education, that is, artificial intelligence in education (AIED). Holmes, Bialik, and Fadel [4], among others, have generally divided AIED into the following three parts [13].

The first is the use of an intelligent tutoring system (ITS), which determines the optimal step-by-step learning path for a well-defined domain of "structured knowledge," such as mathematics or physics. ITS can be divided into domain models, pedagogical models, and learner models, according to the nature of the knowledge. The domain model addresses content knowledge for learning, the pedagogical model addresses pedagogical knowledge for teaching, and the learner model

addresses the students' knowledge. ITS utilize these three models to develop a system, provide customized activities, collect learners' activity data, analyze the collected data, and update the model itself [4]. Representative AIEDs using ITS include MATHia at the Carnegie Mellon University [14].

The second is the use of a "Dialogue-based Tutoring System (DBTS)," which engages students in the dialog of learning by utilizing advanced natural language processing and natural language generation technology. Autotutor, developed by the University of Memphis, is an example of a DBTS using the principle of the Socratic dialog method [15]. That is, when a learner responds to a question or problem in writing or verbally, Autotutor recognizes the answer, determines the learner's level of understanding, and provides feedback to help the learner understand the answer by correcting misconceptions [16]. In other words, a DBTS can be said to be a precise addition of the collection and analysis functions of learner responses to an ITS.

The third is the use of an exploratory learning environment (ELE). Exploratory learning environments provide automated feedback to correct learners' erroneous learning outcomes by applying a constructive approach. That is, learners are encouraged to actively construct knowledge on their own by exploring and manipulating elements of the learning environment rather than following a set step-by-step sequence. Exploratory learning environments are atypical and open learning environments, in which learners can explore as they wish [17][18]. Programs, such as "Fractions Lab" [19] and "Betty's Brain" [20], are representative examples.

With the explosive growth of AI technology, there is a shortage of talented people with the ability to continuously develop and research AI technology and those who can train them professionally. Countries around the world are adopting various policies to secure talent in the AI field, as they are in fierce competition [21][22]. Furthermore, there is a shortage of teachers who can teach AI curricula.

"AI expert training education" is broadly divided into a system that trains experts who develop AI and a system that cultivates teachers who will teach AI. AI model development requires knowledge of computer structures, programming languages, and various development tools, as well as knowledge about statistics, linear algebra, and differential equations. There is a limited number of talented people with this specialist knowledge. Countries around the world have established AI departments and are accelerating the training of AI experts in master's and doctoral programs [21][22]. In addition, they are expanding interest in training teachers who can teach AI from an educational perspective, such as AI literacy for K-12 courses [21][22].

For example, South Korea announced the "National Strategy of AI" in 2019 and a plan to foster high-level human resources at the master's and doctoral levels, such as creating or expanding AI-related departments in the undergraduate programs of universities and establishing AI graduate schools to foster AI experts [23]. Moreover, to strengthen the AI capabilities of teachers, it stated that it will cultivate 10,000 incumbent teachers as AI instructors by providing customized AI training for each school level and acquiring the latest technology trends by 2021. Furthermore, it stated that retraining to strengthen AI convergence education competency will be carried out for 5000 incumbent instructors of 38 graduate schools of education by 2025 [23].

3. Prospect

No field is immune from an AI shock. The field of education, which drives human social life by developing intelligence and utilizing intelligence, is directly affected by AI. This is because the educational effect can be multiplied by using AI in teaching and learning processes. Currently, AIED has become a constant rather than a variable. Based on the results confirmed in this study, the future direction of education is explored, while summarizing the impact of AI on education.

Firstly, research on AIED is increasing in quantity, but more research is still needed [4]. Papers on AIED have been increasing since 2001. Research papers have been increasing exponentially since 2015, as papers published after 2019 accounted for 37% (1872) of the total. This indicates that AIED has been an active research field since 2015. Education is a broad field that has economic, social, and cultural impacts. Various studies that redesign the paradigm of education from the purpose of education to contents and methods, based on AI, are urgently needed. Research on AIED needs to be further accelerated, such that AI-based education can be established early.

Next, international collaboration should be encouraged for research on AIED. The average collaboration rate of the top 40 countries with high international collaboration rates was 34%. Although the United States plays a central role in international collaboration, the proportion of collaborative papers was not high, at 18.83%. Meanwhile, Canada played an important role in international collaboration in the AIED field, as both the number of joint papers and the ratio of joint papers were high. Examining AIED from the perspective of international joint research and collaborative research beyond

the national level is more desirable. The Organization for Economic Co-operation and Development highlighted the importance of international collaboration by providing "National AI Policies & Strategies," an online platform for establishing and sharing AI public policies [24]. AI is a global issue. This is because AI needs to be viewed from the perspective of humankind to open the door to a sustainable future.

Moreover, research topics related to AIED should be more diverse. Topics emphasizing AI, such as Topic 6 (AI-driven edu-tech) and Topic 8 (machine learning algorithm), emerged and were confirmed to be hot topics, but specific areas of AIED were not highlighted. Of course, traditional fields of education, such as "content of teaching and learning" and "assessment and evaluation," cannot be disregarded. However, efforts are needed to redesign the educational paradigm from the perspective of AIED. For example, by classifying the learner types of AIED in consideration of the stages and characteristics of education, such as early childhood education, elementary and secondary education, higher education, and lifelong education, customized education, should be carried out. Learning areas, such as mathematics, science, language learning, and music, will need to be restructured based on AI. There is a need to expand research on AIED in fields directly related to AI, such as statistics, mathematics, computational physics, computers, semiconductor design, and neurophysiology. In addition, in terms of the learning method, exploratory learning using AI, writing analysis, mentoring, and learning analysis, should be expanded. Specifically, fields that understand AI, such as AI literacy and AI ethics, and fields that use AI educationally, such as ITS, DBTS, and ELE, along with research on education for fostering AI experts, should be more active areas.

Finally, in-depth research that directly applies AI algorithms and technologies to education should be further promoted. The keywords "artificial intelligence," "machine learning," and "deep learning" rarely appear in the keywords and topics presented in this study. Artificial intelligence-essential words, such as "supervised learning," "unsupervised learning," "reinforcement learning," "chatbots," "artificial neural networks," "virtual reality," and "augmented reality", are not often observed in AIED. This implies that AI algorithms and technologies have not yet been fully utilized in the AIED. For the development of AIED, education-based AI research that examines AI from an educational perspective, beyond simply using AI application services, should be strengthened. This is because we have entered an era in which education without AI cannot exist.

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