Guest Editorial: Precision Education - A New Challenge for AI in Education

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ABSTRACT: As addressed by Stephen Yang in his ICCE 2019 keynote speech (Yang, 2019), precision education is a new challenge when applying artificial intelligence (AI), machine learning, and learning analytics to improve teaching quality and learning performance. The goal of precision education is to identify at-risk students as early as possible and provide timely intervention on the basis of teaching and learning experiences (Lu et al., 2018). Drawing from this main theme of precision education, this special issue advocates an in-depth dialogue between cold technology and warm humanity, in turn offering greater understanding of precision education. For this special issue, thirteen research papers that specialize in precision education, AI, machine learning, and learning analytics to engage in an in-depth research experiences concerning various applications, methods, pedagogical models, and environments were exchanged to achieve better understanding of the application of AI in education.

Keywords: Precision education, Artificial intelligence, Learning analytics, Human-centered AI

1. Introduction: New challenges for AI in education

This special issue concerns the use of artificial intelligence (AI) by focusing on new design methods and tools that can be evaluated and leveraged to advance AI research and educational policies and practices for improving teaching and learning. New technology brings new challenges for the application of AI in education. In addition to technology-oriented intelligent tutoring system and robotics, researchers have now begun paying more attention to education-oriented pedagogy, cognition, and humanity (Luan et al., 2020). With the advancement of deep learning and transfer learning, AI research in education is encountering new challenges in terms of reshaping the research trend from general-purpose intelligence to transfer of intelligence, from computation to cognition, from customization to adaptation, from known to unknown, from technology to humanity, and from the one-size-fits-all approach to precision (Yang, 2019). Researchers who used to focus on cultivating common sense through measures such as utilizing knowledge application for general-purpose intelligence are now moving toward transferring intelligence, which is the transfer of trained knowledge from one domain to another. In particular, the advancement of natural language processing (NLP) has enabled the application of pre-trained knowledge to fine-tune domain. In addition to outperforming in terms of computation ability, AI is now moving toward human-perceived areas, such as perception, emotion, psychology, and cognition, which require cognitive thinking. AI algorithms have progressed from being customized beforehand for use on different people to being adapted to fit individual needs in real time. AI algorithms not only perform reasoning to search for insights but also can uncover the unknown about the unknown, such as hidden values and unknown results. AI can improve human productivity through technology, in addition to promoting human intelligence through machine intelligence. From being used to provide one-size-fits-all type of solutions, AI can now offer a one-of-a-kind precise solution for each individual. To address the challenges faced, the focus of AI research is shifting from technology-oriented focus on increasing production and performance to humanity-oriented focus on augmenting human intelligence with machine intelligence.

2. Precision education: Research goal, topics, and implementation

Precision education was inspired by the precision medicine initiative proposed by the former US President Obama in his 2015 State of the Union address. The emergence of precision medicine revolutionized the one-size-fits-all approach to the treatment of diseases by considering individual differences in people's genes, environments, and lifestyles and by improving the diagnosis, prediction, treatment, and prevention of diseases. Similar to the medicine field, the design of the current education system does not fully consider students' IQ, learning styles, learning environments, and learning strategies. Inspired by precision medicine, precision education is an innovative approach that emphasizes the improvement of diagnosis, prediction, and treatment and focuses on preventing at-risk students. In general, at-risk students refer to students who are predicted to show low academic performance or drop/withdraw from a course, or students who demonstrate low engagement in terms of learning behavior, emotion, and cognition.

The research goal of precision education is to identify at-risk students as early as possible and provide them with timely intervention through diagnosis, prediction, treatment, and prevention. The research steps of precision education include conducting a diagnosis of students' engagement, learning patterns, and behavior and making predictions concerning students' learning performance and improving predictive models, followed by devising treatment and prevention plans through timely intervention from teachers, learning strategies, and activities. The research topics of precision education can be categorized into governance and policy and technology and practice. Important topics such as ethics, norms, rules, and other concerns related to precision education fall under governance and policy. The effect of precision education on emerging pedagogical environments, such as MOOCs (massive open online courses), e-books, coding, AR/VR, robotics, and games, warrant exploration, in addition to examining critical factors that influence students' learning performance under the governance of precision education. Furthermore, the influence of teachers' intervention on students' learning performance after the governance of precision education merits investigation. The important topics that fall under technology and practice include the design of pedagogical models and tools, learning strategies and learning activities, and evaluation and assessment methods. Data analytics concerning precision education, including text, audio, image, and video analytics, and data visualization for precision education, including dashboard and simulation, also merit investigation.

Precision education can be implemented by applying AI and learning analytics to identify at-risk students and by providing timely intervention to improve teaching quality and the learning outcomes of students. To improve teaching quality, teachers need to identify students' issues of concern and provide feedback. Identification of areas or topics in which students are struggling is critical for the governance of precision education. These measures can enable teachers to achieve better understanding of how their content is being used and how effective it is, thereby facilitating continual enhancement. For optimal learning outcomes, the educational content needs to be tailored to students' level of understanding and students' performance needs to be monitored so that teachers can accordingly modify their teaching to meet students' needs. To take charge of their own learning, students should be enabled to become aware of their performance in comparison with their peers and continually assess whether they are keeping up with the group. Moreover, students should be trained to identify gaps in their prerequisite knowledge and key study skills in which they are lacking. These measures will facilitate the development of students' skills and knowledge in a more personalized and self-paced manner. Students should be provided with an assessment of their progress and information on measures they should adopt to meet their educational goals. Obtaining students' consent for data collection and use will ensure their privacy.

Precision education can be further improved through smart evaluation. The diagnosis and smart evaluation of students' learning activities can be achieved through pre-class preview, reflection, oral reports, and assignments, teaching of special topics, and essay writing and by introducing the examination mechanism into the smart evaluation system. Non-objective factors such as subjectivity, knowledge category, and personal preference hinder manual evaluation. Therefore, the provision of automatic evaluation, question scoring, and feedback can improve the non-subjective factors concerning manual evaluation. The generation and adoption of new deep learning algorithms in the past few years have facilitated the application of deep learning in natural language processing (Transformer, BERT, and GPT3) and has been shown to be more effective than the previous generation of deep learning (CNN, RNN, and LSTM) and traditional machine learning algorithms (LR, SVM, and RF). These new algorithms can achieve performance that is closer to human behavior. To conduct smart evaluation, teachers provide textbooks (textbooks and slides), and the system employs natural language processing technology for text summarization and interception of key concepts in the text content (textbook). Furthermore, the system automatically generates test questions and reference answers (automatic question generation) from the passage in which the key concepts are located. The test questions generated can be multiple-choice, yes/no, fill-in-the-blanks, short-answer, or essay-type questions. If students provide written answers, the system can automatically compare their answers with the reference answer and provide a score (short-answer grading) by using deep learning technology and feedback. A smart evaluation system uses AI's deep learning technology, which offers accuracy that is closer to manual evaluation than that obtained through traditional machine learning methods. In summary, learning strategies and the design of learning activities and evaluation methods directly influence learning behavior and effectiveness. Therefore, they are critical key factors that strengthen learning analysis and improve both teaching effectiveness and students' learning effectiveness.

3. Contribution of papers to this special issue

Thirteen papers have been included in this special issue that can be classified into five categories. The papers include systematic overviews and literature reviews concerning precision education, framework and practice of precision education, diagnosis of behavior patterns through the application of precision education, identification

of key concepts and quality ideas considering precision education, and prediction and factor analysis regarding precision education.

Three papers address systematic overviews and literature reviews concerning precision education, paper authored by Dirk Tempelaar, Bart Rienties and Quan Nguyen, entitled "The Contribution of Dispositional Learning Analytics to Precision Education"; paper authored by Xieling Chen, Di Zou, Haoran Xie, and Gary Cheng, entitled "Twenty years of personalized language learning: topic modelling and knowledge mapping"; and paper authored by Hui Luan and Chin-Chung Tsai, entitled "A review of using machine learning approaches for precision education"

Three papers address framework and practice of precision education, paper authored by Fuzheng Zhao, Gwo-Jen Hwang, and Chengjiu Yin, entitled "A Result Confirmation-based Learning Behavior Analysis Framework For Exploring The Hidden Reasons Behind Patterns and Strategies"; paper authored by Jiun-Yu Wu, Christopher C.Y. Yang, Chen-Hsuan Liao, and Mei-Wen Nian, entitled "Learning Analytics 2.0 for Precision Education: An Integrative Theoretical Framework of the Human and Machine Symbiotic Learning"; and paper authored by Tzu-Chi Yang, Yih-Lan Liu, and Li-Chun Wang, entitled "Using an institutional research perspective to predict undergraduate students' career decisions in the practice of precision education."

Three papers address the diagnosis of behavior patterns through the application of precision education, paper authored by Christopher C.Y. Yang, Irene Y.L. Chen and Hiroaki Ogata, entitled "Toward Precision Education: Educational Data Mining and Learning Analytics for Identifying Students' Learning Patterns with Ebook Systems"; paper authored by Xuanqi Feng and Masanori Yamada, entitled "An Analytical Approach for Detecting and Explaining the Learning Path Patterns of an Informal Learning Game"; and paper authored by Mehmet Kokoç, Gökhan Akçapinar, and Mohammad Nehal Hasnine, entitled "Unfolding Students' Online Assignment Submission Behavioral Patterns using Temporal Learning Analytics."

Two papers address the identification of key concepts and quality ideas considering precision education, paper authored by Albert C.M. Yang, Irene Y.L. Chen, Brendan Flanagan, and Hiroaki Ogata, entitled "From Human-grading to Machine-grading: Automatic Diagnosis of e-Book Highlighting in Precision Education", and paper authored by Alwyn Vwen Yen Lee, entitled "Determining Quality and Distribution of Ideas in Online Classroom Talk using Learning Analytics and Machine Learning."

Two papers address the prediction and factor analysis regarding precision education, paper authored by Hui-Chen Lin, Yun-Fang Tu, Gwo-Jen Hwang and Hsin Huang, entitled "From Precision Education to Precision Medicine: Factors Affecting Medical Staff's Intention to Learn to Use AI Applications in Hospitals", and paper authored by Feifei Han and Robert A. Ellis, entitled "Predicting Students' Academic Performance by Their Online Learning Patterns in a Blended Course: To What Extent Is a Theory-driven Approach and a Data-driven Approach Consistent?"

4. Conclusion and future research: Human-centered AI in education

As addressed in the introduction, taking humans into consideration is a challenge for AI; therefore, the application of AI in education should be human centered. Human-centered AI can be interpreted from two perspectives: AI under the control of humans (Shneiderman, 2020) and AI concerning the human condition (Stanford HAI, 2020). Considering the perspective of human-controlled AI, AI can be distinguished according to the degree of human control involved. One level concerns complete control by humans, with AI only assisting automation, and the other level concerns human autonomy that is completely determined by AI. Human-controlled AI leverages the collaboration between human control and AI automation to boost human productivity with offering a high level of reliability, safety, and trust (Shneiderman, 2020). From the point of view of AI concerning the human condition, AI algorithms have to take humanity as the main consideration, perform explainable and interpretable computation and judgement processes, and continuously adjust AI algorithms by considering the human context and societal phenomena to augment human intelligence with machine intelligence, thereby contributing to the welfare of humankind.

Research on human-centered AI advocates an in-depth dialogue between researchers from diversity of thought, genders, ethnicity, cultures, and disciplines to facilitate better understanding of human-centered AI. Beneficial interactions between researchers can promote the adoption of human-centered AI in education by augmenting human intelligence with machine intelligence. For human-centered AI, research topics concern governance and policy, including biases in AI algorithms, use and misuse of AI, the societal impact of AI, AI in governance, AI

governance, AI risk management, AI accountability, and AI self-surveillance. The research topics related to technology and practice include explainable AI, interpretable machine learning, flexibility and contextual understanding by humans, explanation and comprehension by humans, intelligent agents (assistants), automated conversational robots (Chabot), AI-enabled personalization, intelligent tutoring systems, student and teacher modeling for smart learning and teaching, smart content, learning pathway and recommendations, differentiated and individualized learning, intelligent assessment and evaluations, automated question generation, automated grading, and plagiarism detection.

AI has the potential to educate, train, and increase human performance, in turn making humans better at their tasks and activities. Proper application of AI can enable human welfare through various means, such as by improving the productivity of food, health, water, education, and energy services. However, misuse of AI because of algorithm bias and lack of governance could inhibit human rights and result in inequality pertaining to job opportunities, gender, and race (Vinuesa et al., 2020). AI may be able to imitate human emotions; however, imitating human feelings is difficult for AI. Human emotions are triggered by hormonal changes produced because of physiological and chemical changes, and feelings are an internal cognitive sensation. The ability to self-reflect and judge in face of psychological conflicts and contradictions, that is, inner cognition, drives humans to execute a series of reflective cycles through learning, unlearn, and relearn. Human beings are not perfect, and only inner beauty holds substance. Human beings should accept that their present selves are the best version of themselves and adjust emotionally to see the invisible mind through the visible world. Such a perception will allow humans to engage with the beauty of the mind.

Acknowledgement

The guest-editor would like to express sincere thankfulness to Prof. Nian-Shing Chen of National Yunlin University of Science and Technology, Taiwan, and Prof. Maiga Chang of Athabasca University, Canada, for their inspiring advices to this special issue. Given the high volume of submissions, this special issue runs with an acceptance rate lower than 20%, only a few papers that most related to “Precision education” are included. We truly appreciate all the authors and reviewers for their valuable contribution and support towards the success of this Special Issue and ET&S.

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