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Artificial intelligence and deep learning in educational technology research and practice

Introduction

In recent years, advanced technologies have transformed various business sectors and have also brought opportunities for pedagogical reforms (Cheng, Li, Sun, & Huang, 2016; Dessi, Fenu, Marras, & Recupero, 2019). Artificial Intelligence (AI) is one of the most influential of these advanced technologies and has been widely applied in online education. The AI market size is expected to reach $390.9 billion by 2025 (Grand View Research, 2019) through a wide array of applications including natural language processing, intelligent decision making and robotic automation. As a branch of AI, deep learning techniques have also achieved tremendous success in various areas (Rizvi, Rienties, & Khoja, 2019; Waheed *et al*., 2020) including personalized recommendation, computer vision, linguistics and bioinformatics. As COVID-19 has compelled schools to close, the outbreak of COVID-19 dramatically increased the usage of online learning applications embedded with AI and deep learning algorithms to support remote learning (Wang, 2020).

The flourish of AI and deep learning techniques offers a foundation for reform in the educational sectors. The implementation of AI and deep learning techniques in the education sector is now changing the industry and has the potential to radically transform the state-of-art of education. AI-enabled digital learning applications change where students learn, who teaches them and how they acquire basic skills. For example, AI tutors could offer additional targeted assistance to students in need (Cukurova, Kent & Luckin, 2019; Kulik & Fletcher, 2016), regardless of family background, geographical location and gender. Automatic recognition has been used in affect detection to model and understand the affective needs of students (Grawemeyer *et al*., 2017). Deep learning and related algorithms could provide intelligent question answering through natural language processing (Ansari, Maknojia & Shaikh, 2016).

Summary of papers in this special section

Based on the increasing intersection between AI and educational technology, we assembled this special section of the British Journal of Educational Technology, with a view to understand the state of the art and future research directions related to AI and digital education. This special section brings together educational technology studies focusing on the design and applications of AI-enabled artifacts on learning processes and learning outcomes at all age groups. The eight papers include contributions from multidisciplinary researchers worldwide. The involved research methods include survey, interview, experiment and machine/deep learning techniques, among others.

The first three papers are empirical investigations that delve into users' perceptions on AI-enabled online learning applications. The first paper by Wang, Yu, Hu and Li (in this issue) explored faculties' intention to use an intelligent tutoring system through survey investigation. The role of relative advantage, compatibility, experience and perceived trust on use intention have been empirically validated. In the second paper, Fu, Gu and Yang (in this issue) investigated the affordances of AI-enabled automatic scoring applications through interviews, and test the role of the identified affordances on learners' continuous learning intention using questionnaire data. The differences between in-job learners and student learners using automatic scoring applications were compared. The third paper, Qin, Li and Yan (in this issue) examined technology, context

and individual-related factors that influence learners' trust in AI-enabled learning environment. Netnography and interviews were conducted to identify the factors inducing trust.

The second set of papers center on algorithm design to facilitate personalized recommendations to potential learners in digital learning platforms. By leveraging individuals' personality information into a basic matrix factorization model, the fourth paper by Sun, Geng, Cheng, Zhu, Xu and Liu (in this issue) presented models for community recommendation in e-learning platforms. The proposed models were validated for their recommendation performance. Based on deep learning methods, the fifth paper by Xu and Zhou (in this issue) designed a course recommendation frame-work that extracts multimodal course features in the context of course video recommendation, with the aim to facilitate personalized recommendations to potential learners.

The last three papers center on promoting learning performance by conducting emotional and cognitive assessments on learners in digital learning practices. Based on multimodal sensor data and machine learning, the sixth paper by Standen *et al*. (in this issue) propose a multimodal affect recognition approach for learners with intellectual disabilities while using AI tools for education. Based on natural language processing and speech data mining, the seventh paper by Moon, Ke and Sokolikj (in this issue) designed and implemented an automatic assessment to track the cognitive and emotional states of adolescents with autism spectrum disorder in VR-based flexibility training. The last paper by Geng, Niu, Feng and Huang (in this issue) explored students' discourse behaviors and sentiment through the investigation of reviews on massive open online courses. Machine learning techniques, SC-LIWC-based approach and statistical analysis were adopted for their study.

Conclusions and future research directions

To sum up, the eight papers in this BJET special section present either empirical investigations on AI-enabled learning applications or AI techniques-driven learning algorithm designs and recommendation studies. The research findings contribute to the current studies on digital education in general (Cheng *et al*., 2016), and AI applications and algorithms in the realm of educational technology in particular (Cruz-Benito, Sánchez-Prieto, Therón, & García-Peñalvo, 2019; Li, Kizilcec, Bailenson, & Ju, 2016; Mavrikis, 2010). The published papers in this special section could provide clues for digital learning tool designers and operators to further develop their strategies to provide personalized learning materials and intelligent learning support to online learners. Interdisciplinary theories and methods adopted in the special section could contribute to the better understanding of the online learning phenomenon and inspire innovative solutions to the problems that exist in the intersections of AI and educational technology.

This special section has also inspired future research directions in need of further investigation:

1. The current research has widely investigated the antecedents and consequences of users' (including learners and lectures) usage intention on the AI-enabled digital learning tools (Hu and Li, in this issue; Fu, Gu and Yang, in this issue), however, the perspectives are scattered. With this backdrop, we encourage researchers to conduct comprehensive studies on possible extensions to the existing models that incorporate multifaceted factors related to the usage intention of AI-enabled learning applications.
2. Since the successful deployment of AI algorithms requires the collection of users' historical record, privacy and security issues might be a cause that arouses online learners' concerns. Ethical exploration on the AI algorithms is a necessary research direction to study for future research (Martin, 2019) in digital education discipline.

3. Due to the nontransparency feature of machine, individuals are aware of being dominated by artificial intelligence algorithms. Existing studies touch a bit on the interpretable, account-ability and fairness of algorithms in online education (Conati, Porayska-Pomsta, & Mavrikis, 2018; Porayska-Pomsta & Rajendran, 2019; Selbst, Boyd, Friedler, Venkatasubramanian, & Vertesi, 2019), but there is limited in-depth investigations on this arena. For example, users' trust on algorithm designers is scarcely investigated but is important for the understanding of the overall landscape.
4. Human-robot collaboration (Seeber *et al*., 2020) facilitates the improvement of learning performance and personalized learning material recommendation, the inconsistencies between AI tutors and human lectures may also arouse conflicts. In view of this, the interactive learning behavior between AI algorithms and human beings should also be an important future research direction.

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