Chapter 1
Current Trends in AI-Based Educational Processes—An Overview

Mirjana Ivanović, Aleksandra Klašnja-Milićević, Marcin Paprzycki, Maria Ganzha, Costin Bădică, Amelia Bădică, and Lakhmi C. Jain

Abstract Artificial intelligence (AI) is a rapidly developing research area, with immense influence on different areas of modern society and with numerous applications in real-life systems and environments. In this chapter we provide a brief overview of current state-of-the-art of developing intelligent educational systems. Particular attention is paid on the application of artificial intelligence methods in teaching and learning processes. Accordingly, we consider recent works that put light on different roles of AI in developing educational systems. Also, an overview of key educational domains that AI techniques influence, i.e.: adaptive personalization systems and intelligent tutoring systems, assessment and evaluation of students' outcomes and learning performances, and benefits and challenges of educational data mining and learning analytics in educational processes is presented.

Keywords Artificial intelligence in education · Personalized tutoring systems · Assessment and evaluation of students' knowledge · Educational data mining · Learning analytics

M. Ivanović (✉) · A. Klašnja-Milićević
Faculty of Sciences, University of Novi Sad, Novi Sad, Serbia
e-mail: mira@dmi.uns.ac.rs

A. Klašnja-Milićević
e-mail: akm@dmi.uns.ac.rs

M. Paprzycki · M. Ganzha
Polish Academy of Sciences, Warszawa, Poland
e-mail: paprzyck@ibspan.waw.pl

M. Ganzha
e-mail: maria.ganzha@ibspan.waw.pl

C. Bădică · A. Bădică
University of Craiova, Craiova, Romania
e-mail: costin.badica@edu.ucv.ro

L. C. Jain
KES International, PO Box 243, Selby YO8 1DS, UK

M. Ivanović et al. (eds.), *Handbook on Intelligent Techniques in the Educational Process*,
Learning and Analytics in Intelligent Systems 29,
https://doi.org/10.1007/978-3-031-04662-9_1

1.1 Introduction

Artificial Intelligence (AI) is recently becoming one of most rapidly evolving research areas, with numerous applications in different academic and industrial domains. Moreover, it is also present in a number of everyday activities of modern digital society. Among numerous application domain uses of AI techniques and methods, one of more appealing is its potential in education. Here, AI can be found in adaptive learning technologies, educational data mining (EDM) and learning analytics (LA), where contemporary and emerging AI-based approaches significantly influence (and support) educational processes and activities.

During the several decades long history of AI, diverse approaches to develop intelligent systems [1, 2] can be distinguished. A key driver of AI research in the 1950s was the focus on symbolic computation. Optimistic expectations were that simulation and programming of the generic logic of human reasoning will produce the systems that would behave "human intelligently". However, the main characteristic of such systems was the absence of domain-specific knowledge. Representational AI was founded in 1980s, and became known as "good-old-fashioned-AI". The essence of such approaches was in the manipulation of knowledge representations and implementation of specific class of intelligent systems, widely known as expert systems. Representational AI approach, used in educational processes, resulted in the development of so-called Intelligent Tutoring Systems (ITS) that included representations of domain knowledge and teaching material, learners' knowledge, and a pedagogic model [3]. However, most recent trend in applications of AI in educational domains is based on data-driven AI and it is oriented towards applications of educational data mining, learning analytics and use of artificial neural networks. This new, data-driven AI trend is a consequence of three key technical developments: appearance of the Internet, intensive use of smart phones in numerous activities and situations, and fast expansion of social media.

With further rapid development of Information and Communication Technology (ICT) and interrelated disciplines and technologies, educational systems offer to teachers and learners, a range of opportunities and challenges [4–6]. For example, there are several characteristic applications of AI in education.

- Important activities that are the usual component in education, like grading and assessment, can be automated by use of AI.
- Adaptation to learner's needs and learning preferences is important in education and by the use of AI it is relatively easy to point out to the learner specific topics and tasks that he/she needs to improve.
- Specially developed AI tutors can support teachers but also can offer additional support to learners and provide helpful feedback from educational process.
- AI crucially influences way of delivering education: who teaches students, where students learn, and how they acquire knowledge and skills. With constant design and development of AI-based educational systems they slowly become more and more able to offer a variety of innovative, tailored, and intelligent services to learners.

– Apart from direct support of core educational activities, AI can help in a majority of other educational activities, like AI-guided training that simplify the transition from college to high school.

However, in spite of the fact that AI has been well established area, with variety of educational applications, inclusion of such systems in day-to-day pedagogical processes is still challenging for educators [7–9]. Nevertheless, the pedagogical advantage is evident, as it can offer significant impact on educational processes and learning outcomes. In this context, this chapter will focus on providing a brief overview of current state-of-the-art of developing intelligent educational systems. We will focus on influences of AI methods and techniques and their applications in educational process, while avoiding discussion of AI support for administrative activities in educational institutions. This is because we believe that the latter does not belong to pedagogy, but to computer-supported administration, which is out of scope of current contribution.

The rest of the chapter is organized as follows. Section 1.2 presents different roles of AI in developing educational systems. An overview of several characteristic educational systems, based on AI techniques is presented in Sect. 1.3. Concluding remarks are given in the last section.

1.2 Different Roles and Applications of AI in Education

Rapid technological and ICT development facilitates changes that result in the fact that AI methods, approaches, and services are nowadays all around us, in majority of everyday activities. Education is definitively one of areas where AI can powerfully make significant changes. In the last decade we witnessed the development of a variety of tools and services that use computer intelligence to help both teachers and learners to get more out of the educational experience.

Usually, in contemporary research, AI and machine learning (ML) are often considered together as closely related approaches. In [10] ML is seen "as a subfield of artificial intelligence that includes software able to recognize patterns, make predictions, and apply newly discovered patterns to situations that were not included or covered by their initial design". Also, an important concept, used in contemporary intelligent personalized educational systems, is that of rational agents [11, 12]. Additionally, based on the current state-of-the-art in AI field it is possible to rise an ethical and philosophical question: will machines/robots/intelligent agents be able to develop consciousness and actual thinking in the future, or will they just simulate human thinking?

However, despite the fact that a lot of AI applications in educational environments already exist, some authors [8, 13] emphasized three categories of AI applications in education: (a) intelligent tutoring systems and systems that support collaborative learning, (b) personal tutors, and (c) intelligent virtual reality.

Intelligent tutoring systems (ITS) are specific systems that allow very important one-to-one personal tutoring. Based on several different components that are part of such systems, they can support: selection of suitable topic and teaching content for a particular student, or decisions about the learning path. They can also provide cognitive scaffolding. However, the drawback of such personal tutoring is a lack of collaboration and students' interaction with their peers, which is known to be an essential social part of the learning process. On the other hand, constant rapid development of different AI techniques offers new possibilities that also allows higher quality support and functionalities that such systems can considerably advance and contribute to collaborative learning as well.

Development and introduction of new AI technologies pushes their more advanced applications in educational settings. So, for example, virtual reality and augmented reality can tremendously increase quality of e-learning and guidance of students in very popular game-based learning environments. Virtual agents (i.e. chatbots), as a fast developing area, are interesting and useful facilitators of teachers and/or students' peers in virtual or remote labs [14]. According to [8], AI in education "includes everything from AI-driven, step-by-step personalized instructional and dialogue systems, through AI-supported exploratory learning, the analysis of student writing, intelligent agents in game-based environments, and student-support chatbots, to AI-facilitated student/tutor matching that puts students firmly in control of their own learning. It also includes students interacting one-to-one with computers, whole-school approaches, students using mobile phones outside the classroom, and much more besides."

Also, some other technological developments influence changes in educational processes in a slightly different way. One can take the advantage of existence of Big Data, which is collected during students' activities within e-learning environments and process and analyze it, to draw some useful conclusions about educational activities. Thus, educational data mining (EDM) and machine learning and learning analytics (LA) can provide just-in-time feedback and assessment of current student's achievement [15] but also can help them in selecting alternative learning paths that will improve their final learning outcomes. Recent applications of AI in educational environments are based on finding characteristic patterns in collected data and using them in different decision-making processes that can improve student's learning paths, improving teaching material, enhance offer of supplementary teaching material, and so on. Advantages of such applications of EDM and LA are that discovered correlations and patterns in collected data are not easily (if at all) understandable to (discoverable by) humans.

Another point of view on the use of AI in educational processes is presented in [4]. Authors considered educational AI tools from the system's/learner's/teacher's perspectives. System-facing tools provide information on the institutional level for administrators and managers. Learner-facing tools help students to learn particular subject/topic. Teacher-facing systems usually reduce tracers' workload by automating their different activities and tasks.

In the paper [16], authors showed deep systematic review of AI applications in higher education. Looking at more than 150 research papers they selected several crucial groups of systems: (1) adaptive systems and personalization, (2) intelligent

tutoring systems, (3) assessment and evaluation, and (4) profiling and prediction. Later, authors made refinement and recognized specific applications in each of these groups:

- **Adaptive systems and personalization group**: teaching course content; recommending personalized content; supporting teachers and learning design; using academic data to monitor and guide students; representation of knowledge in concept maps;
- **Intelligent tutoring systems group**: teaching course content; diagnosing strengths and automated feedback; curating learning materials; facilitating collaboration; the teacher's perspective;
- **Assessment and evaluation group**: automated grading; obtaining feedback from learning sessions and processes; evaluation of student understanding, engagement, and academic integrity; evaluation of teaching;
- **Profiling and prediction group**: admissions decisions and course scheduling; drop-out and retention; student models and academic achievement.

In this section we presented different roles of AI in developing and using modern, sophisticated, and powerful educational systems recognized by different authors. Despite the fact that various views and opinions exists, it is evident that AI methods will significantly influence the further development of high quality educational ecosystems.

1.3 Some Characteristic Educational Systems Based on AI Techniques

Existing trend of interest and investments in AI, by world leading companies and research centers, democratization of higher education but also experiences with COVID-19 pandemic situation, in the last two years, resulted in significant financial pressure and challenges to propose proper solutions and resolve numerous problems in developing future, more intelligent, educational systems.

Consequently, it is logical to try to employ powerful AI methods to find adequate high-quality solutions [17]. Rather, newly established phenomena of "massive open online courses" (MOOC) allowed an enormous number of students, all over the world, to participate in a broad range of online courses. Apart from numerous advantages of such kind of education, a variety of problems appeared, especially for teachers. Having diverse students from different countries with different ways, habits, and characteristics of learning (pre-knowledge and skills for courses, rates of progress, …) raised emergent problems, such as: providing personalized feedback, assisting students to achieve satisfactory learning outcomes, implementing reliable assessment approaches and criteria [10]. On the other hand, we witness that different research and educational institutions have been developing a range of so-called intelligent,

adaptive, or personalized educational systems for different courses [5, 7]. However, it is evident that in majority of cases, these systems are usually part of research projects, realized as proof-of-concept, and are used in real learning environments only for several years, i.e. until the projects end.

Fortunately, there are also positive cases when development and improvements of some systems are part of long lasting research and educational activities in different institutions and countries and they are used in real educational processes and during the years they are constantly evolving while becoming enhanced with additional functionalities [20–22]. Nowadays, such systems gather huge amount of learners' data, and analyze it. As a result, they can significantly impact and influence learners' and teachers' activities.

Rapid development of software, hardware, and data processing strongly influenced the new renaissance era of AI that together with EDM and LA, as well as with sentic computing (including face and emotion recognition), plays an essential role in developing a wider range of applications in sophisticated educational ecosystems. In the rest of this section, we will briefly present several groups of characteristic AI-based educational systems and their essential functionalities.

1.3.1 Adaptive Personalization Systems and Intelligent Tutoring Systems

Development of adaptive and personalized educational systems is highly influenced by learners' learning characteristics, preferences, and styles. Developmental efforts are generally oriented towards achieving the best learning curve, learning effectiveness and efficiency for individual learner. Accomplishment of these functionalities is not an easy task. It requires extra knowledge, and it forces and represents one of the key issues in realization of reliable personalized educational systems. Several examples of such systems will be briefly presented below.

As a result of a large project, the multifunctional educational system—StuDiAsE [23] had been developed. The system supports numerous functionalities based on AI methods like: Learner Diagnosis, Assistance, and Evaluation. It can monitor the comprehension of the learner based on text comprehension theory [24], and it can assess learner's pre-knowledge based on his/her profile, to obtain personalized scaffolding. Additionally, the system can evaluate learning performance and control several factors that influence the learner's motivation. Finally, interaction with the system is based on dialogue theory [25].

Among variety of AI supported educational systems, intelligent tutoring systems (ITS) are probably the most important and dominant [8]. Usually, they support step by step tutorials adjusted to learner's individual style of learning, especially when subjects are presented in the system in well-defined manner. High quality ITSs should generate guidance and adequate hints to learners but also should adjust the level of difficulty of available teaching material and subjects. Typical architecture of an ITS

includes three key AI models: domain model, pedagogical model, and learner model. Based on available data from these models, AI algorithms can support adaptation and propose individual/personalized sequences of learning activities and topics.

An interesting web-based ITS is focused on learners' cognitive styles [26]. Cognitive styles of learners in such systems influence teaching material organization and their efficiency and success of learning. Instead of using questionnaires to identify learning styles, an innovative approach is based on a multi-layer feed-forward neural network used to observe learner's browsing behavior.

A personalized intelligent web-based tutoring system is presented in [27]. Apart from support of personalization, the system includes elements of recommendations and collaborative tagging techniques that are based on pedagogical aspects of learning. Employment of collaborative tagging allows increasing of learners' motivation and their better comprehension of the learning content. Selected tag-based recommendation increases the system's capability as it offers an additional functionality to quickly identify supplementary material suitable for learner to improve his/her knowledge. Personalized recommendations in the system should be consistent with the previously acquired knowledge of the learner.

1.3.2 Assessment and Evaluation

With existing intense interest in the applications of AI in education [2, 28], there is also a significant interest in the applications for educational assessment. Recent developments in AI-based educational assessment are increasingly focused on means of improving assessment efficacy and validity. To achieve appropriate results, the primary activity is the analysis of the large volumes of process data, collected from assessment contexts.

In general, AI-based educational tools devoted to learning and teaching usually support some kind of assessment or evaluation of students' knowledge acquisition [29]. However, in the majority of such tools, the pedagogy underlying the educational action is not considered. In this overview paper, different systems based on AI are briefly presented and some characteristic ones are mentioned in the rest of this section. Janpla and Piriyasurawong [30] develop an AI-based software to produce e-learning tests by selecting questions for online examinations. Already mentioned Samarakou et al. [31], proposed StuDiAsE system, which is focused on continuous monitoring and assessment and also includes different aspects of assessment of students' gained knowledge. Applied AI approach proved useful to support personalized feedback and to evaluate performance of engineering students.

An adaptive learning system with self-assessment that also targets students with disabilities, is presented in [32]: "In the next future, we can expect that, within adaptive e-learning systems, both automatic and manual procedures will interoperate to elicit users' interaction needs for ensuring accessibility". Presented "results indicate that the procedure allows students, both disabled and non-disabled, to self-assess and report adequately their preferences to access electronic learning materials".

Completely different approach can be found in [33], where authors focused on simulation-based training in medicine supported by AI. A Virtual Operative Assistant has been developed to provide automatic feedback to students using metrics of performance. In this system, virtual reality and AI were integrated in order to classify students according to their proficiency performance and to support them with adequate feedback to help them to improve their knowledge and skills.

Another system that combines VR and AI, to achieve the assessment of competence in different dental tasks is presented in [34]. Automatically assessing and grading medical students' collection of patient information is presented in [35]. Further, in the paper [36], authors proposed automatic assessment of different kinds of collaboration-based activities built on active learning methods. In the system presented in [37], students automatically receive grades and have possibility to visualize their results as an adequate feedback. The system was used within an AI-based course for teaching AI. Use of intelligent grading systems is frequent used in teaching programming and evaluating students' performance. For instance, automatic assignment of a grade for the task a student performed in programming is described in [7].

An example of different directions in using AI for students' assessment is the ability to automatically evaluate students' essays in English. Liu et al. [13] proposed an AI-based system able to evaluate students' engineering essays in English. Another AI system for formative assessment performs an automatic grading of learners to give feedback and to adapt the specified tasks accordingly.

Effects of the use of e-assessment can also negatively influence students' knowledge evaluation, as reported in [38]. To minimize negative effects, a lot of innovative e-learning platforms have been developed, with range of possible tasks and functionalities, starting from different types of questions but also solving relatively complex programming tasks. Nowadays, some available e- learning platforms support multimodal presentation of teaching materials and collecting students' responses: in-video quizzes or, for example, in [39] authors used specially developed system for "easy authoring, recording, and reviewing interactive multimedia exercises embedded in lecture videos". Students' can make audio/video recordings of their responses and teachers can immediately review these responses.

It is clear that technology enhanced systems based on AI can make learning and assessment more attractive and productive. Very interesting system is presented in [40]. It is a distributed event collection and analysis architecture that enables students to solve practical programming questions during lectures. Students' interactions with the system generate a lot of information about specific tasks/questions. The results of processing of information are visually presented to the teacher during the class. Hence, the teacher can properly react and change style and dynamics of teaching. In this platform the social dimension of teaching and students' results is not considered. Summary of group results of all students for particular question are important, as students can personally assess their position and learning performance comparing to their classmates. Such approach, realized in privacy-preserving way, is offered by MasteryGrids OSSM (Open Social Student Modeling) interface [41]. Personal performances and progress of a student are compared and visually presented with

the progress of the class. So, students can see their position within the class and can try more tasks and questions in order to achieve better results.

1.3.3 Intelligent Interfaces in Educational Systems

Human–Computer interfaces (HCI) play important role in communication between user and computer/software application. Through the history of development of ICT technologies, computer hardware and software, wide range of different HCI techniques have been developed. The recent trend is a consequence of rapid development of different forms of personal digital assistants. One of the very popular AI approaches that supports educational processes is using a chatbot [42]. Typical example of such assistant, usually mentioned in the literature, is Apple's Siri [43, 13]. Siri uses advantages of ML and natural speech to answer questions, to return relevant search information, and perform appropriate actions or some other activities. Despite the fact that Siri has a rather simple voice-controlled interface, this project has significant effects on further development of nowadays more complex solutions.

Intelligent software agents and numerous forms of their visualization represent a keystone in the new era of HCI in different areas including educational systems. Various educational systems usually contain a component that facilitate HCI. Modern HCIs enabled communication between the system and user (student and teacher) in more user-friendly and higher in quality. Teacherbots, strongly based on AI methods and techniques for personalized education, provide tailored teaching material, guidance, help, and hints during learning. They also can be seen in another role i.e., as teachers' assistants in organizing teaching material and in providing fast reactions/answers to student's questions.

Another characteristic example is "Jill Watson" (teacherbot based on IBM's Watson platform [44, 15]). It represents affordable, personalized, and intelligent solution for traditional user interfaces, where learners are usually passive consumers of presented teaching material.

While delivering a massive open online course, Georgia Institute of Technology, having a great number of students would like to provide high-quality learning and tailored assistance to them. Without personalized assistance students drop out rate was increasing so they attempted to find a solution to provide personal attention and decided to incorporate in their courses a virtual teaching assistant who will try to reply to a variety of predictable students' questions. To fulfill this task Jill was trained on a comprehensive database containing the students' questions.

In educational field most studies that consider chatbots are focused on individual users. However, another important pedagogical aspect of teaching is students' collaboration and teamwork. To address the collaborative group settings some authors considered alternative approaches [5]. The focus is shifted on how chatbot-mediated learning can improve learning outcomes of students in team-based assignments. For example, David et al. [5] used chatbots to support the teacher, as teaching assistants, in group settings for classroom orchestration improvement. In the paper [9], author

presented effects of use of chatbots to facilitate team-based projects. The important conclusion drawn is that chatbots can improve learning performance and a higher quality of collaboration through teamwork. Also, some quality indicators of educational chatbots are proposed which are based on intense research, and they pointed some important aspects such as Pedagogy, Reliability, Usability, and Interactivity.

1.3.4 EDM and LA: The Benefits and the Challenges in Educational Processes

Emergent development and applications of ML techniques opens a new era, and brings many possibilities and challenges for higher education. Educational data mining and learning analytics definitively offer immense benefits and advancements in developing intelligent educational settings.

Siemens and Gasevic [45] defined Learning Analytics (LA) as "the measurement, collection, analysis and reporting of data about learners and their contexts for the purposes of understanding and optimizing learning and the environments in which it occurs".

Recent research in educational LA is focused on finding an answer for very complex and important questions: what knowledge and skills did student gain (is gaining) and whether and how deeply a student was (is) engaged in the learning process. New methods, approaches and techniques should help in predicting student's learning outcomes in e-learning environments. LA based on educational data analysis can help teachers, and a range of educational experts to look for students' online information connected to the learning processes. The goal of LA in online educational settings and computer-supported instruction is to improve the learning experience and the whole learning process.

Apart from analyzing educational data related to teachers and learners, LA methods are used to discover characteristic patterns of learning behavior, in order to improve learning performance and quality. Additionally, interpretation of obtained results and gaining new understandings can offer the educational stakeholders' new insights to support their decisions and actions directed towards improvements in teaching, learning, and organizational effectiveness [10].

From the point of view of teaching and learning effects, LA helps monitoring and predicting student's academic performance. It provides opportunity to immediately identify topics in which students might be facing problems and accordingly, to facilitate immediate reactions and interventions that can help preventing poor learning performance [46].

El Alfy et al. [6] analyzed large number of recent papers and pointed out to the potential benefits and challenges that LA can provide for different educational stakeholders. Based on their analysis, numerous benefits and challenges are presented. Identified challenges and benefits of LA are separated into two groups: Management related and Teaching and learning related.

Management related challenges are enlisted in [6]: Lack of staff and technology available to learning analytics projects; Need for custom-made analytics initiatives that is context specific requiring human and structural capacity building; Learning analytics frameworks need to be sensitive to idiosyncrasies of the educational institution and its stakeholders; and Need to foster organizational adoption & cultural change.

Teaching and learning related challenges are enlisted in [6]: Limitation of results of learning analytics is derived from values of aggregate data such as marks in summative assessments.

Management related benefits are enlisted in [6]: Data mining supports decision makers in HEIs to frame norms to improve student enrolment; Learning analytics is highly responsive to real-time learning processes; Learning analytics capability to link library services with institutional objectives and outcomes; Big data and analytics could be used to improve selection of staff and training interventions, cut costs, improve retention, and performance. as well as meet strategic goals.

Teaching and learning related benefits are [6]: Learning analytics overcome key measurement challenges in educational assessments; Developing automated tools that promote accountability and academic integrity in the e-learning environment by analyzing patterns in the student-generated content; Detect which students are lagging behind and the reason of their low levels of engagement in online learning; Aggregate data from multiple courses to detect patterns for remedial actions for students performance; Monitoring students' performance and progress individually as well as in comparison with peers; Provide real time feedback to students about their progress and class engagement through SMS notification; Identify most effective intervention strategies in helping academically at-risk students succeed; Develop predictive models of students' academic performance; Predictors of individual performance in a teamwork context; The ability to demonstrate how the instructor's course preparation and assistance activities affect different dimensions of student engagement activities; Determining student behavior model, prediction of performance, increase self-awareness amongst students, improve feedback on assessment, recommend resources.

1.4 Concluding Remarks

Several important educational domains, where AI methods and approaches are very promising in overcoming current limitations, are pointed out in [3].

– Educational programs supported by AI methods can give learners and teachers a constructive feedback, based on observed learners' progress during learning. They can also notify teachers about learning performance. Scaffolding is frequently part of such systems and can help teachers to improve crucial parts of teaching material and subjects.

- AI tutors can deliver additional support to students—they provide, for both learners and teachers, significant feedback about the success of the learning process. They are especially useful for courses in which exist limitations in teaching high-order creativity and critical thinking.
- Teachers can be supported by AI tutors and can integrate AI teaching material as supplementary, to help weak learners' hands-on experiences in the form similar to human interaction.
- Automation of grading—recent AI techniques cannot truly replace teachers in grading even simple tests or students' homework. Particularly, essay grading is still in preliminary phase but with great tendency to be substantially improved in the future.
- In spite of the fact that still there are limitations in more qualitative online grading, actual grading is performed instantly thus giving teachers access to data immediately.
- AI also allows tailored and personalized teaching. AI powered educational systems can deliver customized lectures to groups of students, freeing teachers to work one-on-one with students who need it the most.

Apart from mentioned benefits of intelligent e-learning environments there are some limitations as well:

- Learning is an inherently cultural process and computers cannot replace the cultural flavor of learning.
- Learning is not only the process of downloading knowledge or passing an examination. Developing a sense of purpose is crucial to self-directed learning and instilling it in others is an absolutely human activity.

Acknowledgements This work has been supported by the joint research project "Agent Technologies in Dynamics Environments" under the agreement on scientific cooperation between University of Novi Sad, University of Craiova, SRI PAS and Warsaw University of Technology, as well as Mirjana Ivanović and Aleksandra Klašnja-Milićević acknowledge financial support of the Ministry of Education, Science and Technological Development of the Republic of Serbia (Grant No. 451-03-68/2022-14/200125).

References

1. DFKI, Intelligent Solutions for the Knowledge Society. The German Research Center for Artificial Intelligence (2015). http://www/dfki.de/web?set_language=en&cl=en. Accessed 30 Oct 2016
2. S. Somyürek, P. Brusilovsky, J. Guerra, Supporting knowledge monitoring ability: open learner modeling vs. open social learner modeling. Res. Pract. Technol. Enhanc. Learn. **15**(1), 17 (2020)
3. M. Fahimirad, S.S. Kotamjani, A review on application of artificial intelligence in teaching and learning in educational contexts. Int. J. Learn. Dev. **8**, 106–118 (2018)
4. T. Baker, L. Smith, Educ-AI-tion rebooted? Exploring the future of artificial intelligence in schools and colleges (2019). Accessed from Nesta Foundation website: https://media.nesta.org.uk/documents/Future_of_AI_and_education_v5_WEB.pdf

5. B. David, R. Chalon, B. Zhang, C. Yin, Design of a collaborative learning environment integrating emotions and virtual assistants (chatbots). In: *2019 IEEE 23rd International Conference on Computer Supported Cooperative Work in Design (CSCWD)* (IEEE, 2019), pp. 51–56. https://doi.org/10.1109/CSCWD.2019.8791893
6. S. El Alfy, G.J. Marx, A. Dani, Exploring the benefits and challenges of learning analytics in higher education institutions: a systematic literature review. Inf Discov Delivery (2019). https://doi.org/10.1108/IDD-06-2018-0018
7. F. Grivokostopoulou, I. Perikos, I. Hatzilygeroudis, An educational system for learning search algorithms and automatically assessing student performance. Int. J. Artif. Intell. Educ. **27**, 207–240 (2017). https://doi.org/10.1007/s40593-016-0116-x
8. W. Holmes, M. Bialik, C. Fadel, *Artificial Intelligence, in Education: Promises and Implications for Teaching and Learning* (Center for Curriculum Redesign, Boston, 2019)
9. J.A. Kumar, Educational chatbots for project-based learning: investigating learning outcomes for a team-based design course. Int. J. Educ. Technol. High. Educ. **18**(1), 1–28 (2021). https://doi.org/10.1186/s41239-021-00302-w
10. O.P. Pardo, R. Martinez-Maldonado, S. Dawson, Provision of data-driven student feedback in LA&EDM. Handb. Learn. Anal. 163–174 (2017). https://doi.org/10.18608/hla17.014
11. W.H. Dai, S. Huang, X. Zhou, X.E. Yu, M. Ivanovic, D.R. Xu, Emotional intelligence system for ubiquitous smart foreign language education based on neural mechanism. J. Inf. Technol. Appl. Manage. **21**(3), 65–77 (2014). http://www.dbpia.co.kr/Journal/ArticleList/159833
12. M. Ivanović, D. Mitrović, Z. Budimac, L. Jerinić, C. Bădică, HAPA: harvester and pedagogical agents in e-learning environments. Int. J. Comput. Commun. Control **10**(2), 200–210 (2015). ISSN 1841-9836
13. M. Liu, Y. Wang, W. Xu, L. Liu, Automated scoring of Chinese engineering students' English essays. Int. J. Distance Educ. Technol. **15**, 52–68 (2017). https://doi.org/10.4018/IJDET.2017010104
14. C.W. Okonkwo, A. Ade-Ibijola, Chatbots applications in education: a systematic review. Comput. Educ.: Artif. Intell. **2**, 100033 (2021). https://doi.org/10.1016/j.caeai.2021.100033
15. R. Luckin, W. Holmes, M. Griffiths, L.B. Forcier, Intelligence unleashed - an argument for AI in education (2016). Accessed from http://discovery.ucl.ac.uk/1475756/
16. I. Tuomi, M. Cabrera Giraldez, R. Vuorikari, Y. Punie, *The Impact of Artificial Intelligence on Learning, Teaching, and Education* (Publications Office of the European Union, 2018). https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/impact-artificial-intelligence-learning-teaching-and-education
17. J. Grove, TeachHigher "disbanded" ahead of campus protest. Times Higher Education, 2 June 2015. http://www.timeshighereducation.com/news/teachhigher-disbanded-ahead-campus-protest. Accessed 28 Apr 2017
18. A. Klasnja-Milicevic, B. Vesin, M. Ivanovic, Z. Budimac, L.C. Jain, *E-Learning Systems - Intelligent Techniques for Personalization.* Intelligent Systems Reference Library vol. 112 (Springer, 2017), pp. 3–294. ISBN 978-3-319-41161-3
19. A. Klašnja-Milićevic, M. Ivanović, E-learning personalization systems and sustainable education. Sustainability **021**(13), 6713 (2022). https://doi.org/10.3390/su13126713
20. J. Barria-Pineda, K. Akhuseyinoglu, S. Zelem-Celap, P. Brusilovsky, A. Klasnja-Milicevic, M. Ivanovic, Explainable recommendations in a personalized programming practice system, in *Artificial Intelligence in Education - 22nd International Conference, AIED 2021, Utrecht, The Netherlands, June 14–18, 2021, Proceedings, Part I*. LNCS, vol 12748. (Springer, 2021), pp. 64–76. ISBN 978-3-030-78291-7
21. M.J. Laakso, E. Kaila, T. Rajala, ViLLE - collaborative education tool: designing and utilizing an exercise-based learning environment. Educ. Inf. Technol. 23(4), 1655–1676 (2018)
22. A. Rodriguez-Ascaso, J.G. Boticario, C. Finat, H. Petrie, Setting accessibility preferences about learning objects within adaptive elearning systems: user experience and organizational aspects. Expert Syst. **34**, e12187 (2017). https://doi.org/10.1111/exsy.12187
23. A.T. Quadri, N.A. Shukor, The benefits of learning analytics to higher education institutions: a scoping review. Int. J. Emerg. Technol. Learn. (iJET) **16**(23), 4–15 (2021). https://doi.org/10.3991/ijet.v16i23.27471

24. G. Denhiere, S. Baudet, *Lecture, Comprehension de Texte et Science Cognitive* (Presses Universitariesde France, 1992)
25. A. Collins, B. Beranek, *A Sample Dialogue Based on a Theory on Inquiry Teaching*, University of Illionosi at Urbana- Cpampaign (1986)
26. L. Jia-Jiunn, C. Ya-Chen, Y. Shiou-Wen, Designing an adaptive web-based learning system based on students' cognitive styles identified online. Comput. Educ. **58**(1), 209–222 (2012)
27. A. Klasnja-Milicevic, M. Ivanovic, B. Vesin, Z. Budimac, Enhancing e-learning systems with personalized recommendation based on collaborative tagging techniques. Appl. Intell. **48**(6), 1519–1535 (2018)
28. G. Siemens, D. Gasevic, "Guest editorial-learning and knowledge analytics. Educ. Technol. Soc. **15**(3), 1–2 (2012)
29. V. González-Calatayud, P. Prendes-Espinosa, R. Roig-Vila, Artificial intelligence for student assessment: a systematic review. Appl. Sci. **11**, 5467 (2021) https://doi.org/10.3390/app11125467
30. S. Janpla, P. Piriyasurawong, The development of an intelligent multilevel item bank model for the national evaluation of undergraduates. Univers. J. Educ. Res. **8**, 4163–4172 (2020). https://doi.org/10.13189/ujer.2020.080942
31. P. Rhienmora, P. Haddawy, S. Suebnukarn, M.N. Dailey, Intelligent dental training simulator with objective skill assessment and feedback. Artif. Intell. Med. **2011**(52), 115–121 (2011). https://doi.org/10.1016/j.artmed.2011.04.003
32. S. Popenici, S. Kerr, Exploring the impact of artificial intelligence on teaching and learning in higher education. Res. Pract. Technol. Enhanc. Learn. (2017). https://doi.org/10.1186/s41039-017-0062-8
33. J. Maderer, *Artificial Intelligence Course Creates AI Teaching Assistant*, Georgia Tech News Center, 9 May 2016 (2016). https://news.gatech.edu/news/2016/05/09/artificial-intelligence-course-creates-ai-teaching-assistant, Accessed 10 Aug 2021
34. M. Pérez-Sanagustín, I. Hilliger, C. Alario-Hoyos, C.D. Kloos, S. Rayyan, H-MOOC framework: reusing MOOCs for hybrid education. J. Comput. High. Educ. **29**(1), 47–64 (2017)
35. R. Luckin, Towards artificial intelligence-based assessment system, Nat. Human Behav. **1**(0028) (2017)
36. E. Kaila, E. Kurvinen, E. Lokkila, M.-J. Laakso, Redesigning an object-oriented programming course. ACM Trans. Comput. Educ. **16**, 1–21 (2016). https://doi.org/10.1145/2906362
37. A.K. Goel, D.A. Joyner, Using AI to teach AI: lessons from an online AI class. AI Mag. **38**, 48–59 (2017). https://doi.org/10.1609/aimag.v38i2.2732
38. V. Triglianos, M. Labaj, R. Moro, J. Simko, M. Hucko, J. Tvarozek, C. Pautasso, M. Bielikova, Experiences using an interactive presentation platform in a functional and logic programming course, in *Adjunct Publication of the 25th Conference on User Modeling, Adaptation and Personalization* (ACM, New York, 2017), pp. 311–316
39. J. Kim, E.L. Glassman, A. Monroy-Hernández, M.R. Morris, Rimes: embedding interactive multimedia exercises in lecture videos, in *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (ACM, New York, 2015), pp. 1535–1544
40. M. Samarakou, E.D. Fylladitakis, D. Karolidis, W.-G. Früh, A. Hatziapostolou, S.S. Athinaios, M. Grigoriadou, Evaluation of an intelligent open learning system for engineering education. Knowl. Manag. E-Learn. An Int. J. **2016**(8), 496–513 (2016). https://doi.org/10.34105/j.kmel.2016.08.031
41. P. Brusilovsky, S. Somyürek, J. Guerra, R. Hosseini, V. Zadorozhny, The value of social: Comparing open student modeling and open social student modeling, in *International Conference on User Modeling, Adaptation, and Personalization* (Springer, Cham, 2015), pp. 44–55
42. K.R. Maicher, L. Zimmerman, B. Wilcox, B. Liston, H. Cronau, A. Macerollo, L. Jin, E. Jaffe, M. White, E. Fosler-Lussier et al., Using virtual standardized patients to accurately assess information gathering skills in medical students. Med. Teach. **41**, 1053–1059 (2019). https://doi.org/10.1080/0142159X.2019.1616683

43. N. Bostrom, E. Yudkowsky, The ethics of artificial intelligence, in *Cambridge handbook of artificial intelligence*. ed. by K. Frankish, W.M. Ransey (Cambridge University Press, 2011), pp. 316–334
44. Deakin University, IBM Watson now powering Deakin. A new partnership that aim to exceed students' needs (2016). http://archive.li/kEnXm. Accessed 30 Oct 2016
45. M. Samarakou, E.D. Fylladitakis, W.G. Früh, A. Hatziapostolou, J.J. Gelegenis, An advanced elearning environment developed for engineering learners. iJET **10**(3), 22–33 (2015)
46. N. Mirchi, V. Bissonnette, R. Yilmaz, N. Ledwos, A. Winkler-Schwartz, R.F. Del Maestro, The virtual operative assistant: an explainable artificial intelligence tool for simulation-based training in surgery and medicine. PLoS One **15**, e0229596 (2020).https://doi.org/10.1371/journal.pone.0229596
47. I. Tuomi, The use of Artificial Intelligence (AI) in education, May 2020 (2020). https://bit.ly/3lCMotK, Accessed July 15
48. E. Wood, L. Zivcakova, P. Gentile, K. Archer, D. De Pasquale, A. Nosko, Examining the impact of off-task multi-tasking with technology on real-time classroom learning. Comput. Educ. **58**(1), 365–374 (2012)
49. O. Zawacki-Richter, V.I. Marín, M. Bond, F. Gouverneur, Systematic review of research on artificial intelligence applications in higher education–where are the educators? Int. J. Educ. Technol. High. Educ. **16**(1), 1–27 (2019)

Recommended for Further Reading

50. U.L. Uskov et al. (eds.), *Smart Education and e-Learning, Conference Proceedings of the KES-SEEL International Conference, 2021* (Springer, Germany, 2021)
51. V.L. Uskov et al. (eds.), *Smart Education and e-Learning, Conference Proceedings of the KES-SEEL International Conference, 2020* (Springer, Germany, 2020)
52. V.L. Uskov et al. (eds.), *Smart Education and e-Learning, Conference Proceedings of the KES-SEEL International Conference, 2019* (Springer, Germany, 2019)
53. V.L. Uskov et al. (eds.), *Smart Education and e-Learning, Conference Proceedings of the KES-SEEL International Conference, 2018* (Springer, Germany, 2018)
54. V.L. Uskov et al. (eds.), *Smart Education and e-Learning, Conference Proceedings of the KES-SEEL International Conference, 2017* (Springer, Germany, 2017)
55. V.L. Uskov et al. (eds.), *Smart Education and e-Learning, Conference Proceedings of the KES-SEEL International Conference, 2016* (Springer, Germany, 2016)
56. V.L. Uskov et al. (eds.), *Smart Education and e-Learning, Conference Proceedings of the KES-SEEL International Conference, 2015* (Springer, Germany, 2015)
57. M. Ivanovic, L.C. Jain, (eds.), *E-Learning Paradigms and Applications* (Springer, Germany, 2014)
58. L.C. Jain et al. (eds.), *Evolution of Teaching and Learning Paradigms in Intelligent environment* (Springer, Germany, 2007)
59. C. Ghaoui et al. (eds.), *Knowledge-Based Virtual Education* (Springer, Germany, 2005)
60. L.C. Jain et al. (eds.), *Virtual Environments for Teaching and Learning* (World Scientific Publishing Company Singapore, 2002)
61. L.C. Jain (ed.), *Innovations in Teaching and Learning* (Springer, Germany, 2000)