Ido Roll · Danielle McNamara ·
Sergey Sosnovsky · Rose Luckin ·
Vania Dimitrova (Eds.)

Artificial Intelligence in Education

22nd International Conference, AIED 2021
Utrecht, The Netherlands, June 14–18, 2021
Proceedings, Part II

2 Part II

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Preface

The 22nd International Conference on Artificial Intelligence in Education (AIED 2021), originally planned for Utrecht, the Netherlands, was held virtually during June 2021. AIED 2021 was the latest in a longstanding series of yearly international conferences for the presentation of high-quality research into ways to enhance student learning through applications of artificial intelligence, human computer interaction, and the learning sciences.

The theme for the AIED 2021 conference was "Mind the Gap: AIED for Equity and Inclusion." Over the past decades, racial and other bias-driven inequities have persisted or increased, diversity remains low in many educational and vocational contexts, and educational gaps have widened. Despite efforts to address these issues, biases based on factors such as race and gender persist. These issues have come to the forefront with recent crises around the world. In this conference, we reflected on issues of equity, diversity, and inclusion in regards to the educational tools and algorithms that we build, how we assess the efficacy and impact of our applications, theoretical frameworks, and the AIED society. The use of intelligent educational applications has increased, particularly within the past few years. As a community, development and assessment practices mindful of potential (and likely) inequities are necessary. Likewise, planned diversity, equity, and inclusion practices are necessary within the AIED society and home institutions and companies.

There were 168 submissions as full papers to AIED 2020, of which 40 were accepted as full papers (10 pages) with virtual oral presentation at the conference (an acceptance rate of 23.8%), and 66 were accepted as short papers (4 pages). Of the 41 papers directly submitted as short papers, 12 were accepted. Each submission was reviewed by at least three Program Committee (PC) members. In addition, submissions underwent a discussion period (led by a leading reviewer) to ensure that all reviewers' opinions would be considered and leveraged to generate a group recommendation to the program chairs. The program chairs checked the reviews and meta-reviews for quality and, where necessary, requested that reviewers elaborate their review. Final decisions were made by carefully considering both meta-review scores (weighed more heavily) and the discussions, as well as by rereading many of the papers. Our goal was to conduct a fair process and encourage substantive and constructive reviews without interfering with the reviewers' judgment.

Beyond paper presentations and keynotes, the conference also included the following:

- An Industry and Innovation track, intended to support connections between industry (both for-profit and non-profit) and the research community.
- A series of six workshops across a range of topics, including: empowering education with AI technology, intelligent textbooks, challenges related to education in AI (K-12), and optimizing human learning.

– A Doctoral Consortium track, designed to provide doctoral students with the opportunity to obtain feedback on their doctoral research from the research community.
– A Student Forum, funded by the Schmidt Foundation, that supported undergraduate students in learning about AIED, its past, present, and future challenges, and helped them make connections within the community. Special thanks go to Springer for sponsoring the AIED 2020 Best Paper Award. We also wish to acknowledge the wonderful work of the AIED 2020 Organizing Committee, the PC members, and the reviewers who made this conference possible. This conference was certainly a community effort and a testament to the community's strength.

April 2021

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Keynotes

Scrutability, Control and Learner Models: Foundations for Learner-Centred Design in AIED

Judy Kay 🆔

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Abstract. There is a huge, and growing, amount of personal data that has the potential to help people learn. There is also a growing and broad concern about the ways that personal data is harvested and used. This makes it timely to draw on the decades of AIED research towards creating systems and interfaces that enable learners to truly harness and control their learning data. This invited keynote will present a whirlwind tour of my learner modelling research and a selection of other work that has influenced my own towards the goal of putting people in control of their own learning data and its use. I will explain the rationale for my focus on scrutability, as a foundation for users to harness and control their learning data, especially for learning contexts.

I will share key lessons from my work for creating AIED systems that are deeply learner centred. Building on this, I will present a vision for AIED, one that takes a learner-centred perspective to designing AIED systems and recognises the inherent limitations of learning data. This is a broad view of AIED that returns its founding goals to create advanced learning technologies.

Keywords. AIED · Learner models · Personalised learning systems · Scrutability · User control · User-centred design · Holistic design · Software engineering · Human-computer interaction

Augmenting Learning with Smart Design, Smart Systems, and Intelligence

Daniel M. Russell

Google Inc., Mountain View, CA, USA

Abstract. We all want better educational systems, no matter what the implementation might be. We tend to think of building ever more capable AI systems as the way to do this, but what is AI? It's rapidly becoming fancy software engineering: the definition continues to shift over time. What CAN we do in education to help students? My answer: Provide great, well-designed content; put it in a framework where others can use it; wrap it within a social system that lets students learn effectively, no matter the place or time; teach students how to learn. From my perspective, we have already built enormously effective information providing systems, but teaching students how to teach themselves remains key.

Daniel Russell is Google's Senior Research Scientist for Search Quality and User Happiness in Mountain View. He earned his PhD in computer science, specializing in Artificial Intelligence. These days he realizes that amplifying human intelligence is his real passion. His day job is understanding how people search for information, and the ways they come to learn about the world through Google. Dan's current research is to understand how human intelligence and artificial intelligence can work together to better than either as a solo intelligence. His 20% job is teaching the world to search more effectively. His MOOC, PowerSearchingWithGoogle.com, is currently hosting over 3,000 learners / week in the course. In the past 3 years, 4.5 million students have attended his online search classes, augmenting their intelligence with AI. His instructional YouTube videos have a cumulative runtime of over 350 years (24 hours/day; 7 days/week; 365 weeks/year). His new book, The Joy of Search, tells intriguing stories of how to be an effective searcher by going from a curious question to a reliable answer, showing how to do online research with skill and accuracy. Please note that the first paragraph of a section or subsection is not indented. The first paragraphs that follows a table, figure, equation etc. does not have an indent, either.

Invited Panels

Mind the Gap: The Bidirectional Relationship Between Diversity, Equity, and Inclusion (DEI) and Artificial Intelligence (AI)

Shima Salehi[1] and Rod D. Roscoe[2]

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Abstract. This panel discussion session explores the potential bidirectional relationship between (a) artificial intelligence (AI) methods and (b) diversity, equity, and inclusion (DEI) approaches in education.

1 A Bidirectional Relationship

This panel discussion session explores the potential bidirectional relationship between (a) artificial intelligence (AI) methods and (b) diversity, equity, and inclusion (DEI) approaches in education. Participants will consider how AI methods can promote DEI in learning environments (AI for DEI) and how DEI approaches can improve AI analysis and interpretation to better meet the needs of diverse learners (DEI for AI).

1.1 AI for DEI

AI methods are particularly powerful for investigating complex relationships among variables, and have the potential to characterize, analyze, and make predictions regarding diverse learners in various contexts. These affordances can empower educators and researchers to more accurately monitor and identify learners' needs and progress. In turn, these insights might inform more equitable learning. For example, AI techniques enable the rapid analysis of rich data (e.g., interactions with simulations) that can inform formative assessments and feedback that are personalized to individual learners.

1.2 DEI for AI

As a potential paradigm shift, artificial intelligence in education (AIED) experts are increasingly attending to aspects of diversity, equity, and inclusion in theie conceptualizations, methods, and applications. For instance, there is a growing awareness of algorithmic bias, such that algorithms and automated systems can create or exacerbate discriminatory or prejudicial outcomes. Similarly, there is increasing awareness that conclusions based on statistical means can be misleading or exclusionary for learners who do not conform to "average" or majority demographics.

To address such concerns, AIED scholars must consider alternative approaches to studying educational phenomena, analyzing data, and drawing meaningful conclusions. For example, models may need to be disaggregated to include more nuanced variables and effects related to demographic factors and social identities. Simultaneously, intersectional approaches are needed to represent learners' multiple identities (and associated power, privilege, and history), and to interpret these effects within our findings and models. Consequently, this paradigm shift in AIED is not only poised to contribute to personalized learning, but to do so for a much broader diversity of learners.

2 Panel Organization

The panel comprises four presenters and two organizers who represent diverse yet complementary backgrounds related to DEI and AIED. Presenters (alphabetical order) include **Nia Dowell** (Assistant Professor, School of Education, University of California-Irvine [1]; **Rose Luckin** (Professor of Learner Centered Design, UCL Knowledge Lab, London) [2]; **Chris Piech** (Assistant Professor, Computer Science and Education, Stanford University) [3]; and **Marcelo Worsley** (Assistant Professor, Education and Social Policy, Northwestern University) [4]. The organizers include **Shima Salehi** (Assistant Professor, Graduate School of Education, Stanford University) [5]; and **Rod D. Roscoe** (Associate Professor, Fulton Schools of Engineering, Arizona State University) [6].

Presenters will first share their experiences regarding the bidirectional nature of DEI and AI in various contexts. Next, presenters and organizers will discuss questions submitted by the audience and questions emerging from the panelists. This interactive format will allow for a more inclusive session by incorporating opinions and experience of the wide-ranging audience. This diversity is crucial as the topic is emerging, nascent, but of significance to the future of the AIED community.

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Research-Based Digital-First Assessments and the Future of Education

Alina A. von Davier[1], Valerie Shute[2], Jill Burstein[3],
Michelle Barrett[4], and Saad Khan[5]

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[5] FineTune Learning

Abstract. AI, learning engineering, computational Psychometrics, and big data coupled with numerous technology breakthroughs propose a new paradigm for education. From adaptive learning systems to digital-first -testing with automated content generation and automatic scoring - the possibilities for efficiency, scalability, and access are promising. The unprecedented disruption of COVID-19 leaves little doubt that advances in learning sciences and technology can augment the in-classroom educational experience. Digital-first assessments, sometimes called intelligent assessments are a new generation of tests where the technological advances and AI affordances are used to (re)create comprehensive assessments that are adaptive, efficient, rigorous, valid, and, most distinctively, attuned to perfect the user's experience. Digital-first assessments may be integrated into other systems (school systems, LMS, etc) being part of the new Internet of Education (IoE), where through integrative frameworks and standards one can optimize the support for each student while protecting their privacy. Stealth assessments through the use of process data from interactive tasks and multimodal data sources are moving from research labs into practice.

The panelists will share their research, provide evidence of how these new methodologies work, and engage the audience in a thought-provoking discussion on the impact of the new tests on education in general.

Keywords. Computational psychometrics · Stealth assessment · Automated writing evaluation · Digital-first assessment · Generating assessment

1 Computational Psychometrics as an Integrative Framework for Digital-First Assessments

In 2015, von Davier coined the term "computational psychometrics" (CP) to describe the fusion of psychometric theories and data-driven algorithms for improving the

inferences made from technology-supported learning and assessment systems (LAS). Meanwhile, "computational" [insert discipline] has become a common occurrence. In CP the process data collected from virtual environments should be intentional: we should design & provide ample opportunities for people to display the skills we want to measure. CP uses the expert-developed theory as a map for the measurement efforts using process data. CP is also interested in the knowledge discovery from the (little, big) process data. Psychometric theories and data-driven algorithms are fused to make accurate and valid inferences in complex, virtual learning and assessment environments.

2 Stealth Assessment—What, Why, and How?

Proposed summary of the presentation: Games can be powerful vehicles to support learning, but this hinges on getting the assessment part right. In the past several years, we have designed, developed, and evaluated a number of stealth assessments in games to see: (a) if they provide valid and reliable estimates of students' developing competencies (e.g., in the areas of qualitative physics understanding, creativity, and persistence); (b) if students can actually learn anything as a function of gameplay; (c) the added value of inserting engaging learning supports (cognitive and affective) into the mix; and (d) if the games are still fun with the embedded assessments and supports. My presentation will cover the topic of stealth assessment in games to measure and support important 21st-century competencies. I'll describe why it's important, what it is, and how to develop/accomplish it. Time permitting, I'll also provide examples and videos in the context of a game we developed called Physics Playground.

3 Extending Automated Writing Evaluation for Integrative Frameworks

I will speak to systems and systems of systems that provide a digital-first assessment of the evidence of learning (either with or without testing) suitable for informing multiple adaptive decision-making loops in the educational ecosystem, including those at the learner, educator, school, district, and/or state levels. I will share a few exemplar theories of action and a conceptual model for such systems. I will provide an overview of industry standards that have been designed to facilitate the implementation of such systems to date and describe gaps and challenges that remain. Finally, I will reflect on research findings to date on hybrid systems that integrate digital adaptive assessment and adaptive instruction and describe a few elements I believe to be important for the research agenda moving forward.

4 Platforms and Standards in Support of Digital-First (Adaptive) Assessments

I will speak to systems and systems of systems that provide a digital-first assessment of the evidence of learning (either with or without testing) suitable for informing multiple adaptive decision-making loops in the educational ecosystem, including those at the learner, educator, school, district, and/or state levels. I will share a few exemplar theories of action and a conceptual model for such systems. I will provide an overview of industry standards that have been designed to facilitate the implementation of such systems to date and describe gaps and challenges that remain. Finally, I will reflect on research findings to date on hybrid systems that integrate digital adaptive assessment and adaptive instruction and describe a few elements I believe to be important for the research agenda moving forward.

5 Generating Assessment Items and Content with Artificial Intelligence

Educational assessment, learning, and publishing companies dedicate significant resources for the creation of original content for use in formative and summative tests, as well as in-classroom learning or open educational resources. Manual content creation can be laborious, highly dependent on domain expertise, and difficult to scale up. This bottleneck has come into sharper focus during the current pandemic, which has accelerated the shift to remote learning and heightened concerns of assessment items exposure.

I will share my experiences in artificial intelligence-based automated item and content generation. I will speak to the advances in natural language processing (models such as BERT [1], GPT3 [2]) that have enabled progress in this exciting field as well as current limitations to this technology and share thoughts on future directions. I will also discuss how AI-based automated item and content generation can result in scalable quality standardization, and open new possibilities for formative assessments and personalized learning experiences.

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Workshops

Supporting Lifelong Learning

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Workshop Description

To achieve the theme of AIED 2021 "Mind the Gap: AIED for Equity and Inclusion", advanced learning technology research needs to support lifelong learners with the knowledge and skills needed to succeed in a rapidly changing world. The proliferation of social media and the recent need for everyone to transit to online learning due to the pandemic have made millions of lifelong learners turn to online learning communities (OLCs). With the availability of big data about learners from the OLCs and the availability of the enabling technologies, opportunities arise to provide personalized support to learners. During the first international workshop on supporting lifelong learning (SLL) co-located with the 20th international conference on Artificial intelligence in education (AIED 2019) some emerging themes were discussed in the areas of learner models, learner feedback, privacy and sustainability of lifelong learning systems.

The goal of the second workshop on supporting lifelong learning is to build on the first workshop by fostering further discussions around optimizing the learner models of lifelong learners to achieve their learning goals. SLL 2021 workshop aims at providing a forum for researchers to critically discuss ways to advance research in supporting lifelong learning beyond the walls of traditional educational systems. The second workshop will cover areas that address the application of advanced technologies like social recommendation, adaptive technologies, collaborative tools, persuasive strategies, learning analytics and educational data mining to support lifelong learners. This workshop aims at enhancing lifelong learning through collaboration, educational games, personalized recommendation, self-motivated learning and educational diagnosis of lifelong learners; and also, to review studies addressing lifelong learning.

Based on the category of papers, time will be allotted for presentation and questions. At the end of the workshop, there will be a discussion on workshop presentations, challenges and the ways forward, and we will develop a co-authored document to summarize the workshop papers. In summary, SLL 2021 will serve to expand the frontiers of knowledge within the advanced learning technology community, by providing opportunities for researchers to establish long term collaborations that can help

to expand on studies that support lifelong learning. In addition, we look forward to the possibility of publishing a Special Issue in a relevant journal with extended versions of the accepted papers in the workshop from SLL 2019 and SLL 2021.

The First International Workshop on Multimodal Artificial Intelligence in Education

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Abstract. This workshop aims at gathering new insights around the use of Artificial Intelligence (AI) systems and autonomous agents for education and learning leveraging multimodal data sources. The workshop is entitled Multimodal Artificial Intelligence in Education (MAIEd). It builds upon the Cross-MMLA workshop series at the Learning Analytics & Knowledge conference. The workshop calls for new empirical studies, even if in their early stages of developments. It also welcomes novel experimental designs, theoretical contributions and practical demonstrations which can prove the use of multimodal and multi-sensor devices ``beyond mouse and keyboard'' in learning contexts with the purpose of automatic feedback generation, adaptation and personalisation in learning. Through a call for proposals, we seek to engage the scientific community in opening up the scope of AI in Education towards novel and diverse data sources.

1 Introduction

At the MAIEd workshop, we want to discuss which scientific, state-of-the-art ideas and approaches are being pursued and which impacts we expect on educational technologies and education. We are especially interested in contributions targeting the intersection of these two fields of AI and multimodal interaction. We are looking for original contributions that advance the state of the art in theories, technologies, methods, and knowledge towards the development of multimodal intelligent tutors,

multimodal intelligence augmentation in teaching and learning and multimodal applications for self-regulated learning. The full text of the Call for Proposal and more information about the MAIEd 2021 workshop can be found on the workshop website http://maied.edutec.science/http://maied.edutec.science/.

Challenges and Advances in Team Tutoring Workshop

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Workshop Description

The "Challenges and Advances in Team Tutoring" workshop is a follow on to two previous AIED conference workshops held in person in 2018 and 2019 [1, 2]. It was clear from the workshops that team tutoring is a diverse and on-going field of study that is in constant development. Therefore, the current workshop specifically focuses on the Challenges and Advances in Team Tutoring. In line with one of those familiar challenges experienced this last year, the current workshop is virtual instead of in-person. With education and work settings shifting to distributed environments, understanding these impacts on collaborative learning and team development through tutoring are critical. The current virtual workshop covers all topic areas related to team tutoring, and provides an opportunity to discuss advances in the field that have been made by both new and returning presenters.

The workshop has three topic areas/themes: 1) Towards Intelligent Tutoring Systems for Teams in Distributed Environments, 2) Challenges and Lessons Learned in Creating Intelligent Tutoring Systems for Teams, and 3) Intelligent Tutoring System based Collaborative Problem Solving and Learning. Each topic area will include presentations of work and periods of open discussion to identify commonalities in approaches. Further gaps will be identified and addressed for future attention.

The workshop is expected to be of interest to those in academia, industry, and government in the field of team tutoring, along with those who would like to learn more about it. The expected outcomes of the workshop include an identification of current gaps and challenges in team tutoring, addressing those challenges across varying contexts and use cases, and defining next steps for the AIED community as they work towards maturing team tutoring solutions.

References

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Third Workshop on Intelligent Textbooks

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Abstract. Textbooks have evolved over the last several decades in many aspects. Most textbooks can be accessed online, many of them freely. They often come with libraries of supplementary educational resources or online educational services built on top of them. As a result of these enrichments, new research challenges and opportunities emerge that call for the application of AIEd methods to enhance digital textbooks and learners' interaction with them. Intelligent textbooks have the potential to benefit a large number of learners in online learning settings, especially after the COVID-19 pandemic. However, a number of research challenges have to be addressed before this vision become a reality. How to facilitate the access to textbooks and improve the reading process? What can be extracted from textbook content and data-mined from the logs of students interacting with it? The Third Workshop on Intelligent Textbooks focuses on these and other research questions related to intelligent textbooks. It seeks to bring together researchers working on different aspects of learning technologies to establish intelligent textbooks as a new, interdisciplinary research field.

Keywords. Digital and online textbooks · Open educational resources (OER) · Modelling and representation of textbook content · Assessment generation · Adaptive presentation and navigation · Content curation end enrichment

The transition of textbooks from printed copies to digital formats has facilitated numerous attempts to enrich them with various kinds of interactive functionalities including search and annotation, interactive content modules, and automated assessments. New research challenges and opportunities emerge that call for the application of AI methods to enhance digital textbooks and learners' interaction with them. Intelligent digital textbooks have the potential to significantly enhance the online learning experience, the importance of which is highlighted by the COVID-19 pandemic. Our workshop seeks to unify research efforts across several different fields,

including AI, human-computer interaction, information retrieval, intelligent tutoring systems, and user modeling. This workshop brings together researchers working on different aspects of intelligent textbook technologies in these fields and beyond to establish intelligent textbooks as a new, interdisciplinary research field.

Advancing AI-Powered Education through Industry-Academia Cooperation

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The goal of "Advancing AI-Powered Education through Industry-Academia Cooperation" workshop co-sponsored by IEEE Learning Technology Standard Committee and Artificial Intelligence Standards Committee is to explore opportunities to empower educational systems with the most advanced AI technologies through industry and academia collaboration and to explore how to standardize on these systems, technologies, and practices, including adaptive learning systems, virtual classrooms, and systems that use machine learning to model student interactions and preferences to improve learning outcomes.

Programs:

– S01 Workshop Opening Remarks and Introduction
– S02* How technical standards and infrastructure support equity and inclusion. ("Mind the Gap: AIED for Equity and Inclusion")
– S03* How Learning Technology Standards Committee and Artificial Intelligence Committee can work together to bring AI to the forefront of education innovation - IEEE LTSC and AISC
– S4** How Industry and Research Community can benefit from advanced Virtual Classroom Technology and IEEE Standards
– S05 Explainable AI
– S06 Digital Textbook and Mobile Learning
– S07 Adaptive Instructional System @LTSC
– S08 Enterprise Learning Record
– S09 Interoperable Learning Record
– S10 LTSC standards Alpha Soup (xAPI, Virtual Classroom, Competencies, ..)
– S11* Cutting-Edge real-world projects. Where the industry is going?
– S12 AIS Consortium Overview and Practices
– S13* Academia and Industry Joint Research - Trend and Applications
– S14* Joint research with Industry and Academia
– S15 AI Architecture in Action

- S16 Intelligent Robot in Classroom
- S17 Final Remarks

    * \<Panel\>
    ** \<Keynote\>

Contents – Part II