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Leveraging AI, big data and educational technology to promote collaborative learning and improve cyberlearning courses: synopsis and linked presentations of the workshop at Orlando, Florida, 4-6 June 2019, and the online workshop, 13-14 August 2020

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Leveraging AI, big data and educational technology to promote collaborative learning and improve cyberlearning courses: synopsis and linked presentations of the workshop at Orlando, Florida, 4–6 June 2019, and the online workshop, 13–14 August 2020

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Abstract: This article presents a synopsis and the summaries of a series of presentations delivered in two workshops that we organised in 2019 and 2020. The purpose of the two workshops is to find practical solutions to the emerged peer learning problems in a distributed learning (DL or cyberlearning) environment, which becomes popular under and after the COVID-19 pandemic. A DL environment not only consists of personal or virtual instructors, online courseware, communicational technologies, but also peer learners. Collaborative learning between peers in a distributed learning environment is inadequately addressed in research literature and paid insufficient attention in practices. In an active and constructive learning environment (Chi and Wylie, 2014) such as team projects and research experiences for undergraduates (REU), learning from peers is as helpful as learning from the instructors. However, collaborative learning from remote peers is much more challenging than face-to-face teamwork. This synopsis can serve as a road map for readers to find your interested topics starting at the broad view of the peer-learning problem in a DL environment and practical solutions as first-hand experiences of 20 speakers. The summaries of the topics, the linked videos, PowerPoint slides, and the references will guide the readers to explore such a hardly treaded territory at a flexible pace, breadth, and depth.

Keywords: distributed learning; learning space; collaborative learning; learning analytics; educational technology; artificial intelligence.

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Biographical notes: Hong Liu is a professor at Embry-Riddle Aeronautical University at Daytona Beach Campus USA. He published 36 peer-reviewed articles in Partial Differential Equations, Robotics, Data Mining, and Data Science Education. His recent research has focused on applying Artificial Intelligence technology and Learning Analytics to promote collaborative learning in a hybrid learning environment.

Xiaoqing Gu is a professor and head of the Department of Educational Information Technology, East China Normal University. Her areas of expertise include Theory and Practice in E-learning, ICT-integrated Pedagogy. Her research has focused primarily on ICT in education, including learning design, ICT-supported content design and development, ICT-integrated pedagogical innovation, computer-supported collaborative learning, and learning analytics to inform pedagogical design. She has well-cited publications appeared in Chinese peer-reviewed journals such as E-education Research and China Educational Technology.

1 Background

The workshops we organised in 2019 and 2020 are unique in their problem-oriented focus and transdisciplinary participants. The workshops' focus is on a particular problem that emerged from peer learning from DL courses. And its participants are the experts invited from many different disciplinary fields, including renowned Learning Scientists, Educational Technologists, Computer Scientists, Software Engineers, and domain experts in Mathematics, Data Science, Biology, Chemistry, and Environmental Sciences. This synopsis may serve as a road map for readers to find your interested topics on the broad view of the problems associated with peer-learning under DL environment and leveraging AI, big data, and educational technology to promote collaborative learning and to improve cyberlearning courses. In the context of this synopsis, we used to term cyberlearning (Borgman, 2008) and DL (Dede, 2004; Flecher, 2005) interchangeably as a combination of in-person and online learning at different locations.

The National Science Foundation IUSE award (1626602, see http://www.gps2dreamcollege.com, 2017–2020) has made it possible for a coalition of small institutions whose primary focus is on undergraduate education to design and assess learning experiences in computational data-enabled sciences and engineering (CDSE, Liu et al., 2017). The coalition has designed and offered six CDSE courses in biology, chemistry, atmospheric science, mathematics, computer science, and data science. Project-based collaborative learning has been used as an effective active learning strategy for these CDSE courses. The positive learner-to-learner interactions and the synergies of the teammates from different majors were identified as the primary factors contributing to the success of the collective learning outcomes (Liu et al., 2018). However, it is hard to evaluate individuals' contributions objectively and to assure that all students have equal learning opportunities in such a complex social learning environment.

As an ad hoc solution for small classes, the instructors of these CDSE courses frequently met the teams to prevent negative team behaviours such as social loafing and heroism and provide timely guidance to students. Such a solution is time-consuming. Therefore, it is hard to sustain and scale up to large classes. Hence, the project team

applied for a supplementary grant to convey a summer workshop in 2019 on Advancing Intelligent Agents for Collaborative Project Based Learning (PBL). The proposal got support from NSF. More luckily, we also obtained incredible support of free facilities and many zero-cost keynote speakers from the Institute of Simulation and Training (IST) at the University of Central Florida (UCF) and IST's associated USA Army Research Labs. Hence, the grant for one workshop allowed us to offer two summer workshops – a face-to-face workshop 4–6 June 2019, and an online workshop 13–14 August 2020, due to the COVID-19 pandemic. We prepared this synopsis to extend the workshops' impact and share the valuable presentations to a broad learning science and technology community beyond the 70 participants of the two workshops.

The first workshop on Advancing Intelligent Agents for Collaborative PBL attracted 30 participants, including CDSE experts and educational researchers from 12 universities in the USA and China, research scientists in AI from the Army Research Lab (ARL), and software developers and data scientists in industries. The primary outcomes of the first workshops are:

- Synergised the expertise of multidisciplinary attendees to understand the status and barriers of theory, practice, development, and policy for the educational technologies and identified new ways to transform them into student learning gain.
- Critiqued the intelligent tutoring systems (ITS) such as GIFT (Generalised Intelligent Framework for Tutoring) of ARL and CTAT (Cognitive Tutor Authoring Tools) of Carnegie Mellon University and learning management systems (LMS) such as Canvas and Moodle.
- Understood the benefits of interoperability for educational data exchange standards such Experience API (xAPI, https://xapi.com/), and databases such as Learner Record Store.
- Discussed the practical challenges for maintaining the in-house developed app BotCaptain and integrating problems with ITS and LMS.

With a slightly different focus from the first workshop, the second workshop is entitled "Leveraging AI, Big Data, and DL Technology to Promote Peer Learning and Improve Cyberlearning Courses." Due to the COVID-19 pandemic, the workshop moved online. It brought together 40 participants, including educators and researchers from 19 universities in four countries – the USA, China, England, and Nigeria. Participants include scientists in AI and DL technology at the Army Research Lab (ARL) and software developers and data scientists in the industry. Among the 40 participants, 23 attended both workshops, and 17 first-time contributors only attended the recent workshop. The primary outcomes of the second workshop are:

- Enhanced the understanding of practical issues related to ITS such as GIFT of ARL, LMS Moodle, interoperable educational data standards such as xAPI and LRS.
- Gained knowledge of the AutoTutor introduced by Dr. Hu at the University of Memphis, CaSS (Competence and Skill System, Eduworks: https://cass.extension.eduworks.com/) from Dr. Goldberg of ARL, and the new Biological Computation concept introduced by Dr. MacLaren at CMU.

- Exchanged strategies and experiences based on active and constructive learning practices such as Course-based Undergraduate Research Experience (CURE) and PBL.
- Learned proven successful practices, such as Game-based Learning of Business Data Analytics, presented by Dr. Ming Wang at CSULA, and Data-driven Teaching Analytics, presented by Dr. Gu at Eastern China Normal University.

In addition to this background as Section 1, the rest of the synopsis is organised into six more sections: 2. Adaptive Learning and DL Technology; 3. Instructional Technology and Cognitive Tutoring; 4. Competence-Based and Data-Driven Assessments; 5. Innovative Learning Spaces; 6. Practices in STEM Education, and 7. The contributors and their bio-sketches. This synopsis only summarises the presentations' talks. We apologise that this synopsis scope does not allow us to report as many details as we wish. Readers can click the highlighted links to access the slides and videos. We recommend that the readers contact the speakers directly if you are interested in learning more about some topics.

2 Adaptive learning and dl technology

The five presentations about adaptive DL and DL technologies focused on the GIFT system of US DoD's Advanced Distributed Learning Initiative (ADL, https://adlnet.gov). The two keynote speakers of 2.1 and 2.2, Drs. Benjamin Goldberg and Keith Brawner in the US Army Research Lab (ARL) served as co-creators of the GIFT. The third speaker in this section, Dr. Xiangen Hu, is the Director of Advanced Distributed Learning Partnership Laboratory at the University of Memphis. He served as the external consultant and subcontractor in the early stage of GIFT.

According to Sottilare et al. (2012), another co-creator and senior team leader, GIFT is a modular, open-source framework for building, deploying, and managing adaptive learning content (https://www.gifttutoring.org/projects/gift/wiki/Overview). This software has the ability to incorporate external hardware and software to model attributes about the learner, tailor instruction to the learners' needs, and allow learners to practice their knowledge in various applications (Sottilare et al., 2018). GIFT is available to users with a GIFT Account at no cost with free online training (Burmester, 2020). GIFT is a multifaceted platform for

1 authoring tutoring and adaptive learning courseware,

2 managing instructions, and

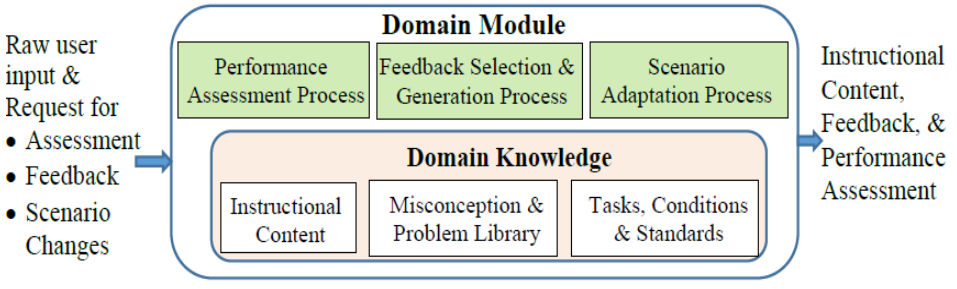
3 analysing effectiveness with an AI-based competence and skill assessment (CSA) engine.

Using GIFT, we can develop network DL DS courses to be flexibly delivered in mixed modes such as in-person, synchronous, and asynchronous online, as well as in a flipped classroom model.

The adaptive learning feature of GIFT is implemented by its Engine for Management of Adaptive Pedagogy (EMAP). Figure 1 shows the GIFT Domain Module that defines domain knowledge. Network course developers will define the Domain Knowledge File (DKF) of the Domain Module. GIFT courseware developers need to specify the metadata

of two modules: a Pedagogical Module and a Learner Module. The pedagogical module selects one domain-agnostic model based on successful learning theories such as Merrill's component display theory (1983) and Chi's ICAP (Interactive, Constructive, Active, and Passive, 2014) framework. The authors tag media and other content to aid content searches in the context of learner conditions and instructional phases. Once a learner completes a tagged task, an Experience Application Program Interface (xAPI) (https://xapi.com/overview) statement is created and saved to the learner's Learning Record Store (LRS). The xAPI is the standard of the ADL initiative for interoperable data exchanges in the DL community. GIFT also has a Sensor Module to detect the psych-physical conditions of the learners. Each course has a different Domain Module. Network course developers will share the same Pedagogical Module and Learner Module.

Figure 1 GIFT domain module



DL courses without adaptive features are not new to academia. A comprehensive history of DL over the last 30 years can be found in Graesser et al. (2019). As a tour de force, adaptive DL courses follow the standard of Total Learning Architecture (https://adlnet.gov/projects/tla) (TLA, Barr et al., 2020) to leverage the power of AI, big data, and communication technologies to provide learning that can be personalised and delivered anytime and anywhere. As a core feature to enable adaptive learning, GIFT can automate data collection for formative learning assessment. If readers are interested in exploring deeper about how to use adaptive DL and GIFT to advance pedagogical research or practical instructional design, please refer to the website maintained by GIFT research and development team (https://gifttutoring.org/projects/gift/documents).

2.1 Generalised Intelligent Framework for Tutoring – History and Direction,[1] Dr. Keith Brawner, USA Army Research Lab

As shown in the video,[2] Dr. Ran Tarr, Co-Chair of the workshop and retired director of a research lab at Institution of Simulation of Training (IST), introduced Dr. Brawner to the audience on 4 June 2019. As one of the GIFT co-creators and a researcher for the GIFT Architectural and Ontological Support, Dr. Keith Brawner gave a keynote at the IST of UCF to review the history of GIFT and point out the future directions. He started at the vision of GIFT dated back in 2011 with a picture of four initiators of the project, Drs. Robert Sottilare, Heather Holden, Keith Brawner, and Benjamin Goldberg in 2012. In 2015, the team grew to 12 researchers and developers. He summarised the capacity

augmentation from 2015–2019. He ended his talk by announcing to the audience "Free to Use" for everybody in the world.

2.2 GIFT with new features in Teamwork – a history of the Government-lead open source platform for tutors,[3] Dr. Keith Brawner, USA Army Research Lab

Dr. Browner gave us his second keynote on 14 August 2020 online through Zoom. As shown in the video,[4] Dr. Ran Tarr introduced Dr. Browner again to the online audience this time. Since about half of the audience are also the first workshop participants, Dr. Browner emphasised more on the capacity and future TLA in this talk. In particular, he took time to explain the new feature on Teamwork assessment and tutoring capacity of GIFT (Sottilare et al., 2020).

2.3 Enabling Intelligent Tutoring for Military Skill Sets: Lessons Learned and Future Plans with GIFT,[5] Benjamin Goldberg, USA Army Research Lab

As shown in the video,[6] Dr. Tarr introduced Dr. Goldberg to give the keynotes about the GIFT tutoring in military skill set, lessons learned, and future plans in his first talk on 4 June 2019. Dr. Goldberg illustrated some simulations of the counter-insurgency in the series game UrbanSim. More specifically, he showed the adaptive learning features and the learning assessment features of GIFT to track the trainees' progress. Then, Dr. Goldberg broke down concepts by concepts of the learning assessment design. He also illustrated how the virtual reality of GIS information is integrated into mobile land navigation. He concluded his talk on future concepts and synthetic training environment.

2.4 Persistent Assessment of Team Readiness through a Competency-based Data Strategy, Benjamin Goldberg, USA Army Research Lab, 2020

As shown in the video,[7] Dr. Goldberg's talk focused on Synthetic Training Environment (STE) as his latest research effort. He introduced STEEL-R (STE Experiential Learning for Readiness) concept based on CaSS, modern game engines, big data, and immersive technology. He presented a common soldier competence framework to support data collection and track competence assertions. Dr. Goldberg then showed how a semi-automated in-action and after-action review process is used as a critical technology for high-quality performance. After that, he illustrated the semi-automated competence assertion and approval process. Finally, he demonstrated an experiential team competency model as an integration of three tiers of competencies: Team tasks, roles, and individual tasks. Readers can find five latest work on Team Competency in the eighth Symposium proceeding[8] edited by Dr. Goldberg.

2.5 Advanced Learning Theories, Technologies, Applications, and Impacts, Illustrated by a simple example of an adaptive instructional system,[9] Dr. Xiangen Hu, University of Memphis, USA

As shown in the LinkedIn Video,[10] Dr. Xiangen Hu presented his teams' work, an AutoTutor framework for promoting advanced learning, illustrated by a simple example of an adaptive instructional system (AIS). In his presentation, Dr. Xiangen Hu introduced

the theories that are relevant learning principles and technologies like Coh-Metrix, SRA, GIFT, xAPI used in his AutoTutor framework. In addition, he showed that this framework consists of three parts: AutoTutor conversation engine (ACE), AutoTutor scripts authoring tool (ASAT), sharable knowledge object (SKO). And how these three parts work together to support the function of the AutoTutor framework. At the end of his presentation, Dr. Xiangen Hu selected some application examples to illustrate how AutoTutor worked well on improving teaching and learning (Graesser et al., 2019).

3 AI-based educational technology and cognitive tutor

Applications of AI to educational technology to complement and personalise learning have become a new business in recent years. Noticeable products and services, to name a few, includes Aleks for math tutoring, KNEWTON adaptive learning for higher education, and Carnegie Learning uses AI to help students develop a deeper conceptual understanding of math. A cognitive tutor[11] is a particular kind of intelligent tutoring system that utilises a cognitive model to provide feedback to students as they are working through problems. This feedback will immediately inform students of the correctness, or incorrectness, of their actions in the tutor interface; however, cognitive tutors also have the ability to provide context-sensitive hints and instruction to guide students towards reasonable next steps. Practically, these AI-based adaptive learning or tutoring system are rarely used without human intervention. To our knowledge, no such AI-based system alone has provided adequate statistics evidence of effectiveness that met the "What Works Clearinghouse standards." However, the trend is clear. Students will spend longer time each year on affordable and flexible AI-based learning technology than human teachers and tutors.

The four topics of this section are diverse, and the perspective is in bird's eye views targeting a broad audience. Dr. William Cain presented how to use telepresence robots to bring social presences for synchronous hybrid learning of remote students. Dr. Michael Spector of the University of North Texas gave two keynotes. His first talk in 2019 presented the big picture about the Current and Future AI Applications in Education. His second talk in 2020 gave many technical details on how to apply AI to assess and intervene in learning and promote students' problem-solving ability. Dr. Matthew Ikle, the PI of the grant, will present Trustworthy Artificial General Intelligence and Blockchain. Dr. Benjamin MacLaren at Carnegie-Mellon University gave a talk on the cognitive tutor for analysis in genetics – focusing on biology computation.

3.1 Telepresence Robots and Social Presences for Synchronous Hybrid Learning of Remote Students, Dr. William Cain, University of Wyoming

As shown in the LinkedIn video,[12] Dr. Hong Liu introduced Dr. William Cain. Dr. Cain introduced the problem of lacking social presence for remote students in synchronous hybrid learning compared with their local face-to-face students and the solution to introduce telepresence robots. The devil is in the details. He illustrated how to optimise the geographic distribution of telepresence robots and face-to-face students. He addressed the implementation fidelity issue, the complexity, and the quality of students' social presence in educational technology innovation. The audience participated in an exciting discussion about the fidelity issue of instructional design.

3.2 Artificial Intelligence in High Education, Opportunities and Risks, Dr. Matthew Ikle, Ideas of Mind Inc. and SingularityNET Foundation

The first presentation[13] Dr. Ikle gave in 2019 addressed both the positive and negative sides of AI in high education. He talked about his experience in teaching AI as content. Then, he discussed AI applications in high education such as adaptive learning, learning evaluation, and strategies to pair students to work in teams. Next, he presented his experience using AI and gaming to motivate students in hands-on robotics projects at his Make-lab in summer REU. The real issue is how to harness hands-on work enthusiasm to guide students to gain deep learning. After that, Dr. Ikle addressed the risks that the students can use AI to shortcut learning without understanding. Finally, Dr. Ikle presented his experience to co-teach microbiology classes with biologists and the necessity to collaborate across disciplinary boundaries.

3.3 Trustworthy AGI, Matthew Ikle, Ideas of Mind Inc. and SingularityNET Foundation

Starting at 40th minutes in the video,[14] Dr. Hong Liu introduced Dr. Matthew Ikle to give his second talk on 14 August 2020. Data security, privacy, and confidentiality are major concerns of all stakeholders in government, academics, and industries. Dr. Ikle brought up the issue of trustworthy Artificial General Intelligence (AGI) when AI penetrated almost every aspect of our lives, including the education system, and big data are collected with or without acknowledging the subjects. It is a matter of time that AI will replace the instructor to facilitate students to gain procedural and factual knowledge. As an AI scientist and educator, he suggested that the instructor's role should be more focusing on the four purposes: Unlock the potential of each student, Unleash the creativity of each student, Enable each student to find one's life passion, and provide requisite skills, background, and feedback.

3.4 Cognitive Tutor for Analysis in Genetics- Biological Computation,[15] Benjamin MacLaren

Dr. Raphael Isokpehi, Co-PI of the grant at Bethune-Cookman University, introduced Dr. Benjamin MacLauren. Showing in the video,[16] Dr. MacLauren observed how the biology teachers failed to help students to understand the dynamics of biology as a system. He made clear that the Cognitive Tutor for Analysis in Genetics (CTAG) is not just for genetics. CTAG embodies a mental model for biology that we call Pathway Algebra, which helps kids simulate & explain theories in science. Dr. McLauren demonstrated eye-open observation that the information processing of a biology system is literally Computational Thinking.

3.5 Technology-enabled feedback and support for complex problem solving and project planning,[17] Dr. Michael J. Spector, 2020

As shown in the video,[18] Dr. Michael J. Spector presented how technology-enabled feedback and support for complex problem-solving (Spector, 2010; Spector, 2016). At the beginning of Dr. Spector's presentation, he took COVID-19 that occurred in 2020 as an example to analyse the major factors affecting the spread of COVID-19 using a

system dynamics method. He obtained a System Dynamics Model of COVID-19. And this led to the theme of today's report, which was technology-enabled feedback. After that, he introduced various evaluation feedback methods such as preliminary formative evaluation, formal and informal measurement, and cognitively deep assessments. Then he introduced what a complex problem and the challenges of complex task evaluation is. In the end, Dr. Spector gave a solution on complex tasks' evaluation feedback, that is, use dynamic enhanced evaluation of problem-solving (DEEP) to conceptualise the problem space.

4 Competence based and data driven assessments

Learning is invisible to the instructors in a face-to-face setting and is not observable to the remotely located instructors in the DL environment. Traditional education uses homework, quizzes, and testing to perform formative and summative learning assessments, and the instructors can provide students timely feedback if the class size is small. It is not so for the MOOCs (Massive Open Online Courses) for lacking peer support, and timely feedback contributed to MOOCs' low retention rate. However, the adaptive DL technology is promising for the technologies embedded data collections, competency-based learning assessment (Stafford, 2019), and content recommendations to provide personalised learning experiences (Walcutt and Sae, 2019) and support life-long learning (Walcutt and Naomi, 2019). Competency-based assessment is the process of collecting evidence and making judgments about whether a person has achieved competency. Noticeable technologies include GIFT, xAPI, and LRS presented in the previous section, and CaSS from EduWorks.[19] This section will summarise eight presentations from academies and industries, including two keynotes from Dr. Xiaoqing Gu from Eastern China Normal University in China and Dr. Ron Tarr from RAPTARR, LLC in the USA.

4.1 Analysing pre-service teachers' reflective writing: A text mining approach,[20] Ye Chen, University of Western Georgia, 2019

Reflection is an essential part of the professional development of teachers. In her talk,[21] Dr. Chen used a text mining approach to analyse pre-service teacher's reflective writing (Chen, 2015; Chen et al., 2016). In teacher education, journal writing has been accepted as an effective practice for stimulating reflective learning. The reflection journals produced by student teachers offer a rich source of data for formative assessment. However, the analysis of textual reflections in classes of large size presents challenges. Automatic analysis of the reflective writing holds great promise for providing adaptive real-time support for these students. Dr. Chen proposed a method based on topic modelling techniques for the task of topic exploration and reflection grade prediction.

4.2 Adopting learning analytics to understand successful teachers' behaviours, Dr. Xiaoqing Gu, Eastern China Normal University, 2020

Dr. Gu's talk is closely related to teaching analytics, a concept introduced in Vatrapu (2012) (Ndukwe and Daniel, 2020). As shown in the video,[22] Dr. Xiaoqing Gu presented how to adopt learning analytics to understand successful teachers' behaviours. In Dr.

Gu's presentation, she first raised two questions: what does good teaching look like, and are there tools/methods that we can use to assess good teaching or for teachers themselves to reflect on their own? Then she introduced the concepts of learning analysis and teaching analysis and the difference between the two. After that, she proposed a solution that uses teaching analysis as a tool to assess teaching or for teachers themselves to reflect on their own. Dr. Gu's reported the current studies of teaching analytics and their team's teaching analytics design framework. At the end of the report, she showed the team's three studies using teaching analysis to evaluate teaching. Results showed that teachers encounter difficulty moving to and continuously staying in an active state of technology adoption without exogenous impacts, such as learning from peers and practice in the classroom. In addition to impacts from one's own experiences, inactive teachers benefited from external interventions, whereas teachers in active states benefit from peer demonstrations and experience sharing.

4.3 Research on Robust Student Learning and Learning Analytics,[23] Raphael Isokpehi, Bethune-Cookman University, 2019.

As shown in the video,[24] Dr. Raphael Isokpehi presented how he used data visualisation in biology courses to motivate students and scaffold learning. Dr. Isokpehi illustrated an innovative approach to teach biology courses with learning analytics to assess learning and provide timely feedbacks.

4.4 Practical Statistics in Open Learning Initiatives,[25] Dr. Kelly Carey Bethune-Cookman University, 2019

Shown as the second half of the video,[26] Dr. Kelly Carey presented her instructional design and implementation of a statistics course as a part of the Open Learning Initiative (OLI). OLI emphasises integrated instructional design by aligning learning objectives, learning assessment, and learning activities in the beginning.

4.5 Performance-based Assessment, Dr. Ron Tarr, 2019

Shown in the short video,[27] Dr. Hong Liu gave a short introduction of the Dr. Ron Tarr, the co-chair of the first workshop who provided the free facilities and invited two of his formal colleagues and researchers in Lab of Army Research Dr. Keith Browner and Dr. Benjamin Goldberg. His contribution of the free facility and zero cost keynote speakers helped to reserve a budget for the second workshop in 2020.

The second video[28] is his talk on performance-based assessment in the context of military and firefighter training. Dr. Tarr reviewed the early training that most focused on procedures. Then, he addressed the challenges of the training officers to make difficult decisions under complex situations. You cannot test them by multiple choices, like the learning activities occurred in a classroom. Next, he mapped Gagne's nine events of instruction into the context of military training based on performance assessment on real-world problems. Finally, he presented the instructional system design model and Advanced Performance Technologies used for the USA Army. He concluded his talk with several first-hand applications of performance-based assessment technology in military and firefighter training.

4.6 Performance Measurement/Assessment and Critical Need in Advanced Learning Technology and Intelligent Tutoring,[29] Dr. Ron Tarr

Dr. Ron Tarr's talk on the zoom workshop in 2020 is shown in the video.[30] The outline of his talks is:

1 Review on Performance Measurement/Assessment,

2 Reflections on Instructional Design and Learning Technology and its role in Performance Measurement,

3 An Approach to modernise Instruction System Development (ISD) and Operational Experience, and

4 Critical Need in Advanced Learning Technology and Intelligent Tutoring.

Dr. Ron Tarr first reviewed the original ISD procedure in 1975. Then, he presented his iterative development model centred on performance assessment in 2003. Next, Dr. Tarr illustrated the application of his model in firefighter training. He concluded his talk with the challenges and recommendations for future work.

5 Innovative learning environment and instructional design

In the context of this section, we use a learning environment for physical facilities, cyber instruments, and platforms, a combination of human agents and virtual agents that support classroom and online learning. A learning environment usually associates with the instructional design for a specific pedagogy to achieve learning objectives. Under the umbrella of the learning environment and instructional design, we will combine the eight diverse topics such as learning space with human and virtual agents, game-based learning, and innovative instructional designs for REU. Speakers include two keynotes from Dr. Xiaoqing Gu from Eastern China Normal University in China and retired leading instructional designer of Embry-Riddle Aeronautical University (ERAU), Dr. Jerry Klein.

5.1 Innovative Learning Space & Game-based Learning, Dr. Xiaoqing Gu, 2019

At this talk, Dr. Xiaoqing Gu presented her study on game-based learning for STEM. She introduced the definition of game-based learning and the disadvantage of education in games, which were:

1 language and levels were too difficult,

2 content issues, such as including bloody violence,

3 teachers spent a lot of time on selection, and

4 game system did not provide teachers with an analysis of students' learning status.

After that, she introduced what STEM is, different degrees of discipline Integration (from STEM 1.0 to STEM 4.0), and why STEM showed us the STEM labs that her team had built. Then, she elaborated on why we implement Game-Based Learning for STEM and

how to balance gaming and learning. At the end of the report, Dr. Gu showed us her latest research results: Nicola Expedition-a critical thinking assessment game and the design of the professional development activities and impacts on teachers' knowledge in maker technology. She mainly introduced how the research was designed and analysed and what conclusions were obtained.

5.2 Mental Models and Instructional Design,[31] Jerry Klein, 2019

In this keynote,[32] Dr. Hong Liu introduced Dr. Jerry Klein, including the role of Dr. Klein helped to connect the PI, CoPIs into the two sponsored projects and keynote speakers. Dr. Klein introduces the model-based learning process that includes (1) clarifying the problem, (2) developing a conceptual model, (3) developing a mathematical model, and finally (4) conducting experiments to validate the conceptual model and mathematical models. Instead of giving a formal definition, Dr. Klein gives three sentences one at a time and illustrates how our mental models change when more plausive and coherent information is added. We process the input information to construct a mental model as follows: integrating new content into the existing knowledge by updating an existing situation model, and constructing a new situation model on the basis of information obtained from the text or discourse. Comprehension is essentially a process of generating a model that corresponds to the situation described in the text.

5.3 Integrated Learning Space and Work Space for Interactive Data Investigations Dr. Raphael Isokpehi, Bethune-Cookman University, 2020

The video[33] is the presentation of Dr. Isokpehi on his NSF-sponsored research on integrated learning space and workspace for interactive data investigation. He presented an experiential learning case study on estuary environment projects and an example to use COVID-19 data to motivate students to learn data analytics in biology applications.

5.4 iCycLe, intelligent Computer-supported hybrid collaborative Learning environment,[34] Timothy Bernard, and Hong Liu, 2019

The video[35] is the presentation of Dr. Hong Liu and Mr. Timothy Bernard on the concepts and preliminary implementation of the iCycle. The readers can find the details from the published paper[36] (Liu et al., 2020) entitled "Harness big data by iCycle – intelligent Computer-supported hybrid collaborative Learning environment."

5.5 Team Competence Model and Data Collection by BotCaptain,[37] Dr. Hong Liu and Mr. Timothy Bernard, 2020

The second half of the video[38] is the talk presented by Mr. Timothy Bernard and Hong Liu on task-agnostic team competency model and data collection agent called BotCaptain. More details can be found in the article published in this special issue entitled as "Task-Agnostic Team Competency Assessment and Metacognitive Feedbacks for Transparent Project-based Learning on Data Science."

5.6 Game-Based Learning for Data Career Development,[39] Dr. Junell McCall, 2020

As shown in the video[40] (second half), Dr. McCall illustrated how to use game-based learning to promote data-intensive career development. She reviewed each phase of industrial revolutions' characteristics and demonstrated the critical need for the students to commend data analytics skills in the new knowledge-based economics. Game-based learning became popular for its success in motivating students to engage in active learning.

5.7 Ming Wang, ERPsim Real-Time Data Analytics on SAP HANA, 2019

In the presentation shown in the video,[41] Dr. Ming Wang demonstrated his game-based learning business analytics course. The course provided students the marketable skills using the industrial scale SAP HANA technology and ERPsim Real-Time Data Analytics to make data-driven business decisions.

5.8 Collaborative Enterprise Data Analytics Learning Powered by ERPsim – Distribution Game, Dr. Ming Wang, 2020

In her second talk in 2020, shown in the video,[42] Dr. Ming Wang demonstrated how she used ERPsim – a Distribution Game to work on a team project in simulated real-world problems. Each student has a different role and access to different data sets. The students need to make an informed business decision based on the datasets they can retrieve and analyse.

6 Practices in stem education

This section is prepared for broader readers who are interested in practices and applications. Three speakers gave four presentations about applying of the theory and tools mentioned above to solve daily teaching problems in their institutions. The first speaker Dr. Xin Li introduced the grand challenges at UCF to bring the DFW rates down for gateway math courses and how he and his colleagues at UCF used Intelligent Tutoring systems such as Aleks and MyMathLab to mitigate the problem. Dr. Angela Shiflet presented her new book on Biology with Simulation Labs for the Global Citizens. She demonstrated how she used an agent-based simulation tool, NETLOGO, to model and simulated biological phenomena for her students in a liberal arts college. Dr. Wolyniak introduced how he and his colleague Dr. Anderson used CURE to bring authentic research in 'big data' to a small liberal arts college.

6.1 Intelligent Tutoring for Math Gateway Courses, Xin Li

In the panel discussion led by Dr. Xin Li shown in the video,[43] the participants discussed how Academies, Industry, and Government could Collaborate to transfer R&D into student learning gains. Nationally, over 60% of students who begin college intending to complete a STEM major leave the STEM field (PCAST, 2012), and the situation has not noticeably changed for the last eight years. Calculus is a gatekeeper to the STEM

disciplines, and DFW rates are staggered around 30–50%. Dr. Xin Li illustrated the NSF-sponsored Calculus teaching reform project to UCF using Aleks and other supplementary learning to offer more engaged learning to Calculus. The most significant challenge in the previous work of UCF was developing ways to effectively deliver instructional content to large classes (450+ seats) and provide cost-efficient and customisable supplementary mentoring. All participants shared an understanding of the challenges of the gateway math courses for the problem staggered over four decades. There are many interesting suggestions to use education technology to break the status quo. However, the consensus is that there are no easy and quick solutions.

6.2 Biology with Simulation Labs for the Global Citizens, Angela Shiflet

Dr. Shiflet gave a keynote presentation in the video[44] on biology with simulation labs for the global citizens as her new textbook. The biology textbook is written for students in non-biology majors. It is organised into modules, each starting with a motivating real-world problem for case studies. She illustrated some interesting examples of genetic problems and ecosystem problems. To facilitate flipped classrooms and engaged learning, each class starts with inquiring questions, group discussion questions and ends up with many quick review questions, pop quizzes, and active learning exercises for group work. Near the end of her talk, Dr. Shiflet demonstrated several NetLogo agent-based models and simulations of several applications that are attractive to college students. The textbook is accessible online, and the agent-based computational models and simulations can be freely downloaded.

6.3 Bringing authentic research in 'big data' to a small liberal arts college, Dr. Michael Wolyniak

As shown in the video,[45] Dr. Michael Wolyniak presented how he and his colleague Dr. William Anderson introduced authentic research in 'big data' to a small liberal arts college. In addition, he illustrated how Dr. Anderson provided hands-on research experiences to the students of both Hampden-Sydney College (HSC) and Adams State University (ASU) in Colorado through cyberlearning. As an interesting episode, Dr. Anderson ordered pizzas and delivered them to the remote students at ASU concerning the hungry students for the evening classes. A primary reason for most students chose liberal arts colleges is because they enjoyed the intimate relationship between instructors and teachers in small classes and the close-knitted small community.

In his second talk 2020, shown in the video[46] Dr. Michael Wolyniak presented how he and his colleagues at Hampden-Sydney College brought authentic research in "big data" to a small liberal arts college. He first brought up the 2011 Vision and Change Report (NSF, AAAS, and HHMI) on how college biology classes should be taught to promote deep understanding effectively. His current research represents a successful model by introducing authentic hands-on research experience for undergraduates to evaluate complex biological problems (Woodin et al., 2010; Brewer and Smith, 2011). He illustrated how to use complex circuit models and simulation to teach synthetic biology as a system working together like a machine. Consequently, participants who have only high school biology knowledge are attracted to his teaching.

7 List of contributors

7.1 Keynote speakers

Dr. Keith Brawner is a senior researcher for the U.S. Army Combat Capability Development Command Soldier Center at the Simulation and Training Technology Center, and is a co-creator of the Generalised Intelligent Framework for Tutoring (GIFT). He has 14 years of experience within U.S. Army and Navy acquisition, development, and research agencies. He holds a Masters and PhD degree in Computer Engineering with a focus on Intelligent Systems and Machine Learning from the University of Central Florida. His current efforts are on artificial intelligence for the Synthetic Training Environment Simulation and the Combat Capabilities Development Command Soldier Center. He manages research in artificial intelligence for training with the Army's AI Task Force, the University of Southern California's Institute for Creative Technologies, and others.

Dr. Benjamin S. Goldberg is a senior research scientist at the U.S. Army Combat Capability Development Command – Soldier Center, and is co-creator of the Generalised Intelligent Framework for Tutoring (GIFT). Dr. Goldberg is a co-creator of GIFT and the current director of the GIFT program. He is also the organiser of the GIFT Symposium in the past eight years, usually conveying in early summer. He is the team leader for a research program focused on the development and evaluation of Training Management Tools for future Army training systems. His research is focused on the application of intelligent tutoring and artificial intelligence techniques to build adaptive training programs that improve performance and accelerate mastery and readiness. Dr. Goldberg has researched adaptive instructional systems for the last 12 years and has been published across several high-impact proceedings. He holds a Ph.D. in Modelling and Simulation from the University of Central Florida.

Dr. Xiangen Hu is a professor in the Department of Psychology at The University of Memphis (UofM) and senior researcher at the Institute for Intelligent Systems (IIS) at the UofM and is professor and Dean of the School of Psychology at Central China Normal University (CCNU). Dr. Hu is the Director of Advanced Distributed Learning Partnership Laboratory at the UofM, and his primary research areas include Mathematical Psychology, Research Design and Statistics, and Cognitive Psychology, including General Processing Tree (GPT) models, categorical data analysis, knowledge representation, computerised tutoring, and advanced DL.

Dr. Jerry Klein (Consultant for Instructional Design) served as the consultant for instructional design for the last two prior NSF funded projects. He owns KnowledgeKraft, LLC after he retired from ERAU as the leading instructional designer. He worked as a researcher at Bell Lab for 20 years.

Dr. Xin Li is Professor and Chair of the Department of Mathematics at the University of Central Florida. He has published over fifty high-quality journal articles on research topics in approximation theory and scientific computing. He served as PI and Co-PI of three NSF funded project for improving students' research and training at both undergraduate and graduate levels, and an IUSE (Improve Undergraduate STEM Education) project. Dr. Li received the Teaching Incentive Program Award in 1994, 2003, and 2009 at UCF.

Angela Shiflet is an emeriti professor at Wofford College and a Larry Hearn McCalla Professor of Mathematics and Computer Science. Dr. Shiflett was named as the 2009

South Carolina Professor of the Year, and Wofford presented her with the Roger Milliken Award for Excellence in the Teaching of Science. She co-authored seven textbooks, including the first textbook in Computational Science for college students, co-authored with her husband, Dr. George Shiflet.

Dr. Michael Spector served as an external consultant and teacher trainer for the two prior funded projects. Spector currently serves as the Interim Associate Dean for Research & Development College of Information and Professor at UNT. He was Executive Director of the Int. Board of Standards for Training, Performance and Instruction and a Past-president of the Association for Educational and Communications Technology. He is Editor Emeritus of Educational Technology Research & Development; he edited two editions of *The Handbook of Research on Educational Communications* and had 150+ publications to his credit.

Dr. Ronald W. Tarr is President and Chief Consultant of RAPTARR, LLC and previously a senior research faculty member at the University of Central Florida and Program Director of the Advanced Performance Technologies and the RAPTER Lab at the Institute for Simulation and Training (IST). His expertise is on applied research into methods of enhancing human performance through unique interventions of current and emerging technologies, including information, simulation and learning technologies.

7.2 Short presentation speakers

Mr. Timothy Bernard is a graduate student of the MSDS program at ERAU with a B.S. in Cybersecurity. He is a leading developer of BotCaptain (https://n0m4d.gitbook.io/botcaptain/).

Dr. William Cain serves as an assistant professor at University of Wyoming. He is a researcher in the field of educational technology and teacher preparation for 21st Century learning. He worked previously as a teacher of English as a Foreign Language for 14 years in Beijing, China.

Dr. Kelly Carey is an assistant professor in Biology & Environmental Science at Bethune Cookman University. Dr. Carrey served as Co-PI of PI of Rapid grant 2029363 (2021), and PI of Excellence in Research NSF 1901377 (2019–2022).

Dr. Ye Chen serves as an assistant professor of Instructional Technology, Media, and Design at University of West Georgia. Dr. Chen teaches courses in technology integration and instructional design and development. Her research interests include design and evaluation of technology-supported learning environments, preparing teachers for integrating emerging technology, and learning analytics.

Dr. Matthew Ikle served as the PI of the NSF IUSE 1626602 and the CoPI of NSF TUES project #1244967. He currently serves as the business owner and president of Ideas in Mind Inc, and as the AI Chief at the SingularityNET Foundation. He served as a full professor of Computer Science at Adam State University (ASU) until his retirement in 2018. After his retirement, he continued his leadership role of IUSE project and planned teaching duties as an adjunct professor at ASU. His research encompasses AI and robotics.

Dr. Raphael Isokpehi is a Professor in Biology at Bethune-Cookman University. Dr.Isokpehi served as the CoPI of the IUSE 1626602, PI of Rapid grant 2029363 (2021), and PI of Excellence in Research NSF 1901377 (2019–2022).

Dr. Hong Liu is a professor at ERAU. He served as the PI of the TUES1244967 and CoPI of IUSE16266602. He served as the faculty initiator for the Master of Science in

Data Science (MSDS) program at ERAU. He published 34 peer-reviewed articles in Math, Computer and Data Science, and STEM Education. Dr. Hong Liu served as the chair of the two workshops.

Dr. Benjamin MacLaren is a cognitive scientist and senior research staff in the Human Computer Interaction Institute of Carnegie-Mellon University. He is the principle designer and implementer of a new curriculum for teaching 'pathway algebra' to high school and college students. The Cognitive Tutor for Analysis in Genetics has been served as a research platform for over a half dozen large grants from NSF, DoEd, HHMI and others.

Dr. Junnel McCall is Associate Director of Career Services Leadership Team Member, Transdisciplinary Data Scholars Development Program at Bethune-Cookman University.

Dr. Ming Wang serves as a professor of information systems at Cal State University, LA, and the SAP University Alliances Faculty Coordinator since 2006. She published 44 journal articles and received the 2015 University Outstanding Professor Award.

Dr. Michael Wolyniak serves as a McGavacks Associate Professor of Biology and Director of Undergraduate Research at HSC. He served as CoPI of IUSE 1626602, CoPI of NSF HDR 1922516 (2019–2022), PI of RUI #1354603 (2015–2017), and PI of NSF 1916486. He was awarded Hampden-Sydney's John Peter Mettauer Award for Excellence in Research in 2013 and Cabell Award for Excellence in Teaching in 2012. Dr. Wolyniak is one of the pioneers in USA who brought authentic course-based undergraduate research experience to liberal arts colleges.

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Notes

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5 https://drive.google.com/file/d/1LbjnNvSuPIgjrBjv9nDZO5UsXJrV26us/view?usp=sharing
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15 https://hundred.org/en/innovations/the-cognitive-tutor-for-analysis-in-genetics-ctag-it-s-not-just-for-genetics
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