CHI 2018 Workshop:
Data-Driven Educational Game Design

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Abstract

This paper describes a "data-driven educational game design" CHI workshop. The intent of the workshop is to bring together experts from CHI, educational games, learning science and data analytics to discuss *how* game playing works for learning and *how* games can be better designed to lead to engagement and learning. The outcome of the workshop will be a journal paper that summarizes the current state-of-the-art in data-driven educational game design and provides recommendations for the way forward for educational game designers and developers.

Author Keywords

Educational Games; Game Design; Data Analytics

ACM Classification Keywords

H.5.3. Information interfaces and presentation (e.g., HCI): Miscellaneous

Background

In this one-day workshop, participants will work together and discuss ways that the CHI, educational games, learning science and data analytics research communities can go beyond determining whether computer-based game playing is an effective instructional method to answering the deeper questions of *how* game playing works for learning and *how* games can be better designed to lead to engagement and learning. We see the issue as being largely *data driven*, by the use of computer-based educational games by

actual learners and by leveraging observations and logged data from that use.

There is palpable excitement in schools across the U.S. and around the world about the potential of computer-based educational games to enhance student learning. A high percentage of teachers in middle and high schools in the U.S. have their students use games at least once a week (55% of 513 teachers, as reported in a survey conducted by Gamesandlearning.org, 2015). Combined with the increasing interest of young people in playing computer games, the enthusiasm about educational games is clearly substantial and growing. For example, Lobel et al. (2017), reported a playing frequency of 4.90 to 5.81 hours per week for children age 7 to 12.

Research is also beginning to provide evidence that educational games can be effective for learning (Clark, Tanner-Smith, & Killingsworth, 2016; Crocco, Offenholley, & Hernandez, 2016; Ke, 2016; Mayer, 2014; Wouters & Oostendorp, 2017). Studies in the STEM area, in mathematics (Habgood & Ainsworth, 2011; Riconscente, 2013), science (Barab et al., 2009; Hwang, Wu, & Chen, 2012), and language learning (Suh, Kim, & Kim, 2010; Yip & Kwan, 2006), have demonstrated learning and/or engagement benefits for educational games.

But *how* have educational games had this impact and *how* can we use what we've learned to design better games, games that lead to student learning? A first consideration is that games are a broad and diverse medium. For example, *Dance Dance Revolution* has a physical interface where you play by moving your body and react quickly, whereas *Civilization* has players interact with a complex system model, with lots of time for reflection at each turn. These differences imply different opportunities and mechanisms for learning, and thus different design decisions. Second, the assumptions of many proponents of educational games about how learning happens with games may be faulty.

It is generally believed that games lead to more engagement through enhanced motivation, which, in turn, leads to better learning. While this process of learning with games seems entirely plausible, research is unclear on the role motivation has in learning with games. For instance, some educational game studies have led to learning benefits for gameplay compared to non-game learning interventions, without showing motivational differences (Clark, et al., 2016; Wouters et al., 2013). In some cases, enticing and exciting game features have been shown to distract students, or even impair their learning outcomes (Lomas et al., 2017; Rowe, Shores, Mott, & Lester, 2010).

Computer-human interaction, educational games, learning science and data analytics are all fields that could contribute to answering these educational game "how" questions, helping us design and develop better educational games. Games themselves can contribute to the conversation, by being used as assessment tools for learning and engagement, and this is a topic we will take up and discuss at this workshop. We will bring together CHI experts, ed game designers, learning scientists, and data analytics researchers to discuss ways in which we, as a multi-disciplinary community, can dig deeper to answer the "how" questions of learning with games. Some of the specific questions we will grapple with during this workshop include:

- What are the most propitious techniques – both qualitative and quantitative – for identifying and analyzing the key features of educational games?
- What have we learned about ways to balance the use of game and learning features in designing educational games? What is the optimal way to bring these disparate (and sometimes conflicting) features together to optimize learning?

- How can data collected during game play, both qualitative and quantitative, be used to help us design and build better games, games that lead to the best student outcomes?

- How can games be used for implicit assessment, as tools for analyzing the instructional affects of games and, ultimately, for designing better games?

As an outcome of this workshop, we will create the foundation for writing a joint journal paper that summarizes the current state-of-the-art in data-driven educational game design and provides recommendations for the way forward for educational game designers and developers. An outline for that paper will be jointly created at the workshop; the actual writing of the paper will primarily take place after the workshop, with contributions from the workshop participants and program committee members. We believe that such a summary of the state-of-the-art requires input and contributions from various fields, including educational games, computer-human interaction, learning science, and data analytics. We intend that this workshop will help to create a new framework for analyzing and designing educational games, one that leverages the actual use of educational games, as well as tracking of that use.

Organizers of the Workshop

Co-Organizers (3 organizers)

Bruce M. McLaren is the main contact person for this workshop, a Research Associate Professor at CMU and the current president of the International Society of Artificial Intelligence in Education (IAIED). Bruce has broad and deep experience with educational technology and learning science research, particularly with intelligent tutoring systems (Aleven et al., 2016; McLaren, Adams, & Mayer, 2015), e-Learning principles (McLaren et al., 2016; McLaren, DeLeeuw, & Mayer, 2011), and educational games (McLaren, Adams, Mayer,

& Forlizzi, 2017; McLaren, Farzan et al, 2017). Bruce was the PI in the development of and experimentation with an educational game called *Decimal Point*, focused on helping middle school students learn decimals. In a study involving more than 150 middle school students, *Decimal Point* led to significantly more learning and was rated by students as significantly more engaging than a more conventional, yet still effective computer-based tutoring approach (McLaren, Adams, Mayer, & Forlizzi, 2017).

Jodi Asbell-Clarke is the Director of the Educational Gaming Environments Group (EdGE) at TERC, a non-profit research and development organization focusing on innovative, technology-based math and science education. Jodi leads EdGE at TERC, a team of game designers, educators, and researchers who are studying implicit STEM learning in digital games. Jodi's academic background includes a MA in Math, an MSc in Astrophysics and a PhD in Education. In 2009, she co-founded EdGE with her colleagues to study how game-based learning can transform science education.

Jessica Hammer is an Assistant Professor at CMU who is also an award-winning game designer (Turkington & Hammer, 2017; Hammer, 2012). She has published extensively on games and learning (Hammer & Davidson, 2017; Hammer & Heller, 2012), as well as on the game design process (Choi et al., 2016).

Program Committee (15 members)

Vincent Aleven is an Associate Professor in the Human-Computer Interaction Institute at CMU and a co-founder of Carnegie Learning, Inc., a Pittsburgh-based company that markets Cognitive Tutor™ math courses. Vincent is Editor-in-Chief of the International Journal of AI in Education. He has published over 250 papers.

Erik Andersen is an Assistant Professor at Cornell University. He is a co-creator of multiple award-winning games for learning and has multiple publications on

large-scale experimentation through games and automatic generation of learning progressions.

Ryan Baker is an Associate Professor at the University of Pennsylvania. He studies how interaction data can be used to infer student learning and engagement, including in the context of complex educational games.

Michael Eagle is a Postdoc at CMU who focuses on analyzing data from human learners in interactive problem-solving environments. Michael has worked in data science in the video game industry and has multiple publications on educational game design and evaluation.

Jacob Habgood is a Senior Lecturer in Game Development and Director of the Steel Minions game studio at Sheffield Hallam University in the UK. He has a decade of commercial experience working in the console games industry, and runs the world's largest PlayStation teaching lab within the university's Department of Computing.

Erik Harpstead is a Systems Scientist at CMU whose research focuses on developing tools and techniques to aid educational game designers in evaluating their design ideas in terms of their educational goals. Erik has authored several publications on educational game design and evaluation.

Amy K. Hoover, is an Assistant Professor of Informatics at New Jersey Institute of Technology. Her research in educational games focuses on assessing player strategies and learning with techniques from artificial intelligence.

Ioanna (Jo) Iacovides is a Lecturer in the Institute of Educational Technology at the Open University, UK. Jo's research focuses on the use of digital games in formal education and on exploring how playful technologies and games support informal learning.

James Lester is a Distinguished Professor of Computer Science and Director of the Center for Educational Informatics at North Carolina State University and has

been investigating learning analytics in game-based learning for more than a decade.

Conor Linehan is a Lecturer in Applied Psychology at University College Cork, Ireland. Conor's work applies behavioral psychology to the design of games for education and behavior change.

James Derek Lomas is an Assistant Professor of Industrial Design at Delft, the Netherlands, and designer of over 35 educational games with PlaypowerLabs.com. Derek conducts research with large-scale game experiments to test theories of learning and motivation.

Richard E. Mayer is an educational psychologist renowned for applying the science of learning to education and has an extensive background in learning theory in technology-rich environments, including e-learning (e.g., Clark & Mayer, 2016; Mayer, 2009) and computer games for learning (Mayer, 2014).

Amy Ogan is an Assistant Professor of Human-Computer Interaction at Carnegie Mellon University. Her work examines the sociocultural context of adaptive learning technologies including game-based environments.

Jonathan Rowe is a Research Scientist in the Center for Educational Informatics at North Carolina State University. His research interests are in intelligent game-based learning environments, learner modeling, interactive narrative, and learner engagement.

Magy Seif El-Nasr is an Associate Professor at Northeastern University. Magy's research focuses on developing models of how users interact within a game environment, focusing on engagement, emotions, motivations, visual understanding, expectations, etc. She published the first book on Game Analytics.

Website
This CHI workshop is advertised through the following webpage:

This website is hosted at CMU, under the account of the main workshop organizer, Bruce McLaren.

Pre-Workshop Plans

Prior to the CHI workshop, we will recruit participants in multiple ways. First, and most importantly, our organizers and program committee will contact people within their professional networks (which overlap largely with the theme and focus of this workshop). Given that all of the organizers and committee members have experience with the CHI, educational games and/or data analytics communities, and have attended many game-related events (e.g., CHI Play, the Serious Play Conference, and the Game Developers Conference (GDC)), we expect that this word-of-mouth approach will attract many participants. Second, we will leverage our access to various mailing lists through professional societies and associations. For instance, McLaren, as the current president of IAIED, has access to a mailing list for that community and will announce the workshop through that channel. Finally, we will have a website that will be used to draw attention to the event. We believe that these efforts will lead to an enthusiastic response and turnout.

Workshop Structure

This will be a one-day workshop, capped at 20 participants, and designed to be as interactive as possible. We intend to use a large portion of the workshop time for discussion and brainstorming about ways to uncover the secrets of educational games, the qualitative and quantitative techniques that are most appropriate for analysis, and how that subsequently supports educational game design. We expressly do not want a "mini-conference" style workshop where everybody presents their own work for the entire day.

The general plan for the workshop is as follows:

1st two hours: The co-organizers will start by summarizing the goals of the workshop and everyone will briefly introduce themselves. During their introductions, each participant will identify and briefly describe an *educational game exemplar*, an educational game they are associated with or find interesting and/or inspiring. As part of discussing the game, each participant should mention any qualitative and/or quantitative techniques that have been used to understand *how* that game has had its impact and *how* its design may have led to student engagement and/or learning. Each different game, along with the associated analysis techniques, will be added to a poster on the wall.

Once introductions are complete, each attendee will be given post-it notes to write questions, research findings, relevant study methods, or other thoughts. They will circulate through the space and add post-its to as many of the exemplar games as desired. During this time, attendees can also meet and mingle.

Next hour and 1/2: Participants will break into groups to discuss the game exemplars. Each group will be assigned a set of games, based on the exemplars generated by members of that group. Groups will spend 15 minutes on each game, discussing both the game itself and the feedback provided during the first activity. Then, they will reflect across all the group's games and develop larger themes, theories, and ideas.

At the end of this section of the day, for the final 20 minutes or so, groups will be re-assigned. The workshop participants, led by the co-organizers, will decide on broad areas of interest that would constitute good working groups for discussion and brainstorming during the next section of the day. With an eye toward the ultimate outcome of the workshop -- writing a journal paper on the state-of-the-art in data-driven educational game design -- the groups will be chosen based on interesting sections of that paper.

At this point, we will break for lunch. Participants will be encouraged to have lunch with their working group.

Next two hours: Breakout groups of 4-5 people will be formed to more fully discuss common approaches and interests. Participants will organize into groups based on common interest, as indicated by the initial introductions and discussed at the end of the first section of the workshop. If any participants find it difficult to be part of a specific group, the organizers of the workshop will guide in this process.

During the breakout group work, participants should grapple with at least two questions: either those that are the stated focus of the workshop (see the "Background" section of the proposal) or other questions of interest that emerge from the initial part of the workshop and are approved by the workshop organizers.

To assure effective outcomes from this part of the workshop, each breakout group will start by naming a "note taker", someone who agrees to record the key points of discussion during the breakout period and who is willing to present the findings during the final hour of the workshop. The note taker will be encouraged to use PowerPoint, or a similar presentation tool, to report back to the group (as well as to provide notes to support the writing of the journal paper)

Final hour: For the first ½ hour of this part of the workshop, each of the 3 or 4 breakout groups will report back to the larger group regarding what they discussed and decided within their groups. Emphasis should be on the key questions of the workshop, either those listed in the "Background" section above, or those that emerge during the initial part of the workshop. The primary product of this workshop - a journal paper which surveys techniques and approaches for analyzing learning with games - will also be discussed and planned during this final period of the workshop. Where to publish such a paper will be a key topic of discussion.

Resources: Resources needed for the workshop are a room with 20 chairs, tables for all chairs and a projector to display PowerPoint slides. The tables should be easily moveable to accommodate the breakout portion of the workshop, when participants will work in smaller groups. The room should be large enough so that 4-5 groups can separate from one another without noise from each group disturbing others. If participants have games on handheld devices that cannot be plugged into a projector, it will be their responsibility to inform the workshop organizers well before the workshop of their technology needs.

Post-Workshop Plans
In order to assure that this workshop has lasting impact, we plan to write a paper that combines the ideas and results of the various breakout groups. The paper will be a roadmap forward for educational game analytics. The paper will be submitted to an appropriate journal.

Call for Participation
The call for participation to this workshop is as follows:

We seek participants for a one-day CHI workshop titled "Data-Driven Educational Game Design." The workshop is intended to bring together CHI specialists, educational game designers, and educational game learning analysts to discuss how to uncover and better understand the affects of games for learning, in terms of engagement, motivation, and learning. Participants should have either designed and developed an educational game or are experimenting with an existing educational game. Having done some data analytics work, either qualitative or quantitative, to understand these games is useful, but not essential, to participating in the workshop. The workshop will start with introductions and game analysis, followed by breakout groups for discussion and brainstorming, followed by reporting back to the larger group regarding methods and approaches for moving the field of educational game analytics forward. A key outcome of the workshop will be a joint

paper that will be written by the workshop participants, one that summarizes the current state-of-the-art in data-driven educational game design and provides recommendations for the way forward. Interested participants should submit a paper of no more than 5 pages to the main organizer, Bruce McLaren of Carnegie Mellon University (bmclaren@cs.cmu.edu). Note that at least one author of each accepted paper must attend the workshop and all participants must register for both the workshop and at least one day of the conference. More information about this workshop can be found at http://www.cs.cmu.edu/~bmclaren/projects/CHI-Workshop-DataDrivenEdGameDesign.html.

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