Analytics for Game-Based Learning

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Abstract
The purpose of this special section is to collect in one place how data in game-based learning environments may be turned into valuable analytics for student assessment, support of learning, and/or improvement of the game, using existing or emerging empirical research methodologies from various fields, including computer science, software engineering, educational data mining, learning analytics, learning sciences, statistics, and information visualization. Four contributions form this special section, which will inspire future high-quality research studies and contribute to the growing knowledge base of learning analytics and game-based learning research and practice.

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1. Introduction

The educational benefits of games have been well-documented over the past decade. In a widely cited meta-analysis, Clark and colleagues (2016) report that games had a moderate to strong effect on improving overall learning outcomes, including cognitive and interpersonal skills, compared to non-game conditions. While ample evidence shows that games, in general, have a great potential to support learning, the vast and rapid data generated from learner interactions with the game can be overwhelming for educators and learners to process, thus possible new insights about learners can remain unavailable.

Learning analytics holds the potential to transform this game data into meaningful insights that can be used by teachers and learners to improve learning, modify strategies, provide formative feedback, or redesign the curriculum around the game (Loh et al., 2015). Reflecting on the work of game-based learning and assessment over the past 10 years, Kim and Ifenthaler (2019) suggested that the field of game-based learning and assessment can greatly benefit from the application of learning analytics in all areas, from the design process to classroom implementation. However, it is a challenge to implement learning analytics in digital games such that they are grounded in theory and practice, technically sound, and useful for teachers and learners without flashy, cumbersome additional features (Ifenthaler & Gibson, 2019). Still, recent research has seen advances in game-based learning embracing the opportunities of data science (Alonso-Fernández et al., 2019).

This special issue brings together scholarly research and theory focusing on contemporary issues related to analytics for game-based learning. The contributions provide insights into how educational data, analytics systems, and advanced digital technologies contribute to successful learning and teaching via game-based learning and assessment.

2. Summary of the Special Section

In summer 2021, a call for submissions was circulated through scientific mailing lists as well as through the regular channels of learning analytics, game-based learning, and educational technology groups. The call defined the focus of the potential submissions as follows:

- Using learning analytics to improve the educational game design process
- Learning analytics to measure process skills such as troubleshooting or productive struggle and 21st Century skills such as creativity and collaboration in game environments

- Applications of learning analytics for game-based assessment: The interplay between the psychometrics and learning analytics
- Applications of learning analytics to promote formative assessment practices and playful pedagogies in classrooms
- Learning analytics to support the implementation of game-based learning in classrooms including recommendations/hint systems, adaptive games/feedback, and dashboards
- The role of teachers and students as co-designers to design, develop, and evaluate learning analytics from the game
- Interoperability, generalizability, and scalability of educational data and learning analytics in game-based learning
- Validating and evaluating learning analytics models and applications in game-based learning

Initially, 23 abstracts were submitted by the end of September 2021. Upon careful review and agreement among the advisory board, nine of them were invited to submit a full manuscript by the end of January 2022. The main criteria for selecting manuscripts were a clearly articulated focus on analytics for game-based learning, and how well this focus was consistently enunciated throughout the proposed work. Each manuscript was assigned to at least three reviewers of the special section review board and additional reviewers from the *Journal of Learning Analytics*. All the initial reviews were completed by the end of March 2022. Based on the comments of the reviewers and the individual feedback of the section editors, the manuscripts were moved to the second round of reviews. Authors were asked to submit their revised manuscript by the end of June 2022 addressing the reviewers' and section editors' comments. The final acceptance of manuscripts was completed by the end of August 2022.

This special section begins with a paper by Jiaqi Yu, André Denham, Jewoong Moon, and Wenchao Ma who critique the lack of information on the impacts of games on learning progression and outcomes. Their research paper, *Developing a Game Learning Analytic System Using a Continuous Conjunctive Model*, presents an event-based strategy for tracking learner interactions with parameters at an attribute level, hence, offering a parsimonious assessment using continuous data. The findings suggest that the attribute mastery of learners improved during the gameplay and that learners benefit from using the scaffolds for three of the attributes instructed by the game.

Game Learning Analytics: Blending Visual and Data Mining Techniques to Improve Serious Games and to Better Understand Player Learning emphasizes that the application of analytics is a complex and costly process that is not yet generalized in game-based learning. Cristina Alonso-Fernández, Antonio Calvo-Morata, Manuel Freire, Iván Martínez-Ortiz, and Baltasar Fernández-Manjón highlight the need for using standard data formats and game-independent analyses as well as visualizations that can be applied to yield meaningful information to better understand learner actions and results in game-based learning.

Min Liu, Ying Cai, Songhee Han, and Peixia Shao seek to understand learning pathways based on behavioral patterns and the relationship with performance levels when learners use a game-based learning environment as their science curriculum. *Understanding Students' Navigation Patterns in Game-Based Learning* offers an insightful glimpse into learner navigation patterns in relation to their performance; however, available log data could not explain all learner actions within the game-based learning environment.

The final research paper of this special section, *Multimodal Data Fusion to Track Students' Distress during Educational Gameplay*, describes how supervised machine learning can be used to build and test classifiers that yield an estimated probability of distress states. Jewoong Moon, Fengfeng Ke, Zlatko Sokolikj, and Ibrahim Dahlstrom-Hakki suggest the feasibility of multimodal data fusion in developing game-based learning analytics and highlight the benefits of optimizing several methodological means for multimodal data fusion in game-based learning research.

3. Outlook

The four papers of this special section cover a wide range of contributions focusing on analytics for game-based learning and assessment, and provide empirical evidence as well as practical implications for an emerging field in learning analytics research. The theoretical foundations, insightful findings, innovative frameworks, and practitioner reports will inspire future efforts that leverage learning analytics to increase the validity of game-based learning research and contribute to the growing knowledge base of learning analytics and game-based learning research and practice.

This collection of papers also highlights a wide range of questions and concerns that researchers and practitioners wish to address in game-based learning, and how game telemetry data has become the primary source of evidence for research into game-based research and practice. The collection also re-emphasizes the need for interdisciplinary approaches to address the unique challenges of game-based learning.

Declaration of Conflicting Interest

The authors declared no potential conflicts of interest concerning the research, authorship, and publication of this article.

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