2022 AECT Conference CFP
https://members.aect.org/events/call/
Conference: Oct 24-28, 2022, Las Vegas, Nevada

Title
Designing a digital educational game to support and measure higher education students' learning of cellular and human biology

Authors
Ji Yae Bong, Educational Technology, Concordia University
Ross Shaw, Biological Sciences, MacEwan University shawr@macewan.ca
Isabelle Sperano, Art and Design, MacEwan University speranoi@macewan.ca
Robert Andruchow, Art and Design, MacEwan University andruchowr@macewan.ca
Dana Cobzas, Computing Science, MacEwan University cobzasd@macewan.ca

Keyword
Gaming, Gamification & Simulation
Design-based research

Short Description (75 words)
This presentation shares the design of a digital educational game, *Life on the Edge*, to support higher education students' learning of biology and a usability study conducted (a) to examine the learning effect, game satisfaction, and flow experience and (b) to investigate the students' reactions on the overall game design and specific learning supportive game features. This presentation will discuss the advanced design of the educational game based on the findings.

Abstract (1000 words)
Digital educational games have received a tremendous amount of attention as a highly effective learning tool (Ke, 2009; Mayo, 2009). Well-designed educational games can engage students and successfully facilitate transferring content and strategies outside of the game environment (Nietfeld, 2020). Extensive work on designing and testing learning-supportive game features has been conducted by researchers (Rahimi et al., 2021; Wouters & Van Oostendorp, 2013; Yang et al., 2021). However, researchers still have struggled to develop theory that can drive effective educational game design (Liu et al., 2021). There is an urgent need for more research identifying player- and game design-related factors that influence game effectiveness and provide insights into the underlying rationale of effectiveness. Such studies are necessary to develop theory that can be used by practitioners to design and facilitate highly effective educational games (Proulx et al., 2017; Yang & Chen, 2020).

To achieve these goals, we, as a team of experts in educational technology, biology, interactive design, and computer science, have designed, developed, and evaluated the digital serious game, *Life on the Edge* (LOTE), using an iterative design and development research approach (McKenny & Reeves, 2012; Rickey & Klein, 2007) to support and measure higher education students' learning of cellular and human biology (authors, 2021; 2019). This presentation shares our initial design of the LOTE game and a usability study conducted (a) to examine the effect of using the game as part of the course materials in university classrooms on learning outcomes, (b) to report

the students' game satisfaction and flow experience, and (c) to investigate the students' reactions on the overall game design (i.e., flow antecedents) and specific learning supportive game features. This presentation will be concluded with the advanced design of the educational game based on the findings.

Method

Participants were the 123 undergraduate students enrolled in two Biology-related online courses in a university in Canada. The LOTE game was integrated as part of their course materials to these courses in Fall 2021. We measured student learning through a comparison of a pretest before gameplay and a posttest after gameplay. The participants also completed a game satisfaction questionnaire (Shute et al., 2020), a flow questionnaire (Kiili, 2006), and a learning-support satisfaction questionnaire (Shute et al., 2020) after gameplay. For data analysis, a paired-sample *t*-test analysis, descriptive analysis, and correlation were used as described in the following section.

Results

We conducted the pre- and post-tests to examine the learning effect. The results showed significant learning gains via a paired-sample *t*-test analysis (M_{pre} = 3.58, SD_{pre} = 1.45, M_{post} = 3.96, SD_{post} = 1.49, $t(122) = -2.60$, $p < 0.05$).

To examine students' perceived game satisfaction, we reviewed their responses to the 5-point Likert scale (ranging from 1, strongly disagree, to 5, strongly agree) survey questions. Overall, the students found the game fun and interesting (M = 4.42, SD = .62) and helpful for learning biology (M = 4.31, SD = .51). They also reported high levels of enjoyment playing the game (M = 4.14, SD = .68). In terms of the questions asking about their game performance, the students reported positive but slightly lower scores. To be specific, they reported that they were pretty skilled at playing the game (M = 3.54, SD = .89) and they believed they performed quite well in the game (M = 3.86, SD = .79). Many students also reported that they put a lot of effort into solving levels (M = 3.91, SD = .79).

We also examined the students' flow experience along with the flow antecedents as the effective game design features. Overall, students reported the positive flow experience (M = 3.83, SD = .51). The five flow antecedents also were positively assessed by the students: Challenge-skill balance (M = 3.82, SD = .69); goal (M = 4.28, SD = .60); feedback (M = 4.19, SD = .53); control (M = 3.91, SD = .74); and playability (M = 3.89, SD = .61). Also, all the flow antecedents had positive relationships to the flow experience: Challenge (r = *.46**); goal (r = *.32**); feedback (r = .30*); control (r = .34*); and playability (r = .27*), *p < .001.

We further examined students' perceptions of the specific in-game learning supportive features that students have the control to use. These eight features are not the essential components of the gameplay and they need to be clicked by players. More than half of the students agreed that game states (82 students, 66.7%) and speed control (65 students, 52.8%) especially helped them solve the game levels. Also, many students reported these three features helped them learn biology: Encyclopedia before gameplay (89 students, 72.4%); game states (66 students, 53.7%); and encyclopedia during gameplay (76 students, 61.8%). Additionally, many students agreed that all eight features were pretty easy to use.

Conclusions and Future Directions

In general, we have confirmed that the gameplay positively influences on understanding of biology concepts and overall, students reported the high level of game satisfaction and positive flow experience. The flow antecedents that are considered as the critical game design features also received positive scores from the students. However, further design efforts and research is still needed to maximize the students' engagement (including flow experience) and learning. In terms of the students' reactions to each in-game learning supportive feature, our findings provide empirical data supporting the different use of game features and learners' different perceptions of them. This presentation will be concluded with the advanced design of the educational game based on the findings.

References

Authors, 2021

Authors, 2019

Ke, F. (2009). A qualitative meta-analysis of computer games as learning tools. In R. E. Ferdig (Ed.), *Handbook of research on effective electronic gaming in education* (pp. 1–32). Hershey: Information Science. http://dx.doi.org/10.4018/978-1-59904-808-6.ch001

Kiili, K. (2006). Evaluations of an experiential gaming model. *An Interdisciplinary Journal on Humans in ICT Environments, 2*(2), 187–201

Liu, Y. C., Wang, W. T., & Lee, T. L. (2021). An integrated view of information feedback, game quality, and autonomous motivation for evaluating game-based learning effectiveness. *Journal of Educational Computing Research, 59*(1), 3–40. https://doi.org/10.1177%2F0735633120952044

Mayo, M. J. (2009). Video games: A route to large-scale STEM education? *Science, 323*, 79–82, https://doi.org/10.1126/science.1166900

McKenny, S., & Reeves, T. C. (2012). *Conducting educational design research*. London: Routledge.

Nietfeld, J. L. (2020). Predicting transfer from a game-based learning environment. *Computers & Education, 146*. 103780.

Proulx, J. N., Romero, M., & Arnab, S. (2017). Learning mechanics and game mechanics under the perspective of self-determination theory to foster motivation in digital game based learning. *Simulation & Gaming, 48*(1), 81–97. https://doi.org/10.1177%2F1046878116674399

Rahimi, S., Shute, V., Kuba, R., Dai, C.-P., Yang, X., Smith, G., & Alonso Fernández, C. (2021). The use and effects of incentive systems on learning and performance in educational games. *Computers & Education, 165*, 104–135. https://doi.org/10.1016/j.compedu.2021.104135

Rickey, R. C., & Klein, J. D. (2007). *Design and development research*. Mahwah, NJ: Routledge/Lawrence Erlbaum Associates.

Shute V, Rahimi S, Smith G, et al. (2020). Maximizing learning without sacrificing the fun: Stealth assessment, adaptivity and learning supports in educational games. *Journal of Computer Assisted Learning*, 1–15. https://doi.org/10. 1111/jcal.12473

Wouters, P., & Van Oostendorp, H. (2013). A meta-analytic review of the role of instructional support in game-based learning. *Computers & Education, 60*(1), 412–425. https://doi.org/10.1016/j.compedu.2012.07.018

Yang, J. C., & Chen, S. Y. (2020). An investigation of game behavior in the context of digital

game-based learning: An individual difference perspective. *Computers in Human Behavior, 112*, 106432, https://doi.org/10.1016/j.chb.2020.106432.

Yang, X., Rahimi, S., Shute, V., Kuba, R., Smith, G., & Alonso-Fernández, C. (2021). The relationship among prior knowledge, accessing learning supports, learning outcomes, and game performance in educational games. *Educational Technology Research and Development, 69*(2), 1055–1075. http://dx.doi.org/10.1007/s11423-021-09974-7