

Digital games and mathematics: Designing a game for learning probability in secondary school

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Introduction

Digital Game-Based Learning (DGBL), a learning approach based on the concept of using digital games for educational purposes, has recently emerged as an important area of education research (e.g. Byun & Joung, 2017). Digital games can provide an alternative to teacher-centered practices by making learning more enjoyable and engaging (Siew, 2018; Es-Sajjade & Paas, 2018). Furthermore, numerous studies indicate that digital games can improve students' mathematical motivation, engagement, active participation, and comprehension (e.g. Siew, 2018; Byun & Joung, 2017). DGBL is also associated with crucial 21st-century skills, including critical thinking, creativity, problem solving, collaboration, communication, and digital literacy (Gee, 2005; Williams-Pierce, 2019). For effective mathematics learning, NCTM (2014) emphasizes the importance of a problem-based learning approach, productive struggle, informative feedback on learning, and the experience of progressive growth, all of which are characteristics of good mathematics learning games (Gee, 2005). Byun and Joung's (2017) meta-analysis of current trends on DGBL in mathematics education revealed that the majority (two-thirds) of existing studies were conducted with elementary school students and that most digital games were drill-and-practice games related to procedural knowledge, in which practice tasks are embedded into digital settings. They concluded that digital games for upper-secondary mathematics have received little attention in research and design.

Game design

Given the abundance of games for drill-and-practice, we developed the game called ProbChallenge, in which players learn about probability, a topic in upper secondary mathematics. The game was developed as part of the ERASMUS+ project GAMMA (GAME-based learning of MAThematics) through a collaborative effort of researchers, educators, and teachers. The game was designed in accordance with the model by Alevén et al. (2010):

Specification of educational objectives (prior knowledge and skills; learning and retention; potential transfer)

Following this framework, the learning objectives of ProbChallenge can be analyzed as follows. The knowledge and experience of handling fractions and percentages are required because the player will use both to express the probability of an event. By playing ProbChallenge, the student or player will learn to determine the sample space and possible outcomes, describe certain and impossible events, calculate the probability of a favorable event, utilize the classical definition of probability, and calculate the probability of intersection, union, and complement. For instance, the player will encounter the map which depicts the favorable outcomes for a specific event, and then the player must select answers that describe that event based on the figures provided to proceed further. One

may wonder, for instance, if the game assists players in applying the concept of probability to daily events. The game events are fictional, but the concept of probability and its calculation can be applied to real-world situations.

MDA (Mechanics-Dynamics- Aesthetics)-framework

ProbChallenge is a narrative single-player game. The player is an intern who reports to the laboratory for work. The game mechanics is quite simple. To continue working in the laboratory, the player must choose, select, or input an appropriate response. The educational content is tightly woven into the game core mechanics. When a game is played, its mechanics generate its dynamics, which evoke a specific aesthetics.

Principles for instructional design

The game provides immediate feedback on each opportunity to apply the targeted math knowledge. The findings of cognitive load theory are implemented, such as the use of worked examples, the avoidance of animations due to their detrimental effect on working memory, and the combination of different types of information—a picture plus a narrative (Sweller et al., 2019).

The game is being piloted in upper secondary schools with promising effect on students' knowledge. It is available for download on Google Play and the Apple Store.

References

- Aleven, V., Myers, E., Easterday, M., & Ogan, A. (2010). Toward a framework for the analysis and design of educational games. In G. Biswas, D. Carr, Y. S. Chee, & W. Y. Hwang (Eds.), *Proceedings of the 3rd IEEE International Conference on Digital Game and Intelligent Toy Enhanced Learning* (pp. 69–76). IEEE Computer Society.
- Byun, J., & Joung, E. (2018). Digital game-based learning for K-12 mathematics education: A meta-analysis. *School Science and Mathematics, 118*(3-4), 113–126.
- Es-Sajjade, A., & Paas, F. (2020). Educational theories and computer game design: lessons from an experiment in elementary mathematics education. *Educational Technology Research and Development, 68*(5), 2685–2703. <https://doi.org/10.1007/s11423-020-09799-w>
- Gee, J. P. (2005). Learning by design: Good video games as learning machines. *E-learning and Digital Media, 2*(1), 5–16.
- NCTM [National Council of Teachers of Mathematics] (2014). *Principles to actions: Ensuring mathematical success for all*. National Council of Teachers of Mathematics.
- Siew, H. P. (2018). Pedagogical change in mathematics learning: Harnessing the power of digital game-based learning. *Journal of Educational Technology & Society, 21*(4), 259–276.
- Sweller, J., Van Merriënboer, J. J. G., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review, 31*, 261–292.
- Williams-Pierce, C. (2019). Designing for mathematical play: failure and feedback. *Information and Learning Sciences, 120*(9-10), 589–610. <https://doi.org/10.1108/ILS-03-2019-0027>