Examining Students' Needs Satisfaction in a Gamified Math Practice

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Abstract: Though many studies suggest the positive effects of gamification on participants' learning and motivation, limited research has examined the basic psychological needs satisfaction in gamified learning. Based on self-determination theory (SDT), this study examined students' actual competence, perceived competence, perceived autonomy, and perceived relatedness in a gamified math practice. The results showed that students had varied degree of needs satisfaction in perceived competence, perceived autonomy, and perceived relatedness. The implications and significance of the study provide practical teaching implementation suggestions and research insights for gamification research.

Keywords: self-determination theory, math education, gamification

Introduction

One of most commonly used game design elements in gamification design is leaderboard, a scoreboard showing participants' current scores and rankings. Though many studies show that the use of leaderboards has positive effects on learning and motivation (Kalogiannakis, Papadakis, & Zourmpakis, 2021); its negative effects on participants' attitudes and motivation have also been reported and discussed in the literature (Andrade, Mizoguchi, & Isotani, 2016; Nicholson, 2013). In this paper, based on self-determination theory (SDT) (Ryan & Deci, 2017), we designed a study where undergraduate mathematics students completed a leaderboard-based math practice, and investigated students' perceived needs satisfaction in this activity.

Literature Review

Research on Leaderboards

Research on leaderboards examined the effects of leaderboard in combination with other game elements such as points and levels (Huang et al., 2020; Sailer & Sailer, 2021) as well as how the integration of leaderboards alone impacted participants' learning and motivation (Landers, Bauer, & Callan, 2017; Landers & Landers, 2014; Mekler, Brühlmann, Tuch, & Opwis, 2017). In general, research reported a positive effect of leaderboard use (Landers & Landers, 2014; Mekler et al., 2017; Nicholson, 2013), although it is clear that not all participants benefit from being engaged with leaderboards (Chernbumroong, Sureephong, & Muangmoon, 2017).

So far, limited studies examined the underlying factors that influence students' enjoyment and intention of continued participation in such gamified activities. In this paper, we aim to use Self-Determination Theory (SDT) as a framework to identify and examine the underlying psychological needs satisfaction that are closely related to students' enjoyment and intention of continued participation in gamified learning.

Self-Determination Theory (SDT)

SDT assumes that "healthy individuals are proactively interested in their surroundings and experiences, naturally engaged and assimilative in an ongoing way" (Ryan, Deci, Vansteenkiste, & Soenens, 2021, p. 98). Deci and Ryan (2004) suggest that the satisfaction or negligence of three psychological needs in social environments can either facilitate or forestall autonomous types of motivation, which are conducive to engagement and optimal learning in educational contexts. The three psychological needs are (a) autonomy: "being the perceived origin or

source of one's own behavior" (Deci & Ryan, 2004, p. 8), (b) competence: "feeling effective in one's ongoing interactions with the social environment and experiencing opportunities to exercise and express one's capacities" (Deci & Ryan, 2004, p. 7), and (c) relatedness: feeling loved or cared for.

Studies conducted by Ryan, Rigby, and Przybylski (2006) on motivation for computer game play suggested that participants' needs satisfaction in autonomy, competence, and relatedness independently predict enjoyment and future game play, but limited studies examined the needs satisfaction in gamified activities (Jahn et al., 2021). In this study, we intended to examine students' needs satisfaction in autonomy, competence, and relatedness when they participated in the leaderboard-based math practice.

Method

Participants

47 undergraduate students participated in the study, who had taken a foundational math course named "Real World Math Skills." This course fulfilled the state-mandated quantitative reasoning requirement for undergraduates majoring in fields such as art and music, among others. Of the total participants, 44.68% were male and 55.32% were female. The average age of the participants was 20.28 with a standard deviation of 3.13.

Instrument

To measure the levels of student perceived needs satisfaction in competence, and relatedness, three subcategories in the BPNSFS survey (Chen et al., 2015) were adopted to measure the satisfaction of competence, autonomy and relatedness when students worked on this leaderboard-based math practice. There were four questions under each subcategory. Some example questions are "I felt competent when answering the questions" (Competence), "I felt like the gamified practice reflected how I want practices to be myself" (Autonomy), and "I felt connected to other participants" (Relatedness).

Procedures

Before the intervention started, the instructor prepared 24 math problems to cover a range of concepts related to Contending with Change. The difficulty level of the problems was moderately challenging. The problems were uploaded to Quizalize, a gamified quiz creation website. During class, students used pseudonyms to log into Quizalize on their own devices and worked on the 24 problems. As they solved each problem, they received instant feedback and points on their screens, and moved on to the next question. A leaderboard was displayed on a large screen in the classroom, showing student rankings in real-time. Once all students completed the problems, the final rankings were displayed on the leaderboard. Finally, the students filled out a survey as described in the Instrument section.

Data Collection

Student survey responses. The student responses to the Likert questions were assigned numerical values from 1 (strongly disagree) to 7 (strongly agree). The scores for each of the three sub-categories, including Competence, Autonomy, Relatedness were determined by computing the average of their ratings for the survey items in each sub-category.

Results

The analyses were conducted to understand the degree of variations on students' perceived competence, perceived autonomy, and perceived relatedness. Table 1 shows that there was a considerable degree of variation in student ratings on each of the three sub-categories: perceived competence, perceived autonomy, and perceived relatedness.

Table 1. Descriptive Statistics of Student Ratings

	Perceived Competence	Perceived Autonomy	Perceived Relatedness
M(SD)	4.73(1.64)	4.33(1.73)	3.20(1.46)
Minimum	1.00	1.00	1.00
Maximum	7.00	7.00	6.00
Range	6.00	6.00	5.00

Skewness	-.384	-.069	.040

Significance of the Study

The findings of the study suggested that the effects of leaderboard-based math practice on student basic psychological needs satisfaction are varied. Some students had high level of needs satisfaction, while others had limited needs satisfaction. The study has significant implications for math education and leaderboard-based gamification, because, instead of focusing on the overall effects of gamification, the results helped researchers and educators understand how students responded to gamified activities differently. It offers a possible way to explain inconsistent findings in leaderboard research. Such knowledge will also provide insights on ways to tailor leaderboard-based activities so as to optimize the effects of intervention on different students.

Acknowledgement

References

Andrade, F. R. H., Mizoguchi, R., & Isotani, S. (2016). The bright and dark sides of gamification. In *Proceedings of the 13th International Conference on Intelligent Tutoring Systems* (Vol. 9684, pp. 176-186). Cham: Springer International Publishing.

Chen, B., Vansteenkiste, M., Beyers, W., Boone, L., Deci, E. L., Van der Kaap-Deeder, J., . . . Verstuyf, J. (2015). Basic psychological need satisfaction, need frustration, and need strength across four cultures. *Motivation and Emotion, 39*(2), 216-236. doi:10.1007/s11031-014-9450-1

Chernbumroong, S., Sureephong, P., & Muangmoon, O. o. (2017). *The effect of leaderboard in different goal-setting levels.* Paper presented at the 2017 International Conference on Digital Arts, Media and Technology (ICDAMT).

Huang, R., Ritzhaupt, A. D., Sommer, M., Zhu, J. W., Stephen, A., Valle, N., . . . Li, J. W. (2020). The impact of gamification in educational settings on student learning outcomes: a meta-analysis. *Educational technology research and development, 68*(4), 1875-1901. doi:10.1007/s11423-020-09807-z

Jahn, K., Kordyaka, B., Machulska, A., Eiler, T. J., Gruenewald, A., Klucken, T., . . . Niehaves, B. (2021). Individualized gamification elements: The impact of avatar and feedback design on reuse intention. *Computers in human behavior, 119*, 106702. doi:10.1016/j.chb.2021.106702

Kalogiannakis, M., Papadakis, S., & Zourmpakis, A.-I. (2021). Gamification in Science Education. A Systematic Review of the Literature. *Education sciences, 11*(22), 22. doi:10.3390/educsci11010022

Landers, R. N., Bauer, K. N., & Callan, R. C. (2017). Gamification of task performance with leaderboards: A goal setting experiment. *Computers in human behavior, 71*, 508-515. doi:https://doi.org/10.1016/j.chb.2015.08.008

Landers, R. N., & Landers, A. K. (2014). An empirical test of the theory of gamified learning: The effect of leaderboards on time-on-task and academic performance. *Simulation & Gaming, 45*(6), 769-785. doi:10.1177/1046878114563662

Mekler, E. D., Brühlmann, F., Tuch, A. N., & Opwis, K. (2017). Towards understanding the effects of individual gamification elements on intrinsic motivation and performance. *Computers in human behavior, 71*, 525-534. doi:10.1016/j.chb.2015.08.048

Nicholson, S. (2013). *Exploring gamification techniques for classroom management.* Paper presented at the Games+Learning+Society 9.0, Madison, WI.

Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness.* New York: The Guilford Press.

Ryan, R. M., Rigby, C., & Przybylski, A. (2006). The motivational pull of video games: A self-determination theory approach. *Motivation and Emotion, 30*, 344-360. doi:10.1007/s11031-006-9051-8

Sailer, M., & Sailer, M. (2021). Gamification of in-class activities in flipped classroom lectures. *British journal of educational technology, 52*(1), 75-90. doi:10.1111/bjet.12948