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Impact of Gamification on Brain Activity and Learner Performance: An in Class Concurrent Measurement

Peace Mabeta [1]*, Priyesh Bipath[1], Murray Louw[2] , Jannie Hugo[2]
[1]Department of Physiology, [2]Department of Family Medicine, School of Medicine, Faculty of Health Sciences, University of Pretoria, Pretoria, South Africa
***** Correspondence: peace.mabeta@up.ac.za; Tel.: (+27) 123192907; Fax: +27-012-321-16-79

Abstract

The optimal application of gamified methods in the teaching of Physiology requires research, as evidence on its impact is rudimentary. The purpose of this study was to determine the effects of gamification on learner attitudes, student performance scores, and brainwave activity in a Physiology learning environment. A cohort of 14 students from the first year Bachelor of Clinical Medical Practice program were randomly assigned to the gamified (G) and non-gamified (N-G) groups. The G group participated in a gamified activity, while the N-G group participated in a didactic teaching setting. The students were assessed on the same content. Electroencephalogram (EEG) recordings were measured using a MyndBand device during student participation in the assigned activities. Software algorithms computed attention and meditation brainwave signals that had been recorded during the testing sessions. The results of the study revealed higher performance scores in the G group when compared to the N-G group. Results also showed a higher median brainwave activity for attention signals in the G than in the N-G group. There was a positive correlation between median attention signals and performance scores. These preliminary findings on the use of gamification in a Physiology classroom setting indicate an improved cognitive outcome that is substantiated by the EEG brainwave attention signals.

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1. Introduction

Historically, the preclinical training of medical students has largely focused on didactic methods of teaching [1]. Developments in technology, as well as the challenge of increased learner-to-lecturer ratios, have necessitated the exploration of multiple learning media and approaches to enhance the learning experience. Furthermore, in complex multi-lingual and multi-cultural environments, creating an interactive classroom poses a challenge. Gamification, the application of gaming elements or mechanics to a non-gaming environment, has been employed in training programs in a variety of sectors and has the potential to alleviate the challenges posed by these complex-learning environments [2-4]. In the context of higher education, various studies have shown that gamification increases learner participation [5,6].

While gaming as a means of improving student motivation has been studied widely, observations have been mainly anecdotal. Most studies found that gamification increased motivation, but some other studies reported no improvement in motivation. [7-9] Furthermore, although gamified learning systems are increasingly being employed in higher education, evidence of their impact on student performance is still limited [10]. Additionally, there is a lack of Physiological data to show the effects of gamified systems on learner focus and concentration. Thus an investigation of the effect of gaming elements on brain activity may further enhance our understanding on the impact of gamification on student learning.

The physiology of memory and cognition are important facets in influencing student learning and academic performance [11-13]. A study monitoring brainwave patterns was previously employed to study brain activity by measuring parameters such as the attentive state [14]. The study showed that the attentive state is associated with learning effectiveness. [14] Generally, brainwaves are classified into various categories based on wave frequency; the theta waves (4-7.99 Hz), alpha waves (8-12,99 Hz), beta waves (13-29,99 Hz) and gamma waves (30-50,99 Hz) [15-17]. In particular, frequencies in the theta/alpha categories are associated with the meditative state, while beta frequencies are associated with the attentive state and focused mental activity [16,17]. Gamma waves are involved in simultaneous processing of information. The purpose of the current study was to investigate the effects of gamification on brainwave activity and whether the brainwave activity related to student performance in assessments and student perceptions of the learner experience.

2. Materials and Methods

2.1. Participants

The study involved a cohort of fourteen students from the Bachelor of Clinical Medical Practice (BCMP) who had enrolled for the first year Physiology module.

2.2. Gamification

The students were assigned randomly to two groups, the gamified (G) or non-gamified (N-G) groups, and the same Physiology course content was used for the two groups of students. Gaming elements in the form of the wheel of knowledge, a game adapted from the wheel of fortune, was employed in the gamified group, while no gaming activity was employed in the non-gamified group. In the latter group, didactic methods were used. In both groups, brain activity was measured while the students undertook the assigned activities. Students were assessed and gained points at the end of their activities. Students in the G group were also requested to provide input concerning their experience of the gaming activities.

2.3. Brain activity assessment

Each of the students in the two groups was fitted with an electroencephalogram (EEG) headset and brain wave activity was measured as they participated in the assigned activities. The MyndBand EEG headset (MyndPlay®, USA) was used for the EEG measurements. The device headset measured raw EEG signals via two electrodes positioned on the forehead of each participant and a ground electrode earpiece. The raw EEG signals of 3 to 50Hz were recorded from which brainwave activity was computed with the NeuroView version 4 software (NeuroSky Inc., USA).

2.4. Statistical analysis

Comparison between the gamified and non-gamified groups were analyzed using the Student's T-test and the Mann-Whitney U Test at a significance of level of $p<0.05$. Analyses were performed using the SPSS (version 25, IBM) statistical software package.

3. Results and Discussion

The mean performance score for the N-G group was 16.9% while the mean performance score for the G group was 63.4% (Fig. 1). Nonetheless one student in the G group obtained a performance score that was in the similar range with scores attained by students in the N-G group. It is also important to note that in terms of formative assessment grades, the students were spread evenly between the two groups.

Thus, the differences in the average performance scores may be partly due to gamification. It is anticipated that an increase in sample size will give a better representation of the effect of gamification on student performance.

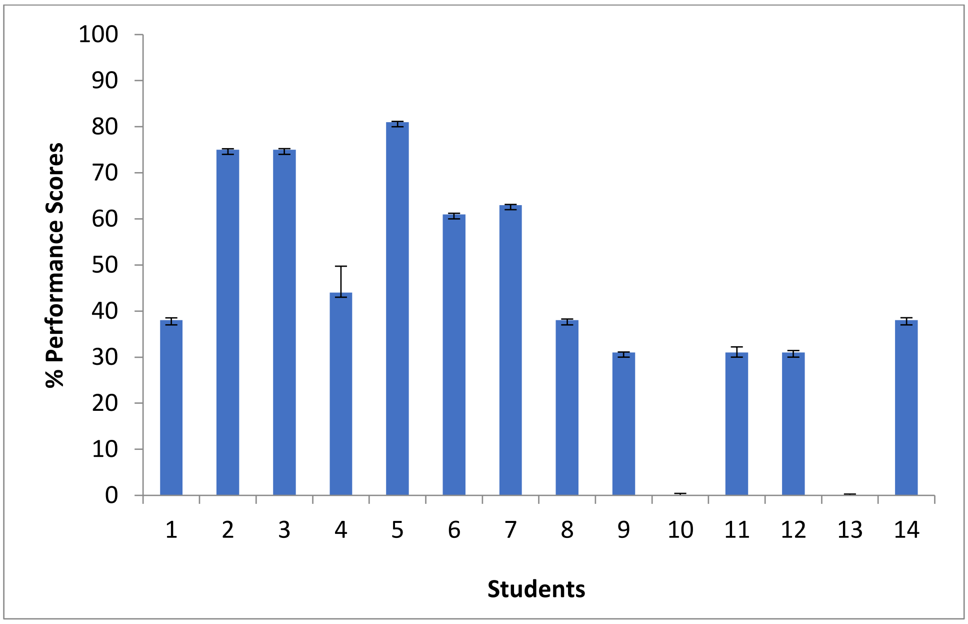

Figure 1. Student performance on gaming (students 1-7) and non-gaming activities (students 8-14). Values are mean percentage scores ±SD.

A survey was conducted to determine participant experience with the gamification activities. In the first part of the survey, the students were asked to indicate whether the experience was positive, neutral or negative. All students except one indicated that they had a positive experience. One student indicated that his experience of gamification activities was neutral (Table 1). In the second part of the survey the students were asked to select phrases that describe their experience of the gamification exercise. Students in the gamified group indicated that they found gamification activities highly stimulating and that they were motivated to participate in learning activities (Table 1). In a recent study, Martin *et al.* (2018) observed an improvement in participation and team dynamics when game-based learning was employed [18]. In addition, the same study showed that students who participated in gamified activities were more aware of the level of their knowledge competence when compared with their peers [18].

Another study reported an improvement in intrinsic motivation, which is defined as participating in tasks due to the satisfaction derived from performing and completing activities rather than to attain high assessment marks [19]. Further, several other studies reported on the positive impact of gamification on the learner experience [20-22]. Taking the findings of the different studies as well as student feedback in the current study, it is plausible that gamified elements may have a role in encouraging motivation in the training of medical students [23]. Moreover, McCoy *et al.* (2016) reported on the potential benefits of gamified system in improving the training of medical students both at the pre-clinical and clinical levels [3]. However, according to some of these studies, there is a need for substantive evidence on the effects of incorporating gaming activities on learner performance [19-22].

Table 1. Gamified student's group perceptions of gaming activities

Participant no.	Experience	Student Comment
1	Positive	Great experience; Would prefer use of gamification in the teaching of Physiology
2	Positive	Enjoyed game; Would prefer use of gamification in learning
3	Positive	Enjoyed game; Would prefer use of gamification in the teaching of Physiology
4	Neutral	Made no difference; It would not make a difference if gamification was incorporated in the teaching Physiology
5	Positive	Enjoyed game; Would prefer use of gamification in the teaching of Physiology
6	Positive	Perfect experience; Would prefer the use of gamification in the teaching of Physiology
7	Positive	Best experience; Would prefer the use of gamification in the teaching of Physiology

In the present study, brain activity waves were measured to establish the impact of gamification on learner concentration. The algorithms generated Attention and Meditation brainwave values via a combination of frequencies from the Theta frequency (4-7.99Hz) which represents deep relaxation, to the Beta/Gamma frequencies (12 – 35Hz) which represent engaged, active to focused mind state. The average Attention and Meditation brainwave values were recorded per session for each participant and are indicated in Fig. 2.

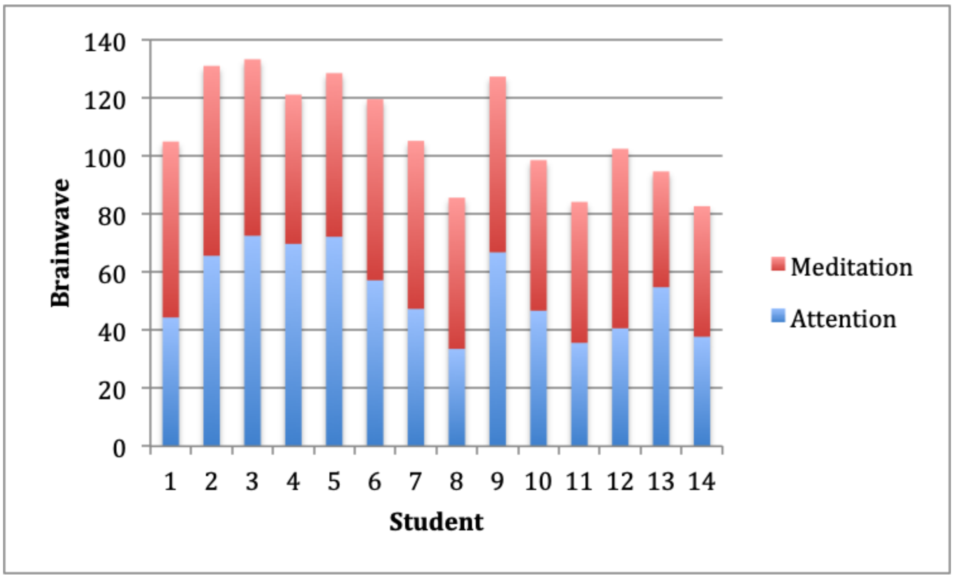

Figure 2. Brainwave activity measured in gamification (students 1-7) and non-gamification (students 8-14) groups.

The results showed that the mean Attention wave values were 45.14 ± 12.01 (mean wave frequency ± SD) in the N-G group. There was a significant increase ($p=0.024$) in the mean Attention wave values in the G group (61.29 ± 11.78). On the other hand, brainwaves that corresponded with the Meditative state averaged 59.26 ± 4.54 for the G group and 51.38 ± 7.90 for the N-G group ($p=0.053$). Furthermore, Attention wave values correlated positively with student performance scores (Spearman rho: 0.4089; $p<0.05$).

4. Conclusion

Our findings revealed an improvement in student performance when gamification was used, as evident from the higher average scores achieved by students in the G group. Furthermore, the improvement in performance scores correlated with increased attention. Contrary to our expectation, the meditation brainwave values were not lower in the gamification group. However, it must be noted that according to normal brainwave activity, an increase in the attention wave values does not necessarily imply a decrease in the meditative state. While there is limited empirical evidence on the impact of gamification on learner performance, our observations in this initial study suggest that the use of gamified elements in the teaching of Physiology may improve learner performance as well as attention. Further studies are underway using larger sample sizes to further investigate the impact of gaming activities singly and in combination with didactic approaches on formative assessment outcome.

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Conflicts of Interest

The authors declare no conflict of interest.

References

1. McCoy, L.; Pettit, R.K.; Kellar, C.; Morgan, C. Tracking active learning in the medical school curriculum: A learning-centered approach. *J Med Educ Curric Dev*. 2018, **5**, 1-5. https://doi.org/10.1177/2382120518765135

2. Hess, G., Hunter Schwartz, M., & Levit, N. Fifty Ways to Promote Teaching and Learning. *J Legal Educ*. 2018, **67**, 1-38.

3. McCoy, L., Lewis, J. H., & Dalton, D. Gamification and Multimedia for Medical Education: A Landscape Review. *J Am Osteopath Assoc*. 2016, **116**, 22. https://doi.org/10.7556/jaoa.2016.003

4. Gentry, S.V., Gauthier, A., Ehrstrom, B.L.E., Wortley, D., Lilienthal, A., Car, L.T., Dauwels-Okutsu, S., Nikolaou, C.K., Zary, N.; Campbell, J.; Car, J. Serious Gaming and Gamification Education in Health Professions: Systematic Review. *J Med Internet Res*. 2019, **21**, e12994.

5. Martín-Hernández, P., Azkue, J. L., & Agut, S. (2018). Game base learning in psychology education: improving undergraduates competence for team working. *EDULEARN18 Proceedings*. *1*, 9728–9732. https://doi.org/10.21125/edulearn.2018.2335

6. Vogel, J.J., Greenwood-Ericksen, A., Cannon-Bowers, J.; Bowers, C.A. Using virtual reality with and without gaming attributes for academic achievement. *JRTE*. 2006, **39**, 105–118. https://doi.org/10.1080/15391523.2006.10782475

7. Alsawaier RS. The effect of gamification on motivation and engagement. *Int J Inf Learn Technol*. 2018, **35**, 56-79. https://doi.org/10.1108/IJILT-02-2017-0009

8. Randel, J.M.; Morris, B.A.; Wetzel, C.D.; Whitehill, B.V. The effectiveness of games for educational purposes: A review of recent research. *Simul Gaming*. 1992, **23**, 261-76.

9. Brezovszky, B.; McMullen, J.; Veermans, K.; Hannula-Sormunen, M.M., Rodríguez-Aflecht, G.; Pongsakdi, N.; Laakkonen, E.; Lehtinen, E. Effects of a mathematics game-based learning environment on primary school students' adaptive number knowledge. *Comput Educ*. 2019, **128**, 63–74. https://doi.org/10.1016/j.compedu.2018.09.011

10. Dichev, C.; Dicheva, D. Gamifying education: what is known, what is believed and what remains uncertain: a critical review. *ETHE*, 2017, **14**: 1-36 https://doi.org/10.1186/s41239-017-0042-5

11. Goodman, B.E.; Barker; M.K.; Cooke, J.E. Best practices in active and student-centered learning in physiology classes. *Adv Physiol Educ.* 2018, **42**, 417–423. https://doi.org/10.1152/advan.00064.2018

12. Guy, R.; Byrne, B. Article Commentary: Neuroscience and Learning: Implications for Teaching Practice. *J Exp Neurosci.* 2013, *7*, JEN.S10965. https://doi.org/10.4137/jen.s10965

13. Katona, J.; Kovari, A. Examining the learning efficiency by a brain-computer interface system. *Acta Polytech Hung.* 2018, **15**, 251–280. https://doi.org/10.12700/APH.15.3.2018.3.14

14. Lim, S.; Yeo, M.; Yoon, G. Comparison between concentration and immersion based on EEG analysis. *Sensors.* 2019, **19**. https://doi.org/10.3390/s19071669

15. Doukakis S. Exploring brain activity and transforming knowledge in visual and textual programming using neuroeducation approaches. *Brain*. 2019, **6**, 9. http://dx.doi.org/10.3934/Neuroscience.2019.3.175

16. Mendoza, L.R.; Martinez, M.E.; Suarez, A.M. The brain as a fundamental axis in learning process. *Int Res J Eng, IT Sci Res*. 2019, **5**, 38-45. https://doi.org/10.21744/irjeis.v5n4.689

17. Marzbani, H.; Marateb, H. R.; Mansourian, M. Methodological note: Neurofeedback: A comprehensive review on system design, methodology and clinical applications. *Basic Clin Neurosci*, 2016, **7**, 143–158.

18. Nevin, C. R.; Westfall, A. O.; Martin Rodriguez, J.; Dempsey, D. M.; Cherrington, A.; Roy, B., Mukesh, P.; Willig, J. H. (2014). Gamification as a tool for enhancing graduate medical education. *Postgrad Med J.* 2014, **90**, 685–693. https://doi.org/10.1136/postgradmedj-2013-132486

19. Banfield, J.; Wilkerson, B. Increasing student intrinsic motivation and self-efficacy through gamification pedagogy. *Contemp Issues Educ Res.* 2014, ***7***, 291. https://doi.org/10.19030/cier.v7i4.8843

20. Furdu, I.; Tomozei, C.; Kose, U. Pros and cons gamification and gaming in classroom. *Brain*. 2017, **8**, 56-62. http://arxiv.org/abs/1708.09337

21. Hardiman, M. Informing pedagogy through the Brain-Targeted teaching model. *J Microbiol Biol Educ.* 2012, **13**, 11–16. https://doi.org/10.1128/jmbe.v13i1.354

22. Yunyongying, P. Gamification: Implications for Curricular Design. *J Grad Med Edu*. 2014, **6**, 410–412. https://doi.org/10.4300/jgme-d-13-00406.1

23. Belkin, P. A. Gamification in education. *J Mod Foreign Psychol.* 2016, ***5***, 28–34. https://doi.org/10.17759/jmfp.2016050302.