Enhancing Undergraduate Cell Biology Learning Through the Application of Gamification

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The IAFOR International Conference on Education in Hawaii 2024
Official Conference Proceedings

Abstract
Learning cell biology presents challenges for undergraduates due to its intricate nature, demanding comprehension of complex cell structures and functions within the human body. To address this, the integration of game design principles into non-game contexts, known as gamification, offers an innovative solution. While traditional learning methods encompass lectures and tutorials, the introduction of gamified elements can foster active learning and provide alternative didactic strategies. This presentation centres on evaluating the impact of gamification in improving students' learning experiences and comprehension of cell biology. This case study employs gamification through collaborative creation of edible 3D cell membrane models, evaluated by instructional staff. This process is accompanied by quiz-style activities targeting cell functions, along with a Pictionary-style component featuring various cell organelles. The session will offer insights garnered from this initiative, encompassing student and lecturer preferences, encountered challenges, identified opportunities, and the rationale behind its current structure, as well as future plans. The outcomes of this initiative revealed an improvement in collaborative teamwork, leading to enhanced communication skills and the reinforcement of fundamental subject knowledge. Challenges within the classroom context encompass student participation in activities and their preconceptions of an ideal undergraduate biosciences educational environment. By engaging students through active, game-inspired learning methodologies, educators can elevate understanding and engagement in intricate subjects like cell biology.

Keywords: Cell biology, Gamification, Undergraduate, Collaborative Teaching

Introduction

There is a range of evidence that game-based learning and gamification are associated with increased enjoyment and motivation, despite conflicting data in recent years (Crocco *et al.*, 2016). The pandemic of 2019 increased the need for diverse online activities within higher education, but the application of these in return to in-person lectures, tutorials and workshops has posed a unique conundrum.

Gamification in learning is a concept whereby the learner is exposed to activities and teaching that emulate the positive aspects of playing a game, both in terms of participation and in goal achievement (Hamari, 2019). The application of game-based learning has increased in the field of higher education, with positive outcomes being reported from both a teacher and a student perspective (Chan and Lo, 2022). Game-based approaches are best used in low-stakes contexts to reduce interference with intrinsic motivation (Norgard *et al.*, 2017). Game-based approaches allow for repetition and are therefore often used for activities related to skill or knowledge acquisition/practice.

There is the potential for intellectual snobbery to exist within the student population, stemming from students' preconceptions of how a biological science degree "should" be taught, in addition to their initial motivations for pursuing such a degree (Barr, 2019; Hsu and Dudley 2022). However, the use of gamification can bridge the gap between students who may be more technologically literate, or who have access to a wider range of resources and those who may not have access to such things. Resource availability is a determinant that is considered when planning teaching sessions, and the use of simple paper-based activities with the materials provided by the teacher can prove to be as effective as a more complex simulation-based activity that requires the use of software (Lean *et al.*, 2006; Gobert, 2022).

Another consideration when planning activities in a higher education setting is whether or not there are any barriers to learning. These barriers may exist on the side of the teachers, or the side of the students (Watson and Yang, 2016). Whilst resources are a barrier these are not the only one; the willingness of teachers to learn how to use games, the time required to create such activities and the uncertainty of how student engagement and satisfaction may change, can all lead to a reluctance on the part of the teachers to implement such activities.

The cell biology requirements of the Biosciences Foundation Year at the University of Surrey encompass the basic understanding of how a cell works, along with the specialised vocabulary required for the subject. The formation of a specialised vocabulary is crucial when developing the learners' knowledge base, and so the initial exposure to such language must be planned with both recall and understanding in mind (Krajcik and Sutherland, 2010; Marintcheva, 2012).

Session Design

Students were placed into teams at the beginning of the academic year. These teams were then used throughout the semester to separate students into streams depending on their intended undergraduate degree subject (e.g. Sports & Exercise Science, Biomedical Science etc.) and to encourage a collaborative effort for all activities. The teamworking approach to cell biology learning has been shown to not affect student satisfaction negatively, something that is important when considering the long-term effectiveness and viability of a new teaching strategy (Kitchen *et al.,* 2003; Wright and Boggs, 2002).

The selection of activities was based on availability of resources, as well as accessibility for students at all levels of understanding. The sessions were planned by week and by topic (Figure 1). The initial introduction of the topic was done in the first week via pre-recorded lecture, accompanied by blank slides for students to take notes, as this has been shown to be effective in increasing attendance and engagement, as well as student recall (Bhaisare and Kamble, 2006). Following this, a Pictionary-style session was done to aid students in identifying the basic structure of organelles, which encouraged recall of the content that had been provided in the video. Then, the teams were given instructions to create a diagram representing the cell as a city. In this, students were encouraged to use the pre-recorded materials, the internet, and their textbooks, to ensure that they had included all the appropriate structures and to allow them to understand how they work within the cell.

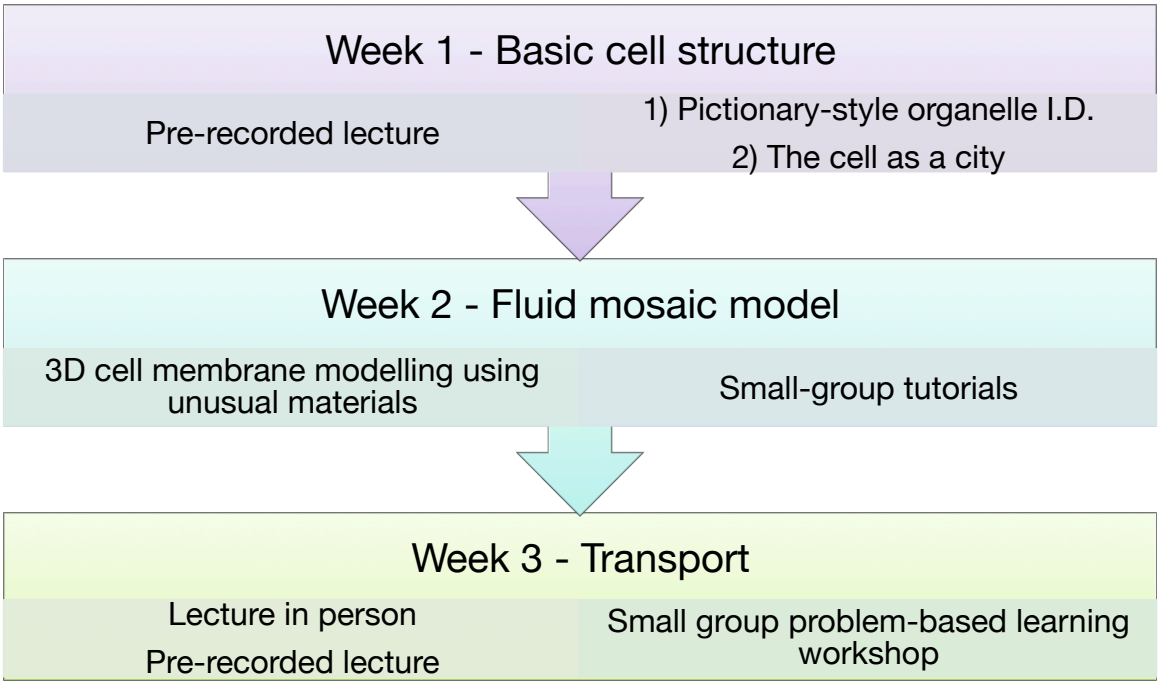

Figure 1: A timeline of game-based activities in relation to content taught in a traditional lecture theatre.

The second week of the topic began with the students creating a 3D model of the cell and its surrounding membrane. This was implemented as a problem-based activity, seeing as students had not seen some of the definitions of each component previously. The use of problem-based learning in cell biology has been shown to consistently be a preferred method to teaching, and has more favourable outcomes (Xu *et al.,* 2021). So, they had to use the session to determine where each component goes to create the 3D shape required. Then, that same week, a small tutorial was done to discuss which were the correct answers and what the functions of each element were in the context of the organelles learned the previous week.

Finally, for the last week of the topic, students learned how the organelles and components of the membrane work to allow movement of substances in and out of the cell. This was done through a pre-recorded video, an in-person lecture and then finally a workshop using problem-based learning to wrap up the cell biology content.

Each team ended up with a range of outputs that were shared on a dedicated Teams site (Figure 2). The students were able to keep a record of their work and revisit the information when needed.

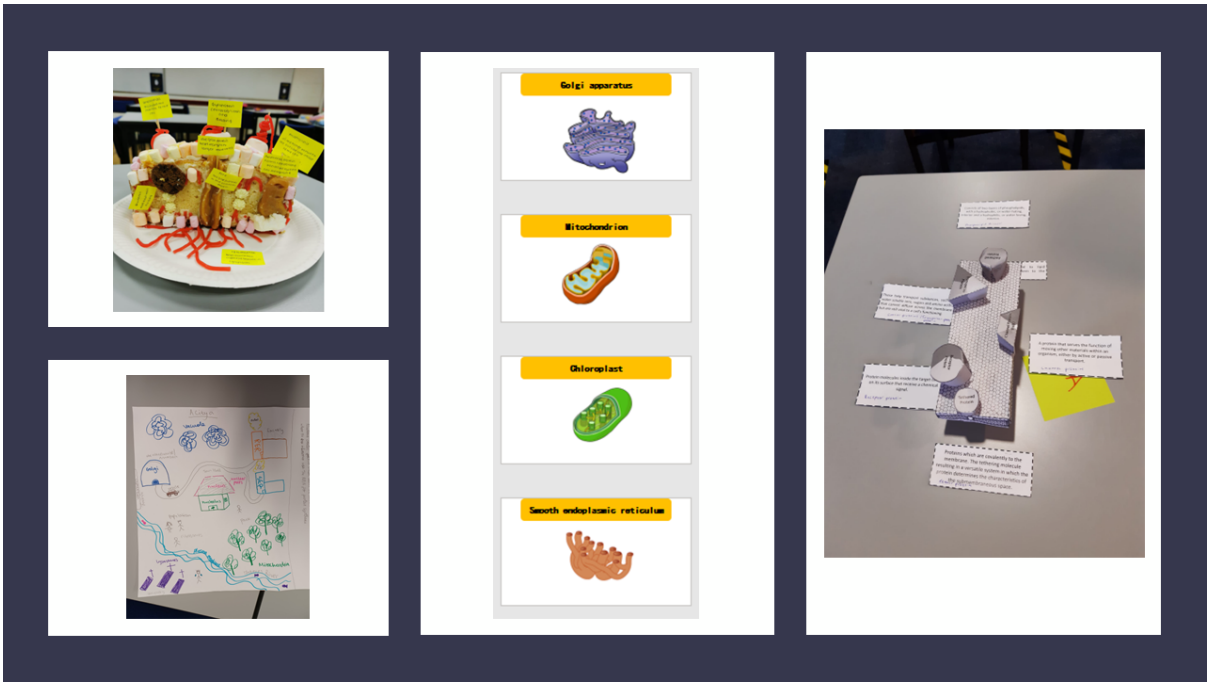

Figure 2: Examples of class activities carried out as part of the gamification sessions.

Discussion

These sessions provide an initial introduction to cell biology, and any basic vocabulary associated with it. However, to increase the difficulty of the content to match the change in degree levels, a more complex system would need to be considered. These activities could be moved to sessions where a revision of previous years' content is carried out before exposure to new material, but the transition might not be as smooth as initially thought. This also raises the interesting question of whether or not students should focus on recall or understanding, especially with regards to scientific terms.

In the context of cell biology on the Biosciences Foundation Year at the University of Surrey, the terms learned can be transferred to molecular biology, physiology, and biochemistry among other topic areas. However, there has been an increase in demand for students who can understand their areas of study, and who can apply these as independent researchers and learners (Manix, 2022). Therefore, only some of the game-based learning could be used to develop these skills. Once again, the transferable nature of each activity would need to be evaluated for each discipline and each level of study.

Where biological sciences are concerned, the preconceptions of students as to what a traditional classroom may look like could lead to a trivialization of the classroom interactions instead of an enrichment. Gamification has long been used in school settings, and so the repetition of such activities may cause students to lack the engagement that educators may otherwise be trying to gain from them.

Conclusion

The outcomes of this initiative revealed an improvement in collaborative teamwork, leading to enhanced communication skills and the reinforcement of fundamental subject knowledge. Student engagement increased, and so incorporating active learning methodologies informed by gamification and pedagogical theory has the potential to enhance comprehension and engagement within challenging subjects such as cell biology. A more structured approach to this work accompanied by qualitative and quantitative measurements, would be an interesting avenue to explore further with future cohorts.

Acknowledgements

We would like to acknowledge Dr Sam Hopkins, Sarah Dolman, and Dr Kikki Bodman-Smith for their help in designing the Foundation Year Cell Biology curriculum and support throughout the teaching. Additionally, the 2022-2023 Biosciences Foundation Year students at the University of Surrey for their participation in these sessions.

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