Clinical anatomy through gamification: a learning journey

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ABSTRACT

BACKGROUND: Gamification has been shown to increase students' participation and has been widely used in medical education in the recent years. However, there are no dedicated games to deliver complete clinical-anatomy content at an undergraduate level.

AIM: This study describes the developmental process of a series of anatomy games for medical students and analyses student participation and experiences around the gamification process.

METHODS: Three diverse anatomy games were developed on the undergraduate medical curriculum. Based on students' playing and simultaneous learning experiences in each game, subsequent game contents were constructively modified. Students from three different universities participated in the study (total cohort=646); their experiences on the different games were documented and compared with each other.

RESULTS: Feedback from 219 players showed that the games were fun (95%) and interesting (81%) and assisted their anatomy learning (97%); students' fun, interest and learning improved significantly in the two subsequent games ($p<0.001$).

CONCLUSION: Carefully designed anatomy games create a fun-filled and interesting learning environment for undergraduate medical students. Learning experiences improved when students' feedback was appropriately addressed to constructively modify the subsequent learning resources.

Anatomy is a visually demanding discipline, and it is often difficult to appreciate abstract concepts using traditional pedagogical teaching methods.[1,2] This limitation is compensated for using multimedia resources, like animations, three-dimensional models and smartphone applications, where the learner can visualise complex anatomical structures in an easy-to-understand animated or three-dimensional environment.[3,4,5] Although these multimedia resources are undoubtedly informative, their efficiency is limited by a varying degree of user interactivity and they are often monotonous. To overcome these issues of interactivity, the concept of gamification is often applied in the educational setting. The Merriam-Webster dictionary defines "gamification" as the process of adding games or game-like elements to an activity to encourage participation. Gamification has emerged as a potential alternative pedagogy,[6,7] as it taps into people's natural desires for competition and achievement.

It is well known that games help learning by creating memories and experience,[8] and the use of educational games could improve student interaction and engagement.[8] Educational games, ranging from minor interactive activities within the classroom setting to games involving computer simulations, are increasingly used in healthcare settings to educate physicians, nurses and patients.[9,10,11] The results of these games have been encouraging, showing active user participation and increased learning outcomes in a stress-free learning environment. However, the concept of gamification in medical education is still evolving, and there is a dearth of interactive educational games to supplement clinical anatomy learning within undergraduate-level medical curricula.

To explore the potential effect of gamification in anatomy education, we attempted to develop a complete set of educational games to play-learn human anatomy for the undergraduate medical students. Following

feedback from an anatomy board game built in house for this purpose, we developed two web-based games on clinical anatomy: one on the clinical neuroanatomy, and the other on the integrated basic sciences of the digestive system. This study describes the development process and the outcome of student learning experiences from those three games.

The objectives of the study are (i) to use an iterative design process to guide development of a series of innovative teaching resources for undergraduate medical students and (ii) to explore student experiences (engagement and learning) around clinical anatomy gamification. Our findings from this study will add to the body of literature on gamification in medical curricula and inform future gamification efforts in clinical anatomy education.

Methods

Undergraduate medical students from three universities (University of Otago, New Zealand (n=300); Manipal University, India (n=72); Khon Kaen University, Thailand (n=274)) were invited to participate in this study. All three universities teach human anatomy following traditional methods that include didactic lectures, cadaver dissections or prosections; gamification is not a regular mode of anatomy-education delivery at any of the three universities. Institutional approval was obtained for the study from all universities; the project was partly funded by the University of Otago's Committee for the Advancement of Learning and Teaching grant and the Otago School of Biomedical Sciences Medical Education Research Grant.

We experimented with a sequential trial-and-error method and design thinking[12,13] to develop the resources; the process involved developing a prototype of the resource, and constructively applied user feedback to modify the game several times. We first built an anatomy board game, and, based on the students' feedback, we then developed a web-based computer game; after analysing the students' experiences and feedback of the first computer game, we deployed a second online game. This progressive experimental learning rectified the technical and pedagogical issues we faced in the previous game versions.

Three steps of the Galvis-Panqueva methodology[14] (analysis and design; development; distribution, data collection and evaluation) were employed while creating the anatomy game project.

Analysis and design: Following initial discussions with students and colleagues from the participating universities, two threshold topics (neuroanatomy and the digestive system) were identified as content for game development. During the design process, a detailed story plot was written, along with a list of individual tasks for the player, the anatomy topics to be covered and the clinical concepts to be learnt with them. The authors kept the games clinically oriented, and the subject content for each game was restricted to the learning objectives of undergraduate medical curriculum in the three universities.

Development: An anatomy board game was initially developed on the ventricular system of the brain and was distributed by the authors from Manipal university to their students. Student feedback on the game's plot and content, the player's experience and their perception of learning anatomy via a computer game were obtained. Results from the anatomy board game were evaluated to plan and modify the development of the subsequent online computer games.

To address the communication gap between the medical (authors) and computer (game developers) professionals, a protype animation for the online neuroanatomy game was developed by the primary author (VP) using CourseLab 2.4 software (Websoft, Moscow, Russia). This prototype, a complete list of instructions and preliminary sketches were provided to the professional game developers (Callystro, India), who only had novice knowledge on human anatomy. The development of the entire game process was supervised, and the draft versions were periodically corrected and updated by all the authors.

Distribution, collection of user-usage analytics and evaluation: The online games were hosted on the developer's computer server and a link to the games was shared to the students from all three universities. All students were encouraged to play the online game; however, their participation was voluntary. At the end of the academic

year, user-usage data were obtained from the server for analysis. From the feedback questionnaire at the end of the game, the students' playing experience and interest in the anatomy games, their willingness to repeat the games and their suggestions to improve development of more anatomy games were also obtained.

Five major elements of gamification in education suggested by McNulty[15] were incorporated appropriately into the game:

1. Perseverance: The anatomy games were designed such that the player does not get locked at any point within the game; after three repeated failures, the correct answer for the task is given and the player is allowed to continue.
2. Game mechanics: The interface was carefully developed to deliver anatomy content in a fun and interactive way,
3. User engagement: Incentives, cues and fun elements were used in all levels of the games.
4. Modifying content: To ensure repeatability and hold attention, multiple quiz formats and scene transitions were used.
5. Storyboarding: The player can track their path and progress within the game in real time.

Plot overview of the computer games

Plot of the online neuroanatomy game: The background of the story is of a medical student suffering from a pre-exam encephalopathy; learning excessive anatomy content made his brain swell, blocking the circulation of cerebrospinal fluid and causing a hydrocephalus. The doctors decide to perform a burr hole craniotomy on the suffering student's head and to send in a miniature player to clear the ventricular spaces and revive the affected student from the serious consequences of encephalopathy. The player explores the clinical anatomy of the brain as a series of challenges and tasks, with hints and descriptions as pop-up dialog boxes (Figure 1). In addition to the serious learning tasks, "fun" elements were also included in the game: for example, a hippopotamus is seen in place of the hippocampus of the brain in the temporal lobe (Figure 2). "Visual mnemonics," whereby the anatomical structures were presented as other familiar objects, were also used to help students remember concepts: for example, the similarity of the cross-section of midbrain to a teddy bear was depicted (Figure 3). The game ends when the patient's hydrocephalus subsides; the player is "tapped out" through a lumbar puncture and receives a certificate.

Plot of the online digestive system game: In their feedback from the online neuroanatomy game, students requested more interactive tasks and practice questions to revise clinical anatomy knowledge. These suggestions were incorporated into the second online game, the digestive system game, which as a result was longer than the first. To keep the playing time shorter and to maintain student engagement with the resource, the digestive system game was developed in two parts: from oral cavity to the end of pharynx, and then the tubular digestive tract.

Part one of the game starts with the miniature player trying to reach and explore a patient's oral cavity by building a ladder of crossword puzzles. The player then anaesthetises the oropharynx by "cutting" the appropriate nerves, deactivating the gag reflex, and making way into the throat. In the later scenes, the player explores the piriform fossa and identifies some chicken/fish bones and hidden diamonds. Relevance of internal laryngeal nerve injury and the traditional "smuggler's pouch" is learnt there, thereby completing part one of the game.

In part two, the player explores the tubular gut. After squeezing through the four constrictions of the oesophagus to reach the stomach, the player slides down along the rugae to take a boat to escape the acidic gastric juice (Figure 4a). Later, the player travels through the small intestine, identifies the duodenal papillae and circular folds (Figure 4b), explores the ileocecal junction opening to reach the large intestine and finally examines the appendix opening for any blockage. After successfully clearing all the tasks, the player is expelled out of the gut with a certificate of appreciation.

Figure 1: Interactive clinical scenarios and tasks used in the online neuroanatomy game: drilling a burr hole and inserting a neuroendoscope into the brain (a, b). The taskbar shows the rewards, lifelines, timer and the navigation map (red circles).

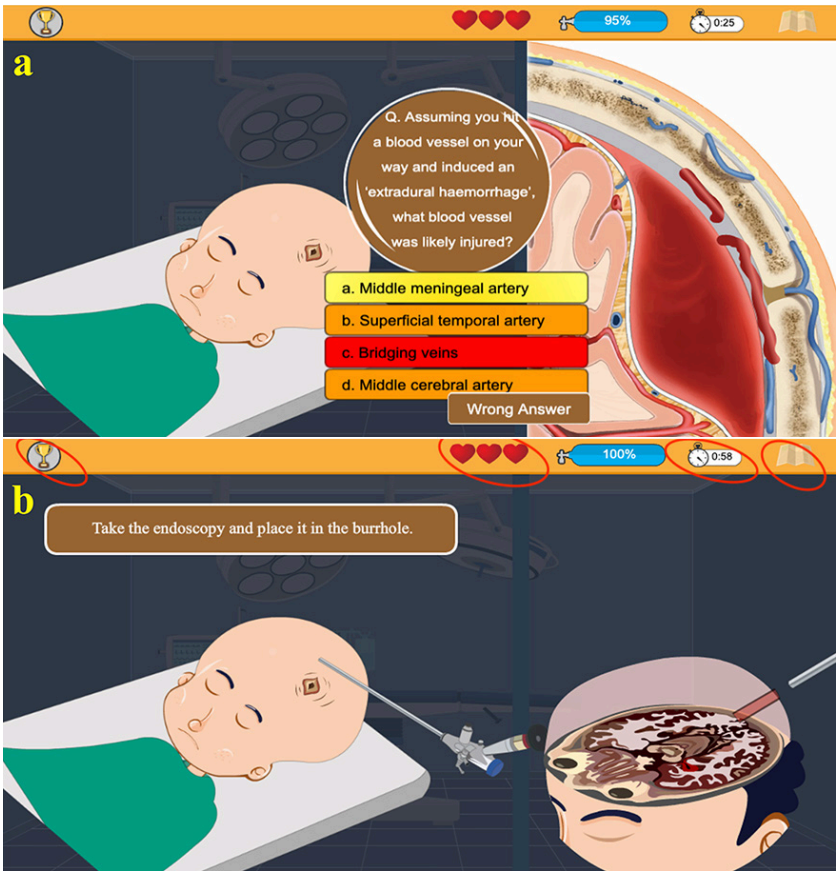

Figure 2: Example of fun elements used in the online neuroanatomy game to improve player attention: a hippopotamus placed in place of the hippocampus in the inferior horn of the lateral ventricle.

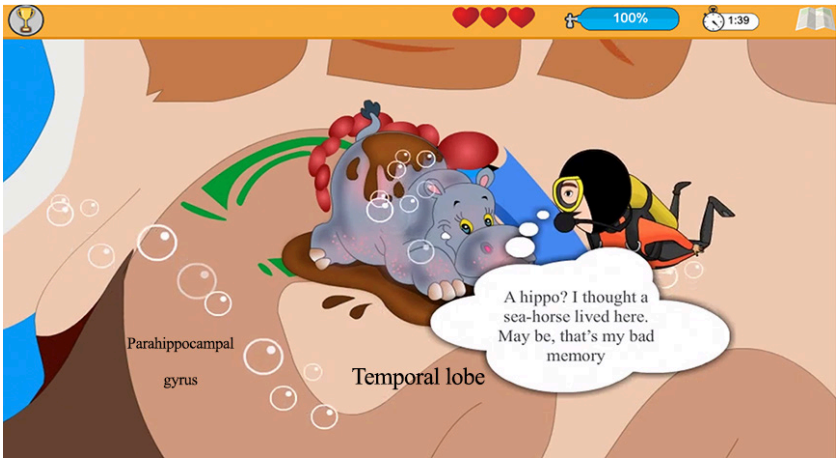

Figure 3: A labelling task where the cross-section of the midbrain (a) is visualised as the face of a teddy bear (b); these tasks are used as visual mnemonics to improve student learning and memory.

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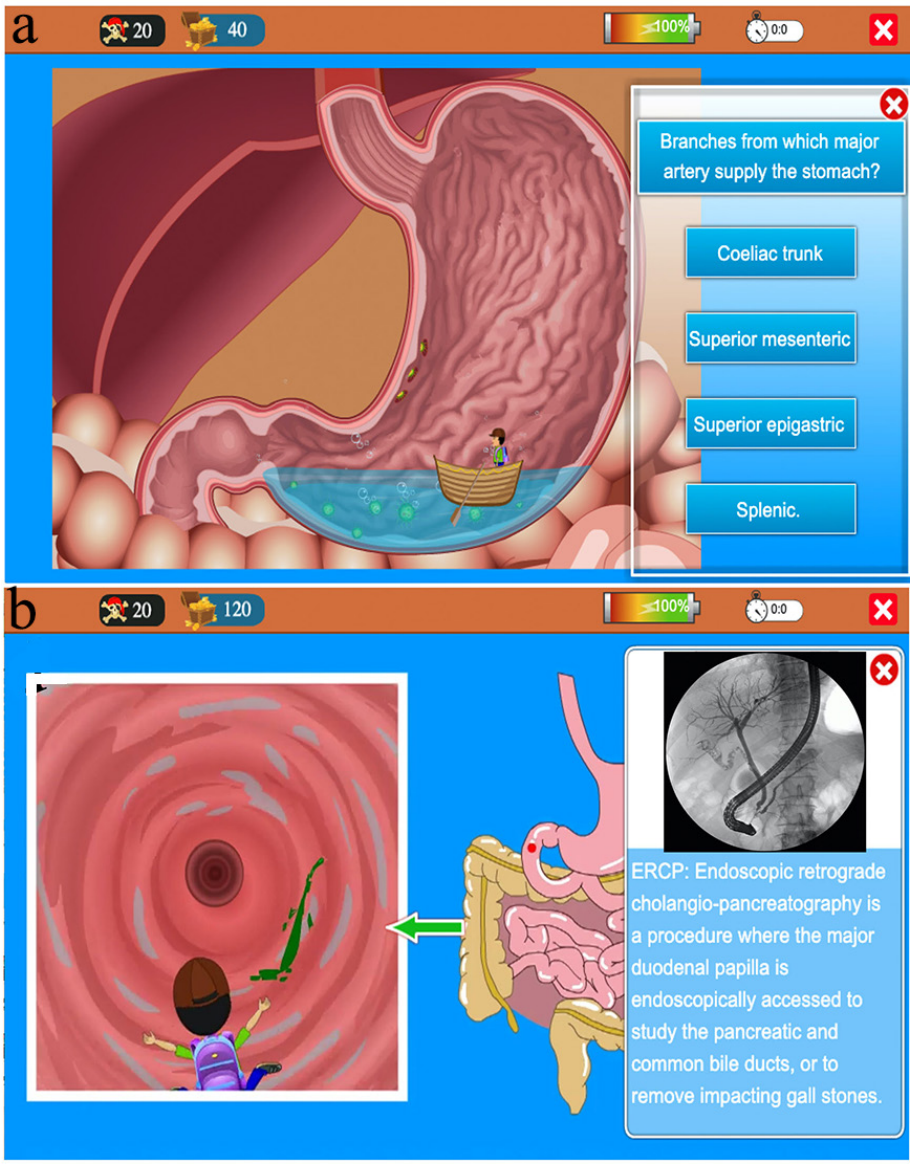
Figure 4: Clinical correlations used within the online digestive system game. (a) The player explores the colonies of *Helicobacter pylori* on the gastric mucosa while safely crossing the gastric juice. (b) Real-time navigation of the player's journey within the gut.



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Results

The anatomy board game was run in a classroom setting, so the results were evaluated soon after the players completed the game. The online games were made available throughout the academic year, and the data were collected at the end of the year. User-usage data, including student demography, completion status, time taken to complete the game and formative scores, were obtained for each anatomy game. However, only qualitative user data related to student experiences were compared between games and between players from the three universities. Comparisons were performed by the Pearson's chi-squared test using STATA software version 10.1 (Stata Corp, Texas, USA).

Feedback from the anatomy board game

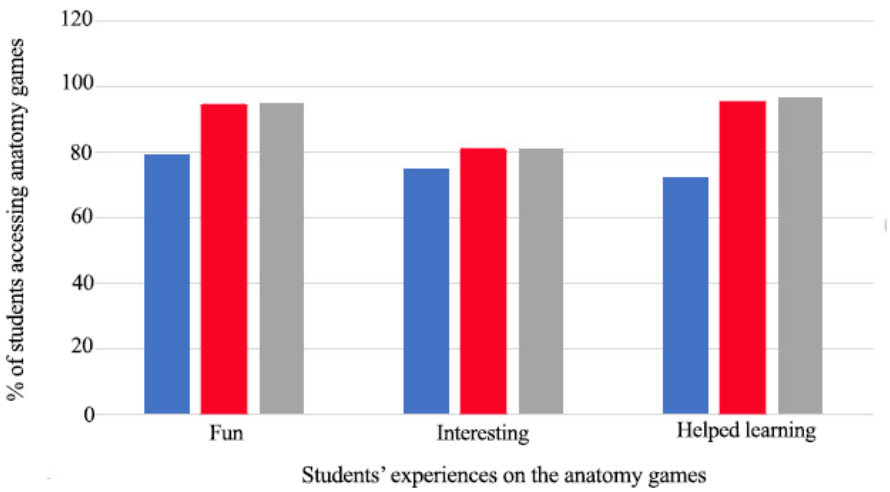
The anatomy board game was played by students from Manipal (n=72). As the game was run as a classroom activity, all students participated and placed their feedback on the game experience. The game was found to be fun (57/72, 79%) and interesting (54/72, 75%) by more than three quarters of the participants, and 72% (52/72) reported that the game helped their learning. Also, 85% of the participants (61/72) expressed their interest of playing a professional computer game if it were developed. In the open-ended feedback on their experiences, students reported that the game was an "interesting educational concept" that made anatomy learning "livelier" and more interesting, and that they felt "motivated" to study neuroanatomy. On the other hand, the students also pointed out that some illustrations on the board game were "not clear" and preferred a three-dimensional game that would give them a "better picture" of the anatomy of the brain. Some expressed that the storyline could have been better; they preferred immediate feedback on the quizzes they answered.

The online neuroanatomy game

Students from Manipal (59/72) and Otago (169/300) played the online neuroanatomy game. Forty-three percent of students (92/228) completed the game in an average of 25 minutes and provided feedback. The rest of the students left the game incomplete at various stages; however, 85% of the players completed at least level 6 (of 10 levels) in the game. Student feedback showed that the game was fun (94.4%) and interesting (80.9%). Playing the game helped them revise their neuroanatomy (95.5%), and they reported a willingness to try more anatomy games (91.1%).

All students (100%) from Manipal reported that the neuroanatomy game was fun and interesting, whereas only 79% and 75% reported that the anatomy board game was fun and interesting. Similarly, the students' learning experience was 72% for the anatomy board game and 92% for the neuroanatomy game; this improvement in students' experiences was statistically significant ($p<0.001$) (Figure 5).

Figure 5: Comparison of player experiences between the three different types of games studied. Blue: anatomy board game. Red: online neuroanatomy game. Grey: online digestive system game.



The students appreciated the storyline, content, visuals and animations of the online neuroanatomy game in comparison to the anatomy board game; the major concern was that the online game was slow paced and the transition time between scenes was long. The students also requested more tasks to perform within the game and more quiz questions in order to revise the anatomy content more effectively.

The online digestive system game

Students from all three universities (total=382; Manipal=51; Otago=126; Khon Kaen=205) played the online digestive system game. The average time taken to complete the game was 25 minutes. Two hundred and nineteen of these 382 players (57.3%) completed the game and placed feedback (Manipal=24; Otago=73; Khon Kaen=122). Of these, 95% (208/219) and 80.8% (177/219) respectively found the game fun and interesting, and 96.8% (212/219) reported that the game improved their digestive system anatomy learning.

Comparing the findings from the online digestive system game with the online neuroanatomy game showed that both these online games were equally fun and interesting. However, the percentage of students who felt that the learning process was improved by the online digestive system game (96.8%) was higher than for the online neuroanatomy game (95.5%); this difference was statistically significant ($p<0.001$) (Figure 5).

Discussion

The concept of an anatomy game was broadly welcomed by the undergraduate medical students from three diverse geographical locations – New Zealand, India and Thailand. The gaming experience was described as "fun" and "interesting" for the board game and both online computer games; however, these aesthetic criteria were rated higher for the computer games. The students also reported that all the games helped them revise their anatomy knowledge in the respective study areas.

The sequential trial-and-error design concept

To our knowledge, this is the first study on gamification in medical education to sequentially create learning resources, constructively modify and recreate new resources based on students' feedback. At every stage of game development and distribution, feedback from the previous stages was carefully considered. For example, the anatomy board game was run in small groups, under faculty supervision, and had a time limit to complete. Copies of hand-drawn illustrations were used in the game scenes. The quizzes were evaluated after the session, and the results for the game were provided the next day; all these aspects were described as limitations in students' feedback, and these issues were all rectified when the first online game (neuroanatomy) was developed: players were given the choice to play independently without supervision, and there was no time limit to answer each quiz. Feedback on the online quizzes was immediate and accompanied by learning tips, and thereby a holistic learning experience was provided.[2] Computer-generated graphical illustrations and animations were used to better depict the anatomical structures.[16]

Despite these changes, there was negative feedback on the length and features of the online neuroanatomy game: it was long, slow and contained fewer tasks and challenges, a factor that we consider a major hindrance for user engagement.[17] While developing the second online computer game (digestive system), these previous issues were addressed. The pace of the game was quickened by shorter transitions between scenes, and the game was distributed as two parts, so each was short.[2] More interactive tasks were included, and more questions were generated for the quizzes; multiple question types, such as crossword puzzles, were also used to encourage interactivity and repeatability.[18]

Meeting student participation and engagement

A major part of this study was to develop a series of interactive anatomy games. Following the self-determination theory to increase students' participation,[19] our online games consisted of several cues to promote an interactive and fun-filled learning environment: players had to collect coins; fun elements (eg, a hippopotamus and teddy bear) were used to relate the neuroanatomical structures; and gastric juice had to be escaped by sailing a boat.[20,21] Extensive use of clinical facts,

discussion of MRI images and immediate feedback on the questions increased student engagement.[2,10,22] Students also liked the innovative idea of integrating the feedback questions within the game—a novel attempt that has not been described elsewhere.

In addition to carefully designing the game content, it was also important to figure out how the students played the game. Although teamwork is shown to improve interaction and socialisation between students,[23] sometimes there is a chance for the slow learners to be dominated and overshadowed by more active students.[24] To partly overcome this issue, we did not run the online games in a classroom setting (as the anatomy board game was). Instead, the students were asked to play independently in their own time (ie, in a stress-free learning environment).[2] Despite these arrangements, only about 60% of the cohort played the online games. Two possible reasons for this reduced number of participants are that, because these were unsupervised sessions, there was an opportunity for the students to team-up or log in as a group to play the game,[24,25] and secondly, because the online computer games were optional, possibly only motivated students participated in these sessions.[25,26]

Learning experience: board game vs computer games

Students' participation, engagement with the games and learning experience improved from game to game. This improvement is possibly due to the constructive modification of the subsequent games' components based on the feedback that the players provided on the previous games. It was interesting to note that the cohort who expressed their limitations on the anatomy board game very much appreciated the following computer game on the same topic. With improved user experience, participants in our study expressed their interest to explore more computer-based anatomy games than board games to learn anatomy. This preference of computer games over the board games was mainly for the games' ability to provide immediate feedback.[27,28,29] From the educators' perspective, computer games were preferred because web-based resources are easy to distribute across institutions, and because it is easy to collect and collect and evaluate computer-game analytics.[2,19,30]

Novelty in the game design process

In addition to the iterative design process, we collected students' demographic data in the game. The players could fill in the details as they sign up for a specific task within the game. Also, student feedback on the game content, and their playing and learning experiences, was integrated within the game tasks. These are novel attempts not described in earlier gamification literature. Students liked this idea of integration; we believe this also took students less time than filling in forms at the beginning and end of the game. This also gave us an opportunity to gain students' opinions at the relevant tasks *in situ*, rather than at the end.

Potential barriers in development of anatomy games

Two major obstacles often faced in educational technology are cost[25,31,32] and translating the medical concepts to the technical team. Although graphic designers are professionals and intimately familiar with designing software, their knowledge in human anatomy is often novice, unless they are primarily involved in medical-education projects.[33] This knowledge gap not only affects the communication between educators and developers. It also increases the cost of the project by prolonging development time. One possible solution for this issue includes involving the students in development of the game content (if they already have a computer proficiency), so that they also learn anatomy during the constructional process; but this is usually difficult with the medical student cohort.[31] Or, as several anatomy board games are already in use,[20,21,26,34] existing games could be adapted, with permission, to reduce the cost of development.[8,21] In this study, we directly involved the authors in game development; creating a simple animated prototype using open-source software not only reduced the cost of development, but also eased communication with the technical team.[11]

Lessons learnt from the game project

In addition to the already defined elements of gamification, we found the following factors to be beneficial while developing and implementing an educational game: The content needs to be clearly

focused on the students' learning objectives. Interactivity is the key; in addition to integrated basic sciences and relevant clinical facts, fun and creativity within the game can promote student engagement. Involving the student cohort in identification of the threshold topics for content development can improve student participation. Keeping the games short and fast paced, and randomly generating each quiz from a bigger collection of questions, can improve student participation, engagement and the repeatability of activities. Direct involvement of staff in content development, like creating some form of game prototype, could not only reduce the project cost but also decrease the communication gap between the medical and computer professionals.

Limitations

The major limitation is that the game could not meet the criteria for all types of players traditionally defined.[35] Unlike other studies,[36,37] we did not categorise the students into a control group and a testing group, since we wanted the entire cohort to benefit from these resources.[2] From a pedagogical view, the number of participants that contributed to the study was relatively low, and it was not the same individuals that played the three different games. Although we had a formative score within the game to test each player's learning, it was not compared with any other academic performance. Moreover, these games were not compatible with mobile phones, tablets or e-readers, which is possibly another factor why not all students were able to play them.

Conclusion

This study showcases the pedagogical and technical factors to be considered during the development of educational games. To our knowledge, this is the first study to develop and test computer games for undergraduate medical students to play-learn the clinical anatomy of different body systems. Carefully designed educational games that are constructively modified based on student feedback effectively improve student participation, engagement and learning experience.

Competing interests:
Nil.
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REFERENCES

1. Charles T, Bustard D, Black M. Experiences of promoting student engagement through game-enhanced learning. In: Ma et al, editors. Serious games and edutainment applications. London: Springer; 2011; p. 425-46.
2. Perumal V, Butson R, Blyth P, Daniel B. Clinical anatomy e-cases: 5-year follow-up of learning analytics. N Z Med J. 2017;130:22-39.
3. Brenton H, Hernandez J, Bello F et al. Using multimedia and Web3D to enhance anatomy teaching. Comput Educ. 2007;49:32-53.
4. Dash S, Kamath U, Rao G, Prakash J, Mishra M. Audio visual aid in teaching fatty liver. Biochem Mol Biol Educ. 2015;44:241-5.
5. van Sint Jan S, Crudele M, Gashegu J, et al. Development of multimedia learning modules for teaching human anatomy: Application to osteology and functional anatomy. Anat Rec B New Anat. 2003;272:98-106.
6. Ang ET, Chan JM, Gopal V, Shia NL. Gamifying anatomy education. Clin Anat. 2018;31:997-1005.
7. Dominguez A, Saenz-de-Navarrete J, de-Marcos L, Fernandez-Sanz L, Pages C, Martinez-Herraiz J. Gamifying learning experiences: Practical implications and outcome. Computers & Education. 2013;63:380-92.
8. Pitt MB, Borman-Shoap EC, Eppich WJ. Twelve tips for maximizing the effectiveness of game-based learning. Med Teach. 2015;37:1013-7.
9. Afyouni I, Rehman FU, Qamar A, et al. Gamifying hand physical therapy with intelligent 3D navigation. SIGSPATIAL Special. 2016;8:42-9.
10. Dithmer M, Rasmussen JO, Gronvall E, et al. The heart game: Using gamification as part of a telerehabilitation program for heart patients. Games Health J. 2016;. doi: 10.1089/g4h.2015.0001
11. Graafland M, Schraagen JM, Schijven MP. Systematic review of serious games for medical education and surgical skills training. Br J Surg. 2012;99:1322-30.
12. Goldman S, Zielezinski MB. Design thinking for every classroom: A practical guide for educators. New York: Routledge; 2022.
13. Goldman S, Kabayadondo Z. Taking design thinking to school: How the technology of design can transform teachers, learners, and classrooms. New York: Routledge; 2017.
14. Galvis-Panqueva A, Mendoza BP. Virtual learning environments: a method for your creation. Informatica

Educ. 1999;12:295-317.

15. McNulty N. Niall McNulty [Internet]. 5 elements of a gamified approach to use in education. [cited 2021 Jun 7]. Available from: https://www.niallmcnulty.com/2017/05/5-elements-of-a-gamified-approach-to-use-in-education/
16. Perumal V. A sectional anatomy learning tool for medical students: Development and user-usage analytics. Surg Rad Anat. 2018;40:1293-1300.
17. Ahmad NB, Barakji SAR, Shahada TMA, Anabtawi ZA. How to launch a successful video game: A framework. Entertainment Computing. 2017;23:1-11.
18. Anyanwu EG. Anatomy adventure: A board game for enhancing understanding of anatomy. Anat Sci Educ. 2014;7:153-60.
19. Rutledge C, Walsh CM, Swinger N, et al. Gamification in action: Theoretical and practical considerations for medical educators. Acad Med. 2018;93:1010-20.
20. Dickey, MD. "Ninja Looting" for instructional design: The design challenges of creating a gamebased learning environment; 2006; Boston. Paper presented at the ACM SIGGRAPH 2006 conference, Boston.
21. Yunyongying P. Gamification: Implications for curricular design. J Grad Med Educ. 2014;6:410-2.
22. Liu M, Papathanasiou E, Hao Y. Exploring the use of multimedia examination formats in undergraduate teaching: Results from the fielding testing. Computers in Human Behaviors, 2001;17:225-48.
23. McIntire CL. Corpus Morphus: The human anatomy board game. Amer Biol Teach. 1995;57:538-43.
24. Shah BA, Sever A, Cressman S. Breast imaging BINGO: An educational game to supplement the traditional assessment style. Med Sci Educ. 2016. doi:10.1007/s40670-016-0247-6
25. McNulty JA, Halama J, Espiritu B. Evaluation of computer-aided instruction in the medical gross anatomy curriculum. Clin Anat. 2004;17:73-8.
26. Svinicki MD. Encouraging your students to give feedback in Techniques and strategies for interpreting student evaluations. New directions for teaching and learning. 2001;87:1-100.
27. Hallfors D, Khatapoush S, Kadushin C, Watson K, Saxe L. A comparison of paper vs computer-assisted self-interview for school alcohol, tobacco, and other drug surveys. Evaluation and Progaram Planning. 2000;23:149-55.
28. Noyes JM, Garland KJ. Computer- vs paper-based tasks: Are they equivalent? Ergonomics. 2008;51:1352-75.
29. Vispoel WP, Boo J, Bleiler T. Computerised and paper-and-pencil versions of the Rosenberg self-esteem scale: A comparison of psychometric features and respondent preferences. Educational Psychological Measurement. 2001;61:461-74.
30. Sundaram G, Perumal V. Moodle based e-learning resource for revising clinical anatomy: An inexpensive and interactive supplement for physiotherapy students. Int J Physiother. 2016;4:409-14.
31. Ma M, Bale K, Rea P. Constructionist learning in anatomy education. What anatomy students can learn through serious games development. Berlin Heidelberg: Springer. 2012; p. 43-58.
32. Royse MA, Newton SE. How gaming is used as an innovative strategy for nursing education. Nurs Educ Perspect. 2007;28:263-7.
33. Jawan R, Zeman MN. A prototype educational model for hepatobiliary interventions: Unveiling the role of graphic designers in medical 3D printing. J Digit Imaging. 2018;31:133-43.
34. Yoon B, Rodriguez L, Faselis CJ, Liappis AP. Using a board game to reinforce learning. J Contin Educ Nursing. 2014;45:110-1.
35. Bartle R. Hearts, clubs, diamonds, spades: Players who suit MUDs. J MUD Res. 1996;1:19.
36. Samarakoon LB, Vithoosa S, Kokulan S et al. Anatomy of teaching anatomy: Do prosected cross-sections improve students understanding of spatial and radiological anatomy? Anat Res Int. 2016. doi: 10.1155/2016/8984704
37. Tam MDBS, Hart AR, Williams SM, Holland R, Heylings D, Leinster S. Evaluation of a computer program (disect) to consolidate anatomy knowledge: a randomized controlled trial. Med Teach. 2010;32:138-42.