Developing a game-based mobile application for anatomy education of healthcare students

Desenvolvimento de uma aplicação móvel baseada em jogos para o ensino da Anatomia de estudantes da área da saúde

José Vitor de Sousa Nascimento, Victor Hugo da Silva Mendes, Vandilson Pinheiro Rodrigues

ABSTRACT

Introduction: Game-based mobile applications have become powerful tools to aid the learning process. In the study of human anatomy, the use of apps has shown promise, providing students with an interactive and accessible way to explore and understand the complexity of the human body. **Objective:** This study describes the performance on digital platforms of an application developed to help healthcare students learn human anatomy content. **Methods:** This mobile application was developed in the Dart programming language and made available for Android and iOS systems. The Anatomania App presented a multifaceted approach to teaching human anatomy, including resources such as quizzes, text lessons, explanatory videos, and flashcards. These screens offer options for adjusting individual preferences and settings. **Results:** This mobile application had a total of 85,807 downloads and 82,839 registered users. This application had a high frequency of users from Portuguese-speaking countries such as Brazil, Angola, Portugal, and Mozambique. **Conclusion:** This educational application has shown the potential to promote a more effective and interactive approach to learning anatomy.

Keywords: Smartphone, Gamification, Students, Anatomy.

RESUMO

Introdução: As aplicações móveis baseadas em jogos vêm ganhando destaque como ferramentas poderosas para auxiliar o processo de aprendizagem. No estudo da anatomia humana, a utilização de aplicações parece promissora, visto que pode proporcionar aos estudantes uma forma interativa e acessível de explorar e compreender a complexidade do corpo humano. **Objetivo:** Descrever o desempenho em plataformas digitais de uma aplicação desenvolvida para ajudar os estudantes de saúde a aprender conteúdos de anatomia humana. **Métodos:** Esta aplicação móvel foi desenvolvida na linguagem de programação Dart e disponibilizada para os sistemas Android e iOS. O Anatomania App foi desenvolvido com uma abordagem multifacetada para o ensino da anatomia humana, incluindo recursos como quizzes, lições em texto, vídeos explicativos e flashcards. Estas opções podem ser ajustadas de acordo com as preferências e definições individuais. **Resultados:** Esta aplicação móvel teve um total de 85.807 downloads e 82.839 utilizadores registados. Esta aplicação teve uma elevada frequência de utilizadores de países de língua portuguesa como o Brasil, Angola, Portugal e Moçambique. **Conclusão:** Esta aplicação educativa demonstrou ter potencial para promover uma abordagem mais eficaz e interativa na aprendizagem da anatomia.

Palavras-chave: Smartphone, Gamificação, Estudantes, Anatomia.

Universidade Federal do Maranhão, São Luís, (MA), Brasil

https://doi.org/10.11606/issn.2176-7262.rmrp.2024.218161

INTRODUCTION

The growing use of applications for mobile devices has encouraged the deployment of this technology for educational purposes[1]. Several studies have shown that gamification techniques can improve students' performance and learning experience, as well as increase engagement[2,3]. Furthermore, the mobile computing environment has undergone radical changes in recent years, including the improvement of smartphone technology and the enhanced accessibility of mobile data services with reduced costs[4,5].

The use of digital tools as a supplementary resource could provide significantly better understanding of complex anatomy concepts in healthcare education[1,6]. In addition, a previous study has indicated that mobile learning in anatomy could provide an uninterrupted, individualised and beneficial learning environment, also generating increased levels of motivation, self-confidence and satisfaction, and reduced levels of anxiety[7]. These authors have encouraged educators to expand the use of mobile technologies to stimulate the learning of the new generation of healthcare students.

Distance learning strategies have gained prominence especially during the COVID-19 pandemic. This was a period in which higher education institutions had to adapt their activities to continue the process of teaching-learning in a distance format[8-10]. In the post-COVID-19 era, blended learning approaches have remained in institutions, reinforcing the need to design studies that can contribute to improving teaching tools[11].

The game-based mobile application represents an innovative approach that uses elements of games to promote more engaging, motivating and personalised learning[12,13]. This methodology has the potential to transform the way students interact with knowledge, making the learning process more meaningful and enjoyable[14]. An in-depth understanding of the anatomy and function of the human body is essential for safe and effective clinical care. Therefore, this study presents a mobile application that uses gamification to engage healthcare students in learning anatomy.

METHODS

This is a mixed descriptive study that evaluated the performance, download pattern and user feedback of a mobile application developed for learning human anatomy. Data were collected for analysis in September 2023. The Anatomania App is a free, user-friendly, interactive, game-based mobile application designed to support anatomy education in remote learning environments.

During the development of the user requirements, the description of the functional and non-functional requirements of the system were developed. The functional requirements are statements of services that the system should provide, how the system should react to specific inputs, and how the system should behave in certain situations. Non-functional requirements, on the other hand, consist of limitations on the services or functions offered by the system[15]. The description of the requirements of this app is listed in Table 1.

TABLE 1. Description of the functional and non-functional requirements of the app.

Requirement	Description
Functional requirements	
User authentication	The system must allow users to authenticate using username and password.
Registering new users	The system must allow for the registration of new users and request information such as name, email, and password.
Password recovery	The system must provide an option for password recovery, allowing users to reset their passwords through a secure process.
Quizzes	Users should be able to conduct quizzes with multiple choice questions on human anatomy to test their knowledge.
Creating questions	Users should be able to create multiple-choice questions to expand the question bank available in quizzes.
Viewing flashcards	Users should be able to view the created flashcards, with the question on the front and the answer on the back, to study and review the content.
Creating flashcards	Users should be able to create flashcards with questions and answers related to anatomy human.
Progress tracking	The app should provide a system to track the user's progress by showing statistics on performance in revised quizzes and flashcards.
Notifications and reminders	The app should send personalised notifications and reminders to encourage users to study regularly and keep a schedule of learning.
Interactive lessons	The app should provide interactive lessons in text format, images or videos, addressing human anatomy topics in a didactic and engaging way.
Ranking	The app should display a ranking of the users with the best performance in the quizzes, highlighting the best results and scores.
Non-functional requirements	
Performance	The application should be intuitive and user-friendly, with a user-friendly interface for users of different levels of knowledge.
Operational	The application must respond quickly to user interactions, avoiding significant delays in loading content and responding to commands.
Security	The application must be stable and reliable, avoiding unexpected crashes and errors during use. User data must be stored securely and protected from loss or unauthorised access.
Offline functionality	The application will work without internet access.
Extensibility	The application should be designed to support an increasing number of users and content without compromising performance or usability.

Upgradeable	The application should be easily maintained and updated, allowing for the addition of new functionality and the correction of possible errors or failures.
Compatibility	The application must have well-defined minimum hardware requirements, ensuring that it can run on devices with different capabilities and resources.

This mobile application was developed using Dart with Android Studio and Flutter framework, which allows development for both Android and iOS devices. Flutter is an open-source framework designed to create high-quality native applications for various platforms, including Android, iOS, web and desktop, from a single codebase. It uses the Dart programming language and provides a user-centred development approach, with a wide range of customisable widgets and a reactive UI architecture[16].

Firebase cloud server was used for cloud services and data management. The mobile application is available for download in the Google Play Store (since 24 January 2021) and the Apple App Store (since 31 December 2022). Users who downloaded the app had the opportunity to share their opinions on its practicality and usefulness through the reviews available on both the Apple Store and the Play Store. Testimonials were collected from these freely available reviews on the platforms, users were named by double letters in order to maintain anonymity (A.A., B.B., C.C., D.D.). Data were analysed using GraphPad Prism 10 (GraphPad Software, San Diego, CA, USA). Descriptive statistics used measures of absolute frequency and cumulative frequency. Results were plotted as line and bar graphs.

RESULTS

The present mobile application allows interaction between users and promotes gamification of learning, making the process more playful and stimulating (Figure 1a). The regular game mode is based on the quiz system (Figure 1b), in which the user chooses which category of human anatomy and the level of difficulty of questions (Figure 1c). Users can also challenge other players (Figure 1d). The inclusion of the ranking in the application aims to gamify learning, stimulating greater engagement on the part of the user (Figure 1e).

The configuration and user management screens allow the user to interact with their data within the system, offering the possibility to customise and integrate their account with the application (Figure 1f). Users can select the fields of anatomy they are interested in, create their own sets of flashcards, track their progress, and revise content as needed (Figure 1g). This adaptive approach encourages continuous and self-learning, with a personalised and flexible learning experience. In addition to providing over two thousand questions on human anatomy, the application allows users to create their own questions and share them within the application community, enhancing users' learning experience (Figure 1h).

FIGURE 1 Screenshots of the Anatomania App. Main menu screen (a), quiz screen (b), categories screen (c), challenge screen (d), ranking screen (e), profile screen (f), flash-card screen (g), question bank screen (h).

Based on the Firebase database (Accessed 27 September 2023), this mobile application had a total of 85,807 downloads and 82,839 registered users. This significant number of users reflects the relevance and popularity of the application, demonstrating high acceptance among users. This application had an expressive registration of users coming from Portuguese-speaking countries (Brazil, Angola, Portugal, Mozambique) since the application is currently only available in Portuguese (Figure 2). Overall, this educational app has demonstrated the potential to promote a more effective and interactive approach to learning anatomy.

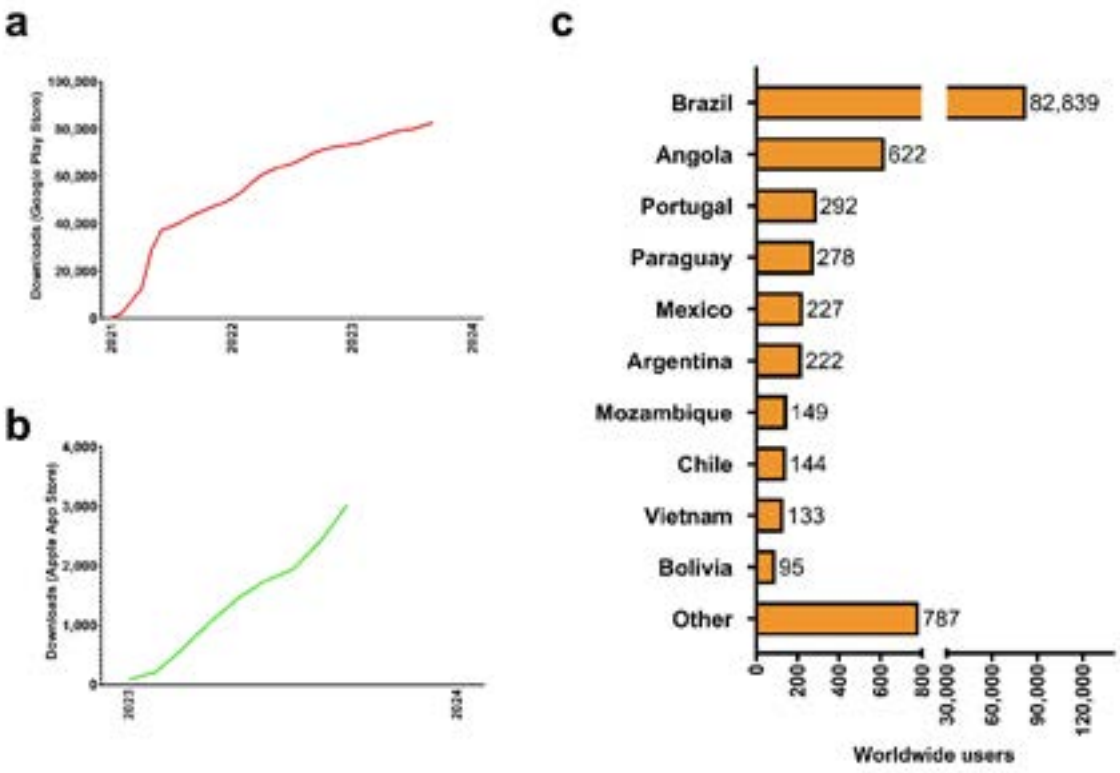

FIGURE 2 Cumulative frequency of Anatomania App downloads in the Google Play Store (a) and Apple App Store (b), and worldwide distribution of users (c).

A collection of user testimonials, available on the platform, is listed below. User A.A. commented on the gamification of learning within the app: “An incredible app for health and biology students. The best way to learn anatomy is by training and this app offers this in a super didactic and fun way. I found myself spending hours playing and did very well in the anatomy exam.” User B.B. commented on the gamification of learning within the app. “It’s a great tool for bringing scientific knowledge to students and anatomy enthusiasts in a playful way,” User C.C. commented on the quality of the content within the app. “It shows me how shallow my general knowledge of anatomy was, I use it to update myself and always have something to talk about with friends.” User D.D. commented on their experience using the app during the COVID-19 pandemic: “I was having a lot of difficulty with anatomy because of missing practical classes due to the pandemic, this app saved me a lot!”

DISCUSSION

The present findings suggest that the App can offer students and health professionals an interactive and accessible tool to improve the study and learning of human anatomy. The Anatomania App presented a multifaceted approach to teaching human anatomy, including resources such as quizzes, text lessons, explanatory

videos and flashcards. The user configuration and management screens have been designed to allow the user to interact with their data within the system, offering the possibility of customising and integrating their account into the application. These screens provide options for adjusting individual preferences and settings. These features have given users the opportunity to study independently, reinforce the knowledge they had acquired and apply anatomical concepts in practical situations.

In addition, the use of the Android Studio and Flutter platforms enabled the app to be efficiently structured, with a minimal rate of errors and bugs. The combination of these two tools also contributed to excellent execution performance, guaranteeing a fluid cross-platform compatibility and satisfactory user experience for iOS and Android users. The integration of the Firebase cloud server enabled secure and efficient storage of the data used by the Anatomania App.

The development and use of educational mobile applications for health brings challenges, but also a number of opportunities. Mobile technologies can be effective tools for improving the knowledge and skills of health professionals, and have some advantages such as their low cost, greater versatility, and greater independence from regional or local boundaries for students to set their own learning schedule[17].

In this context, gamification has gained prominence and is defined as the use of game design elements in areas not related to games themselves. This methodology has been shown to be effective in developing skills, motivating students and enhancing the educational experience[18]. Gamification is having a significant impact in various sectors, arousing particular interest in anatomy education as a complementary form of learning, in response to the difficulties of accessing cadaveric material. Game components such as tournaments, ranking, challenges and a virtual assistant can have a motivating effect on student learning and satisfaction[19].

Game-based mobile applications can adapt content and activities to meet the needs of each student, promoting remote learning, learning analytics, and quick feedback. Additionally, gamification can encourage collaboration and teamwork. Many games are designed to be played in groups, which promote communication, cooperation, and knowledge sharing between participants. In this way, gamification in education encourages interaction between students and promotes collective learning[20].

However, it is important to emphasise that gamification in education should not completely replace traditional teaching methods, but rather complement them. Games can be used as a pedagogical tool to enrich lessons and stimulate students' creativity, curiosity and interest. It is important that educators have a solid understanding of the advantages and disadvantages of gamification in curriculum planning. They should be cautious when incorporating new elements and take into account both the different types of students and the learning objectives[21].

Some limitations of this study should be addressed. The descriptive design adopted does not allow us to investigate associations or the impact of using the application on student performance. The present study presented the app's receptivity performance on the platforms where

mobile applications are made available. Therefore, future studies should evaluate the effect of using the application on short- and long-term retention of knowledge about human anatomy content, and its impact on the future clinical practices of these health professionals. Although the app is only available in Portuguese, which may be considered a limitation, it has attracted a significant number of users in several countries where Portuguese is not their native language. This demonstrates the interest in and demand for content related to anatomy education. It may be possible to consider making the app available in other languages in the future to further expand the app's reach.

CONCLUSION

In conclusion, the development of mobile applications for teaching students is a constantly expanding field, and the present App represents a promising auxiliary tool for teaching human anatomy. Future studies should be designed to investigate the impact of these technologies on healthcare students' performance and practice in anatomy education.

REFERENCES

1. Golenhofen, N., Heindl, F., Grab-Kroll, C., Messerer, D. A., Böckers, T. M., & Böckers, A. (2020). The use of a mobile learning tool by medical students in undergraduate anatomy and its effects on assessment outcomes. Anatomical Sciences Education, 13(1), 8-18. https://doi.org/10.1002/ase.1878
2. Felszeghy, S., Pasonen-Seppänen, S., Koskela, A., Nieminen, P., Härkönen, K., Paldanius, K. M., et al. (2019). Using online game-based platforms to improve student performance and engagement in histology teaching. BMC Medical Education, 19, 273. https://doi.org/10.1186/s12909-019-1701-0
3. Mahrous, A., Botsko, D. L., Elgreatly, A., Tsujimoto, A., Qian, F., & Schneider, G. B. (2023). The use of artificial intelligence and game-based learning in removable partial denture design: A comparative study. Journal of Dental Education, 87, 1188-1199. https://doi.org/10.1002/jdd.13225
4. Christopoulos, A., Pellas, N., Kurczaba, J., & Macredie, R. (2022). The effects of augmented reality-supported instruction in tertiary-level medical education. British Journal of Educational Technology, 53(2), 307-325. https://doi.org/10.1111/bjet.13167
5. Ali, Y., & Khan, H. U. (2023). A Survey on harnessing the applications of mobile computing in healthcare during the COVID-19 pandemic: Challenges and solutions. Computer Networks, 224, 109605. https://doi.org/10.1016/j.comnet.2023.109605
6. Saghiri, M. A., Vakhnovetsky, J., & Nadershahi, N. (2022). Scoping review of artificial intelligence and immersive digital tools in dental education. Journal of Dental Education, 86(6), 736-750. https://doi.org/10.1002/jdd.12856
7. Bolatli, G., & Kizil, H. (2022). The effect of mobile learning on student success and anxiety in teaching genital system anatomy. Anatomical Sciences Education, 15(1), 155-165. https://doi.org/10.1002/ase.2059
8. Al-Alami, Z. M., Adwan, S. W., & Alsous, M. (2022). Remote learning during Covid-19 lockdown: A study on anatomy and histology education for pharmacy students in Jordan. Anatomical Sciences Education, 15(2), 249-260. https://doi.org/10.1002/ase.2165
9. DePhilip, R. M., & Quinn, M. M. (2022). Adaptation of an anatomy graduate course in ultrasound imaging from in-person to live, remote instruction during the Covid-19 pandemic. Anatomical Sciences Education,

15(3), 493-507. https://doi.org/10.1002/ase.2177
10. Ghosh, S. K. (2022). Evolving strategies in whirlwind mode: The changing face of anatomy education during Covid-19 pandemic. Anatomical Sciences Education, 15(6), 1103-1119. https://doi.org/10.1002/ase.2214
11. Cheng, X., Xu, Y., Tang, H., Chan, U., Li, Y. Q., & Yang, X. (2023). Chinese anatomy educators' perceptions of blended learning in anatomy education: A national survey in the post-COVID-19 era. Anatomical Sciences Education, 2023:00-00. https://doi.org/10.1002/ase.2328
12. Yadav, A. K., & Oyelere, S. S. (2021). Education and Information Technologies, 26, 2539-2562. https://doi.org/10.1007/s10639-020-10373-3
13. Krouska, A., Troussas, C., & Sgouropoulou, C. (2022). Mobile game-based learning as a solution in COVID-19 era: Modeling the pedagogical affordance and student interactions. Education and Information Technologies, 27, 229–241. https://doi.org/10.1007/s10639-021-10672-3
14. Wilkinson, K., Dafoulas, G., Garelick, H., & Huyck, C. (2020). Are quiz-games an effective revision tool in Anatomical Sciences for Higher Education and what do students think of them?. British Journal of Educational Technology, 51(3), 761-777. https://doi.org/10.1111/bjet.12883
15. Jha, N., & Mahmoud, A. (2019). Mining non-functional requirements from app store reviews. Empirical Software Engineering, 24, 3659-3695. https://doi.org/10.1007/s10664-019-09716-7
16. Zammetti, F. (2019). Practical Flutter. Berkeley, CA: Apress. https://doi.org/10.1007/978-1-4842-4972-7
17. Chandran, V. P., Balakrishnan, A., Rashid, M., Pai Kulyadi, G., Khan, S., Devi, E. S., et al. (2022). Mobile applications in medical education: A systematic review and meta-analysis. Plos One, 17(3), e0265927. https://doi.org/10.1371/journal.pone.0265927
18. Ang, E. T., Chan, J. M., Gopal, V., & Li Shia, N. (2018). Gamifying anatomy education. Clinical Anatomy, 31(7), 997-1005. https://doi.org/10.1002/ca.23249
19. Castellano, M. S., Contreras-McKay, I., Neyem, A., Farfán, E., Inzunza, O., Ottone, N. E., et al. (2023). Empowering human anatomy education through gamification and artificial intelligence: An innovative approach to knowledge appropriation. Clinical Anatomy. 2023:00-00. https://doi.org/10.1002/ca.24074
20. Krishnamurthy, K., Selvaraj, N., Gupta, P., Cyriac, B., Dhurairaj, P., Abdullah, A., et al. (2022). Benefits of gamification in medical education. Clinical Anatomy, 35(6), 795-807. https://doi.org/10.1002/ca.23916
21. Rutledge, C., Walsh, C. M., Swinger, N., Auerbach, M., Castro, D., Dewan, M., et al. (2018). Gamification in action: theoretical and practical considerations for medical educators. Academic Medicine, 93(7), 1014-1020. https://doi.org/10.1097/ACM.0000000000002183.

Acknowledgments

The authors would like to thank professors and lecturers from the Department of Morphology at the Federal University of Maranhão for providing valuable advice and assistance in every stage of the mobile application development process.

Author contributions

JVSN: Conceptualization, methodology, project administration, investigation, writing original draft. VHSM: Conceptualization, methodology, investigation, visualization, writing original draft. VPR: Supervision, Methodology, statistical formal analysis, visualization, writing original draft, review and editing.

Funding

This study was supported in part by the Brazilian National Council for Scientific and Technological Development (CNPq) and the Research Support Foundation of Maranhão State (FAPEMA).

Corresponding Author:
Vandilson Pinheiro Rodrigues
vandilson.rodrigues@ufma.br

Received: nov 03, 2023
Approved: nov 19, 2023
Editor: Prof. Dr. Felipe Villela Gomes
