A Case Study of Using Web 3D Game Technology for a Scalable Midwifery Training Simulation

Xi Guo
College of Computing
Birmingham City University
United Kingdom
xi.guo@bcu.ac.uk

Alison Edwards
School of Nursing and Midwifery
Birmingham City University
United Kingdom
alison.edwards@bcu.ac.uk

***Abstract*— Digital simulation offers numerous advantages for midwifery training and in particularly enhancing decision-making skills. By providing realistic, risk-free learning experiences, fostering repetition and feedback, and offering a variety of scenarios, digital simulation stands out as an effective tool for preparing midwifery learners for the complexities of clinical practice. However, creating a 3D-based simulation system that supports scalable solutions poses challenges. Apart from the cost of 3D content; designing a simulation that ensures engagement with learners as well as scalability is still a problem. This paper discusses a design and implementing case study of such a system using gamification methodologies, focusing on scalability and efficiency. The system uses web-based digital media, including web 3D game technology, for educational simulation. It showcases how web-based game technology facilitates simulation design and concludes with future considerations.**

Keywords—Midwifery education, digital simulation, web 3D game, gamification, scalable

I. INTRODUCTION

Midwifery education at universities is challenging due to the rigorous blend of theory and practical skills, alongside the need for adaptability in evolving healthcare practices. Digital simulation offers numerous advantages for midwifery training, particularly in enhancing decision-making skills [1]. The digital simulation lets learners practice their skills repeatedly in a safe environment. It gives instant feedback and presents a range of scenarios that are accessible and standardized. So, digital simulation is a very effective tool for preparing midwifery students for the complexities of clinical practice. [2]. Digital simulation enhances midwifery training by providing realistic scenarios in a safe environment. Incorporating digital 3D components add depth and realism, allowing students to visualise and interact with lifelike models and environments leading to improvments in clinical skills and decision-making [3, 4, 5]. However, designing such a simulation system and achieving the learning goals are still a challenge. The cost and scale of the technology also affect the impact of the innovation.

This paper discusses a case study of how to apply gamification design and implement to such a system, considering two main issues: efficient learning engagement and future scalability. It contributes a case study on how to use web 3D game technology to facilitate educational simulation design and implementation. The paper starts with the project introduction and related work. Then the process of gamification design and implementation; followed by a demonstration of the results and a discussionion about future works.

II. RELATED PROJECT

A. Digital 3D simulation for midwifery training

Midwifery education at universities presents challenges for learners due to its demanding nature. For teachers, aside from the challenging curriculum delivery, cohort size poses a problem. For instance, large cohorts and limited teaching space/resources hinder ensuring simultaneous engagement within the limited session time. These challenges, coupled with the responsibility of ensuring safe childbirth, make midwifery education an intensive and rigorous journey for learners [1-6]. However, with limited resources, it is challenging for learners to transfer the skills from textbooks and lessons to real scenarios. Since Covid-19 [6] there has been increased discussions and adaptations to online or blended forms of learning [7]. Compared to the traditional physical learning process, digital simulation provides a flexible learning resources that facilitates the learning process and allows students to engage and practice anytime and anywhere. Well-designed 3D simulations enhance learning outcomes by visualising the learning context, simplifying the cognitive process and allowing students to practice in a safe, close-to-reality environment without affecting real patients [3, 8].

Previous similar works [8, 9] using online 3D social platforms and 360 videos, have been noted. However, most 3D simulation systems provide limited engagement with learning content [8] or limited interaction [9]. More advanced scenarios using Virtual Reality (VR) require powerful client-side servers and/or advanced PC (or headset) equipment [5, 10-13]. Some simulations require specific locations to run. Therefore, most simulations are still limited by devices, relying on good rendering devices despite being claimed as accessible anywhere. Web technology offers cross-platform access, providing scalable solutions without additional software using a standard web browser. However, simulating interactive 3D content on web pages remains challenging. While similar projects exist (not necessarily directly designed for Midwifery) most are based on 2D video or image/text content [9, 14, 15]. In [16], a system similar to this project is introduced, however, the prototype only provides interaction with a 3D anatomy model with limited explanation on enhancing learner engagement. A design framework is needed to enhance learner engagement beyond a simple interactive 3D model.

B. Gamify the learning materials.

Gamification is a methodology that applies game elements in non-game contexts [7, 17]. Although similar to game-based learning, in a learning context, game mechanics are used as part of the learning engagement activity [17]. Consequently,

2024 IEEE Gaming, Entertainment, and Media Conference (GEM) | 979-8-3503-7453-7/24/$31.00 ©2024 IEEE | DOI: 10.1109/GEM61861.2024.10585499

learners' motivation, engagement, knowledge acquisition, and more recently, flow experience could be enhanced [18, 19]. The study shows that avatars, meaningful stories, and teammates affect the experience of social relatedness. However, gamification is not simply about adding game elements to the target context. It requires systematic thinking about how the game elements will help enhance and achieve the design goals [20, 21]. A lot of analysis and design are required during the process to achieve the best impact [21-23]. Some frameworks have also been proposed to help gamification design, for example, FRAGGLE [22] and SGI [23]. Compared with other frameworks, FRAGGLE is based on Agile methodologies [24] to achieve fast prototype results ready for testing. It focuses on the learning context and provides a framework that can be used as guidance for the gamification design process targeting learning engagement and efficiency.

III. Gamification Design Process

This project is still at an initial stage and aims to achieve scalability targets to maximize practical impact in higher education midwifery courses. Therefore, FRAGGLE was chosen as the main guidance for the gamification design process. This framework supports fast prototyping and fits well within the Higher Education context [22]. However, FRAGGLE is only provides high-level guidance that mainly focuses on learning design and especially engagement. The scalability of the project will also need to be considered, particularly the cost of the technology. Therefore, another layer of design should be added to the framework. Also, in the guidance, most of the examples are used to describe the learners' expectations while less consideration is given to the teachers. As this research is driven by teachers, the activities are adapted to fit the available resources.

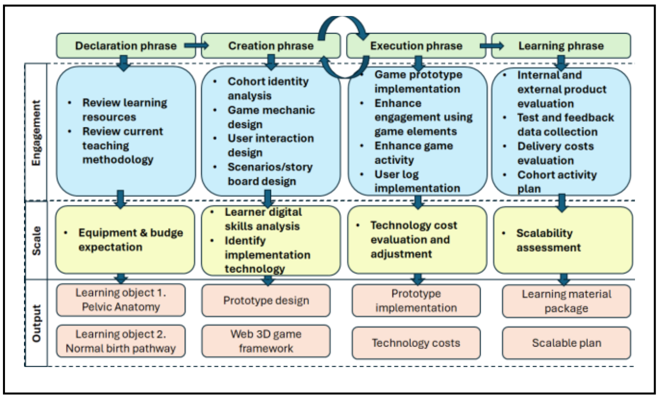

Fig. 1. Gamification design process using FRAGGLE framework

Fig. 1 shows the overall gamification design process using the FRAGGLE framework. The columns demonstrate four phases during the process: Declaration, Creation, Execution, and Learning. Each column includes layers of analysis activities (targeting engagement and scalability) to gamify the materials, as well as output examples of each phase. The detailed process is described below:

A. *Declaration phase*

According to FRAGGLE, the first phase is to assess the necessity of gamification. "Problems" and "causes" are analysed during the process. The activities in the "engagement" layer aim to identify learning objectives that can potentially be gamified to achieve better outcomes when compared with traditional learning materials. Through the teacher's analysis of the existing teaching plans, skills training usually receives better engagement since it is mostly hands-on practice. However, the learning materials that require learning theory and apply the theory to decision-making are normally challenging because learning theory is sometimes considered to be "boring" and not interactive. Also, during the teaching, there is a lack of context and links between the traditional learning materials and practical application, which makes it difficult to find a way to practice decision-making in Midwifery education. When reviewing the current teaching methods, it has been observed that the learning materials mainly comprise of images and videos, aiding learners in conceptualising the subject matter. However, this poses a challenge for junior learners with limited hospital exposure.

Equipment and budget expectations are also analysed during this process since it will directly affect how scalable the system can be. In this case study, the expectation is that existing University PCs and Laptops can be used without any upgrades or additional software. As there are large cohorts of students in the midwifery course and limited teaching space, it would be beneficial if the system can be accessed at anytime and from anywhere. Where possible, the students can use mobile devices too.

After analysis, two topics are selected for gamification: "Pelvic anatomy" (learning objective 1) and the clinical scenario "normal birth pathway" (learning objective 2). Other topics such as "Uterus contractions" are identified as materials that can be simulated more easily using a simple video explanation. "User Stories" and "Acceptance Tests" are mainly collected from the teachers' observation of the experience. The measurement set for this project is to find out how feasible it is to use such a system in real classroom teaching and to find out the students' engagement with the project.

B. *Creation phase*

In this phase, game elements such as player profiles, mechanics, stages, actions, and triggers are developed for the prototype. "Cohort identity analysis" identifies target learner features, focusing on Midwifery university students from both Bachelor's and Master's courses. These students must acquire skills from Learning Objectives 1 and 2, with varying levels of existing midwifery knowledge. Given limited information on their learning styles, game mechanics should be easy to grasp. Previous research favours the "exploring" game type, chosen for its popularity and engagement without pre-session training. This approach embeds learning content within game scenarios, promoting the normal birth delivery pathway (Learning Object 2). Learning Object 1 is integrated as a mini-game within the main narrative, encouraging curiosity-driven exploration of the theory. Learners are expected to progress by acquiring knowledge, solving puzzles, and making correct decisions during scenario exploration, supported by various user interaction types.

The interaction is designed with three types of hotspots: numbered ones for exploring medical documentation (Fig. 2. B), puzzle ones for learning activities and clues (Fig. 3), and decision-related ones unlocking new scenarios. Avatar and panorama animations provide feedback, with encouraging video feedback for wrong decisions and successful delivery news for correct ones. Learners' digital skills, mainly basic web browser use, are analysed. Thus, web 3D game technology is chosen for implementation. This decision informs prototype design and the development of a Web 3D game framework.

Fig. 2. Output of the gamification interaction design

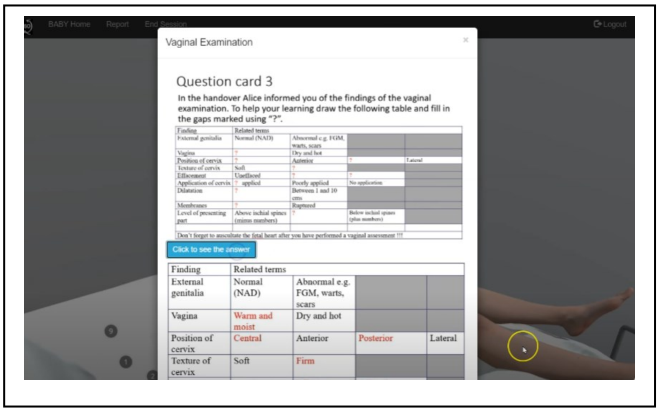

Fig. 3. Example of the puzzles with learning activities

C. Execution phase

In this stage, the overall learner interaction cycle is logically linked together. The gamification process in this project begins with the 3D avatar animated video task brief (Fig. 2, A), followed by exploring the game with narratives supporting non-linear choices. Learning activities are embedded in gameplay, supported by interaction with interactive 3D models (Fig. 2, C), numbered hotspots, quizzes, and multimedia resources (Fig. 2, B). Some scenarios are designed using 3D avatar animation to provide personalised interaction and learning experiences. For example, Fig. 2, D demonstrates the woman's birth ball position using 3D animation. According to FRAGGLE, it is necessary to track user interactions to develop a personalised learning journey. Therefore, the system captures all learners' interactions, such as "clicks" and "pano movements," and categorises them automatically according to interaction types such as "scenario exploration" and "decision-making".

The visiting history pathway is also captured. All user login information is associated with each user's journey and stored in the database for further assessment. An automatically generated user log page is also generated after each exploration, providing learning and teacher feedback. The decisions made by learners in the simulation are visualised using an automatically generated linked node graph (Fig. 4).

To balance the technology innovation costs (including development and equipment costs) and ensure the project's sustainability and scalability, a fast Minimum Viable Product (MVP) is produced using Web 3D technology, with 3D content and videos stored on a cloud-based repository. The technology cost is also evaluated. For example, the initial test uses 3D animation to give task briefs and feedback. After the first internal test cycle, it is changed to avatar animated video, achieving the same result and being more cost-effective as the video host is cheaper and faster than 3D animation content. The front-end platform uses HTML and JavaScript code to implement the main mechanics. The back-end platform uses PHP and MongoDB, as well as a MySQL server. Basic user authentication is also implemented, and individual data can be saved with password protection. During the process, it was necessary and beneficial to go back to creation phase and update the design accordingly so that the overall design could be improved.

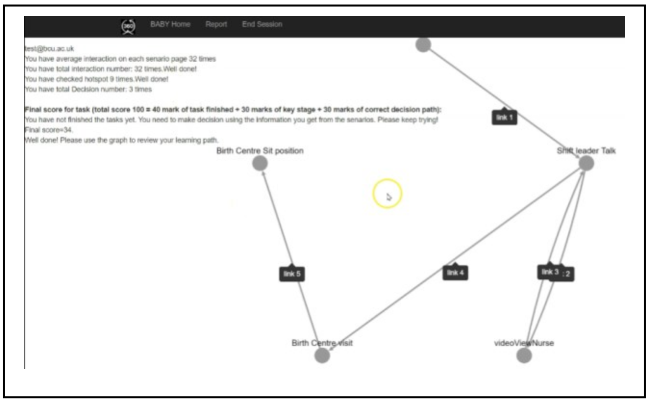

Fig. 4. Example of automatic generated user decision path

D. Learning phase

The purpose of this phase is to collect activity data and evaluate it against the achievement target set in the declaration phase. Internal pilot tests involve teacher and student volunteers. Initial feedback suggests the system is easy to access and operate via a browser, with functions working as expected. However, scenarios are time-consuming and require extensive practice. Additional user testing is necessary to gather more data for system evaluation. A learning material package is generated, including session plans, project briefs, and user tutorials for the simulation system. A scalable plan adaptable to current teaching methods with minimal costs is developed and refined based on test results. The project only requires a web server and cloud service for 3D content, accessible on both PC and mobile devices with multiple user access.

IV. RESULT AND LIMITATIONS

The overall design is complete, and the MVP is achieved, ready for user testing. The FRAGGLE model proved useful, aligning well with agile project management, efficiently planning prototype generation. However, a few limitations of the project is summarized below:

Lack of co-creation with the learners: This model primarily focuses on learner perspectives but also acknowledges the importance of considering teachers' viewpoints. In certain stages, questions can be crafted to gather both learner and teacher expectations. Initially, collecting data from teachers is often more efficient, given students' limited understanding of overall learning goals. However, after validating the prototype, input from both learners and teachers is valuable, especially in co-creating learning materials. Future work is required to improve the design by involving more participants from both the learners and teachers' group. Revisiting and reflecting on the creation phase post-execution aids in aligning design with cost-effective objectives.

Limitation on the evaluation: The result shows FRAGGLE works well as a general guidance for gamification learning materials design. Overall, the findings highlight the potential of gamification to support Midwifery education by enhancing learner engagement. However, further data collection is required to evaluate the effectiveness of the project from both learner and teacher's view. Future work is required to embed this project into real teaching sessions.

Limitation on the scalability: While the Web3D application supports the scalable plan, future work is still required to address technical challenges for large 3D assets, different Midwifery cenarios and practical constraints essential in realising the full benefits of gamified learning experiences. Future research should focus on refining scalable implementation strategies, evaluating long-term effectiveness, and addressing the diverse needs of learners in the digital age.

V. CONCLUSION

In summary, this case study demonstrated how gamification offers a pathway to innovative educational experiences in Midwifery. Using gamification models such as FRAGGLE as a guidance is very helpful to fast prototype MVP. This case study explained how to apply FRAGGLE and transfer the traditional learning content into a digital simulation. It added a layer of analysis of scalability and costs during the process and demonstrated an MVP output. However, learner and teacher feedback are important during this process. Evaluation data is required to measure the efficiency of the methodology. Also, more careful thinking of the technology used as well as cost-effective way of scalable implementation is still required. Future research and refinement of implementation strategies are vital for maximising the impact of gamification on learning outcomes.

ACKNOWLEDGMENT

Thanks to the midwifery teaching team and students from Birmingham City University for their support.

REFERENCES

[1] The Nursing & Midwifery Council Standards for Pre-registration midwifery programmes. [Internet]. Nmc.org.uk. 2023, https://www.nmc.org.uk/globalassets/sitedocuments/standards/standards-for-pre-registration-midwifery-programmes.pdf [cited 28 March 2024].

[2] J. Vermeulen, R. Buyl, F. D'haenens, E. Swinnen, L. Stas, L. Gucciardo, and M. Fobelets, 2021. Midwifery students' satisfaction with perinatal simulation-based training. Women and Birth, 34(6), pp.554-562.

[3] M. Gray, T. Downer, D. Hartz, P. Andersen, J. Hanson, Y. Gao. The impact of three-dimensional visualisation on midwifery student learning, compared with traditional education for teaching the third stage of labour: A pilot randomised controlled trial. Nurse Education Today. 2022 Jan 1;108:105184.

[4] M. Gray, T. Downer, J. Hanson, D. Hartz, Y. Gao, P. Andersen. The impact of three-dimensional visualisation on midwifery students' application of knowledge of the third stage of labour to practice: Qualitative findings of a pilot randomised controlled trial. Women and Birth. 2023 Feb 1;36(1):e36-43.

[5] C. Pereira Santos, J. Relouw, K. Hutchinson-Lhuissier, A. Buggenum, A. Boudry, A. Fransen, M. Van den Ven, I. Mayer. Embodied Agents for Obstetric Simulation Training. In Proceedings of the 28th International Conference on Intelligent User Interfaces (pp. 515-527). 2023, March.

[6] S. O'Connor, Y. Wang, S. Cooke, A. Ali, S. Kennedy, JJ. Lee, RG. Booth, Designing and delivering digital learning (e-Learning) interventions in nursing and midwifery education: A systematic review of theories. Nurse Education in Practice. 2023 Apr 12:103635.

[7] T. Lee, SW. Yoon, S. Fernando, S. Willey, A. Kumar. Blended (online and in-person) Women's Health Interprofessional Learning by Simulation (WHIPLS) for medical and midwifery students. Australian and New Zealand Journal of Obstetrics and Gynaecology, 62(4), pp.596-604. 2022.

[8] M. Gray, T. Downer, D. Hartz, P. Andersen, J. Hanson, Y. Gao. The impact of three-dimensional visualisation on midwifery student learning, compared with traditional education for teaching the third stage of labour: A pilot randomised controlled trial. Nurse Education Today. 2022 Jan 1;108:105184.

[9] ML. Honey, S. Diener, K. Connor, M. Veltman, D. Bodily. Teaching in virtual space: Second Life simulation for haemorrhage management. InAscilite Conference, Aukland 2009.

[10] M. Gray, T. Downer, D. Hartz, P. Andersen, J. Hanson, Y. Gao. The impact of three-dimensional visualisation on midwifery student learning, compared with traditional education for teaching the third stage of labour: A pilot randomised controlled trial. Nurse Education Today. 2022 Jan 1;108:105184.

[11] MM. Saab, M. McCarthy, B. O'Mahony, E. Cooke, J. Hegarty, D. Murphy, N. Walshe, B. Noonan. Virtual reality simulation in nursing and midwifery education: A usability study. CIN: Computers, Informatics, Nursing. 2023 Oct 1;41(10):815-24.

[12] L. Zhao, X. Dai, S. Chen. Effect of the case-based learning method combined with virtual reality simulation technology on midwifery laboratory courses: A quasi-experimental study. International Journal of Nursing Sciences. 2024 Jan 1;11(1):76-82.

[13] T. Downer, M. Gray, P. Andersen. Three-dimensional technology: evaluating the use of visualisation in midwifery education. Clinical Simulation in Nursing. 2020 Feb 1;39:27-32.

[14] RP. Cant, SJ. Cooper. The time is right for Web-based clinical simulation in nursing education. Journal of Nursing Education and Practice. 2015 Aug 26;5(11):113-9.

[15] SY. Liaw, LF. Wong, EY. Lim, SB. Ang, S. Mujumdar, JT. Ho, SZ. Mordiffi, EN. Ang. Effectiveness of a web-based simulation in improving nurses' workplace practice with deteriorating ward patients: a pre-and postintervention study. Journal of medical Internet research. 2016 Feb 19;18(2):e37.

[16] OM. Holuszko, J. Abdulcadir, D. Abbott, J. Clancy. Health Care Providers' Readiness to Adopt an Interactive 3D Web App in Consultations About Female Genital Mutilation/Cutting: Qualitative Evaluation of a Prototype. JMIR Formative Research. 2023 Sep 28;7(1):e44696.

[17] K. Becker, What's the difference between gamification, serious games, educational games, and game-based learning. Academia Letters, 209, pp.1-4. 2021.

[18] E. Pesare, T. Roselli, N. Corriero, and V. Rossano, "Game-based learning and gamification to promote engagement and motivation in medical learning contexts," Smart Learning Environments, vol. 3, pp. 1-21, 2016.

[19] W. Oliveira, J. Hamari, L. Shi, A. M. Toda, L. Rodrigues, P. T. Palomino, and S. Isotani, "Tailored gamification in education: A literature review and future agenda," Education and Information Technologies, vol. 28, no. 1, pp. 373-406, 2023.

[20] F. Llorens-Largo, F. J. Gallego-Durán, C. J. Villagrá-Arnedo, P. Compañ-Rosique, R. Satorre-Cuerda, and R. Molina-Carmona, "Gamification of the learning process: lessons learned," IEEE Revista Iberoamericana de tecnologías del aprendizaje, vol. 11, no. 4, pp. 227-234, Oct 19, 2016.

[21] E. Wiklund and V. Wakerius, The Gamification Process: A framework on gamification, 2016

[22] A. Mora, P. Zaharias, C. González, and J. Arnedo-Moreno, "FRAGGLE: A FRamework for AGile Gamification of Learning Experiences," Rome, Italy, Springer, pp. 530–539, 2016.

[23] A. AlMarshedi, V. Wanick Vieira, and A. Ranchhod, "SGI: a framework for increasing the sustainability of gamification impact," International Journal for Infonomics, vol. 8, no. 1/2, pp. 1044-1052, 2015.

[24] M. Fowler and J. Highsmith, "The agile manifesto," Softw. Dev., vol. 9, no. 8, pp. 28–35, 2001.