Educational Gaming for GMP: Developing an Android Game for Good Manufacturing Practice Training

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Abstract

This research presents the development of a game that teaches Good Manufacturing Practices (GMP), a subject that requires hands-on practice. During the COVID-19 pandemic, educational institutions have transitioned to online learning. To simulate the experience of an actual classroom, this research presents a development of a GMP board game into an online GMP game using an Agile development framework, which allows time-effective development for the game to be deployed during the pandemic. The key feature of the developed educational game includes an online engine to let students compete with their peers and interactive learning to improve remote engagement. The satisfaction and knowledge scores, two evaluations of the online GMP game, indicate that the developed game is more effective than learning through an in-person board game.

Keywords: Agile framework, Game development, Good Manufacturing Practice

1. Introduction

Online platforms play a crucial role in our daily activity during the COVID-19 pandemic. Students migrated traditional classrooms with face-to-face activities to online platforms, which facilitated virtual meeting applications and e-learning, enabling them to continue learning from their residences during the pandemic [1]. This adaptation aims to ensure that enrolled students' learning continues despite lockdowns and social distancing. However, such a transition from face-to-face to remote learning presents several challenges, particularly in replicating the experience of in-person classes that rely on group interaction and hands-on experiences [2, 3]. Hence, it remains a challenge for educators to develop a platform to replicate an activity that meets the course's objective as well as encourage student participation on an online platform [4, 5]. This study aims to enhance students' learning experience in remote learning of Good Manufacturing Practices (GMP). Additionally, considering the ongoing evolution in digital education post-COVID-19, this study also reflects on how educational games serve as an active learning tool in remote or hybrid classrooms. Game-based learning is increasingly recognized as a powerful approach to maintain student engagement and promote deep understanding in distance learning environments [6, 7].

GMP is an essential course in the undergraduate food management and safety program. Traditionally, students learn rules of safety regulation in food manufacturing through lectures and practice their decision-making skills in laboratory settings. Students apply their lecture knowledge to real-world scenarios in these practical components, honing their problem-solving and critical thinking skills. Recently, educators introduced a board game as an educational tool to enhance student engagement and understanding by creating competitive learning environments with their peers [11]. Despite the success of board games, the onset of the COVID-19 pandemic disrupted these in-person activities. The government restricted all school activities to remote learning, which limited the use of hands-on activities, including the board game [9, 10]. Consequently, this study develops and evaluates an online GMP game inspired by the concept of a board game that was used in the GMP class to provide an interactive and engaging learning experience for students in a virtual environment. This approach addresses the limitations of traditional online learning by incorporating the developed online GMP game as a learning tool to simulate the practical, decision-making aspects of the GMP course.

The objective of this research is to develop an interactive game that allows students to practice GMP rules in real-world scenarios. By utilizing an online platform, we create a competitive learning environment where multiple students (game players) engage in competition with their peers. The game requires students to apply the GMP rules they learned during the online lectures, incorporating decision-making elements into the gameplay. The game scenarios require decision-making, which is based on a set of rules randomly determined from virtual cards. The card-style game introduces unpredictable factors to the practice of critical thinking.

The game design and development follow Agile principles, which focus on iterative progress, teamwork, and ongoing feedback. This method facilitates the developing team to change, maintain quality, and track the project's progress in a time-effective manner. Using Agile also allows for frequent testing and refinement, which improves gameplay

and user experience over a period of time. We develop the game as a mobile application, enabling students to play it while attending online classes on their laptops. We chose the Android mobile platform, with its substantial share of the mobile device market, to ensure the game is accessible to most students. Android accounts for approximately 72% of the global mobile OS market share [12]. We employ Unity, a powerful and versatile game engine, to conduct the development. We can easily port this engine to other platforms like iOS, Windows, and macOS, and it also supports Android. This adaptability allows the game to adapt to a variety of devices in the future.

2. Background and Related Works

2.1 Good Manufacturing Practices: GMP

GMPs are quality assurance guidelines that ensure the consistent production and control of pharmaceuticals, food, and other consumer goods [13]. These guidelines regulate manufacturers to use safe and hygienic methods that meet quality standards for their intended use. GMP, or "current Good Manufacturing Practice" or "GMP," covers sanitation, equipment maintenance, and accurate documentation for production and quality control. GMP ensures that pharmaceutical and biotechnology manufacturing, testing, and packaging processes are defined, validated, and documented. Reducing contamination, mix-ups, and errors helps preserve medicines, vaccines, and biologics [14]. GMP prevents contamination and ensures safety in food production from raw material sourcing to packaging. Manufacturers must create SOPs, perform hygiene checks, and keep detailed records [15].

Beyond drugs and food, GMPs apply to cosmetics, dietary supplements, and medical devices. In cosmetics manufacturing, GMP ensures product safety and ingredient testing, labeling, and packaging. To ensure device efficacy and reliability, GMP guidelines cover design, production, and quality assurance [16]. GMPs cover transportation, storage, distribution, and handling throughout the supply chain. Contractors and third-party manufacturers must also meet strict quality standards. GMP requires manufacturers to manage product defects, recalls, and consumer complaints to respond quickly [14]. GMP adds standards for specialized products to meet their needs. For instance, sterile pharmaceutical and food processing guidelines address the risks and challenges of producing these products [13, 14]. This thorough approach ensures that all consumer goods, including food and medicine, meet safety and quality standards.

2.2 Game Development using Agile frameworks

Many software engineering applications, including game development, have previously adopted agile. For instance, Proaño et al. developed the 3D game for learning traffic signals, aiming to teach children between the ages of 9 and 12 to be responsible pedestrians and drivers [8]. The team used Agile to generate the pipeline for developing the entire system. Similarly, Verenych and Semenov investigated requirements and developed hyper-casual games using Agile [17]. In applications that require frequent and complex communication between team members, Agile Scrum was considered. Scrum further improves the concept of Agile by integrating Agile concepts with team development principles. For instance, Pratomo and Widyani used the Agile Scrum framework to develop the simulator for project management [18].

3. Methodology

To ensure the educational content accuracy, the development team collaborated closely with a department of Food Safety Management and Technology's member who served as the GMP boardgame owner. This expert in GMP reviewed and approved all game features and learning components to align with real-world GMP principles. The GMP game development was conducted using Agile Framework.

3.1 Agile Framework

An agile framework is an approach in software development that iteratively implements and tests a small set of software components. Several iterations of implementing and testing features is a key concept in the Agile framework, which is suitable for pioneer software that is complex or dynamic. Although the digital game is based on the GMP board game, several modifications were introduced. The original game mechanics involving card types and contamination rules were retained, while new features such as a point-based system, digital card interaction, and real-time multiplayer capabilities were introduced to suit the digital format. Specifically, there are multiple components, including card distribution systems, a separate game room, a network connection, and a user interface, that are required to be designed and implemented for mobile devices. Implementing all these components at once may cause incompatibility and make the software fail to run. With the core principle of Agile that iteratively introduces features, the main components were implemented and tested first before auxiliary features such as network connections and multiple game rooms.

Another contribution of agile is that each iteration of development produces software that is functional but with limited features. In the circumstance of teaching a class during the pandemic, the product of agile iteration can be adopted for teaching a class in a timely manner. Each Agile sprint was structured to include a planning session where tasks were prioritized. Sprint 1 focused on the core game system including contamination logic and card functions. Sprint 2 added the user interface and interaction mechanics. User feedback from test runs was collected through forms and direct interviews and then used to refine the interface and instructions in Sprint 3.

The GMP game was developed following the Agile methodology. The Agile framework with steps in GMP development is shown in Fig. 1. The development process is as follows.

1. Planning: Developing team meet to plan the follow steps in agile, especially, with a timeline setup in this step. All members discuss and agree on their responsibility on the software. This is a crucial step for each member to learn about skills of team member before assigning a task during design and implementation steps. A project manager and team leaders are also appointed in this step.

2. Requirements: The game developing team starts investigating the concept of GMP board game and lists all features (software components) that required to make a GMP game run. Team member may ask for guides and recommendations from players who have played the board game as well.

3. Analysis: After gathering all requirements, game features are listed with an attention pay to its priority to make

the game run. For example, game system incorporating card system and rules has a higher priority than online system management. Developing environment, coding languages and technical scopes are discussed during this step which takes skills of team member and difficulty to implement features into account.

4. Design: In addition to the system, the design also includes user interface and user experience. Board game is visualized as a full-screen gameplay where character and cards are designed, which is developed from the concept of GMP board game, to attract students and increase their engagements. Some rules from the board game are revised to fully utilize capability of online gaming and to replace the in-person involvement in the actual board game. All graphic designs are transformed to Unity engine format to facilitate the software implementation.

5. Implement and Test: Following Agile framework, all features obtained from analysis and design are queued – once at a time – for the implementation and testing. Necessary features to operate the GMP game are implemented and tested prior to auxiliary features. All software implementations were performed on the Unity platform and tested on the android device. We acknowledge current limitations include exclusive support for Android OS. The game has not been optimized for iOS devices or for environments with limited internet connectivity.

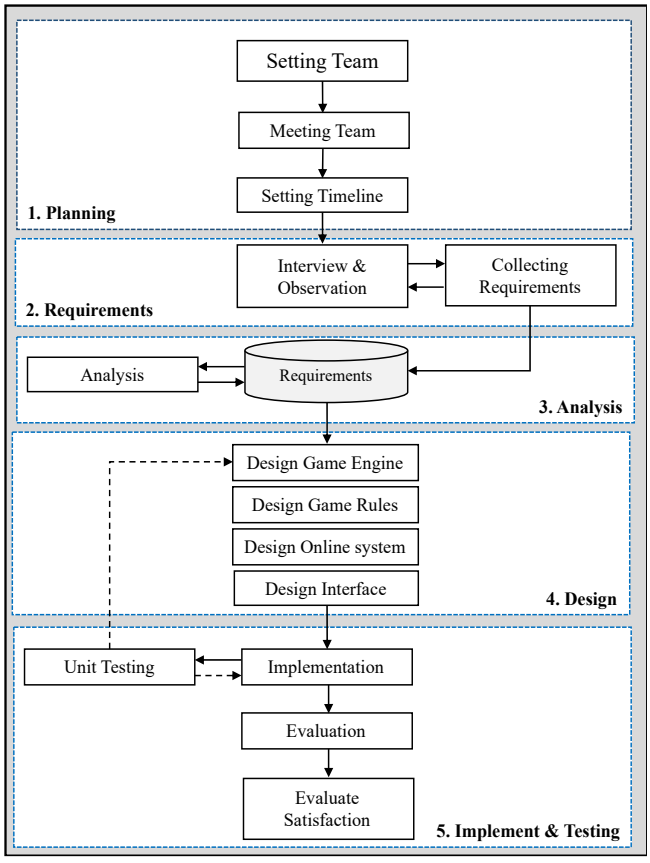

Fig. 1. Agile framework of the GMP game

The features were also improved during implementation-testing iteration according to comments from the testing unit. The time scheduled for each implementation-testing iteration differs greatly depends on the task difficulty but was limited to a maximum of two weeks. It is important to note that the two-week duration refers to a single iteration cycle within the Agile framework, not the entirety of the development process.

During testing, four players engaged in an average of 6 to 9 full rounds per session, spending approximately 5 to 7 minutes per round. Informal observation and feedback suggested that players with higher game engagement tended to score slightly higher on the post-game evaluation, although formal correlation analysis was not conducted due to small sample size.

3.2 Evaluation Method

All subjects participated in this study were undergraduate students at Rajamangala University of Technology Krungthep. A total of 11 subjects, 6 students majored in food technology and safety program and 5 students majored in information system program. All students had no prior knowledge on the GMP materials.

Two evaluations were performed. The first evaluation compares student's understanding from learning through board game and through GMP online game. The second evaluation measures user experience from learning through playing the GMP game. The criteria are 1) "Overall system design", 2) "Appropriate text color and size", 3) "User experience", 4) "Concise language usage and graphics", 5) "Appropriate background sound and multimedia", and 6) "Quality of game instruction (sound recording)." Mean and standard deviation are reported.

4. Results and Discussions

4.1 User interface and Gameplay

After launching the GMP game, users were asked to create a new game party or join a waiting room using private code given to the person who created the room. A snapshot of the waiting room is shown in Fig. 2.

Fig. 2. The Waiting room.

Fig. 3. Game play order

Players can begin the game when there are 2-4 players joining the waiting room. The system supports up to a

maximum of 4 players. In each game play, each player is assigned an order randomly and will carry on until the game ends. Each player takes turn following the assigned order and the game considers a round when the last player chooses an action. A screen showing player order is visualized in Fig. 3.

In the first round, each player begins with a money of $30 and three cards. Each card represents an action to reduce the three contamination values, which are 1) microorganism contamination, 2) physical contamination and 3) chemical contamination. Please refer to Table 1 for more details. These three contaminant measurements are always visualized at the top of screen. A player lost when at least one of three contamination values reaches zero. The game ends when there is only one player left, and that player is the winner.

Table 1 Contamination Card

Contamination types	Color code	Examples
1. Microorganism	Green	Yeast, Bacteria
2. Physical	Blue	Trash, Paper, byproducts
3. Chemical	Purple	Toxic byproducts

Each player can only perform an action in their round, as visualized in Fig. 4.

Fig. 4. A screen of players when they begin their round

Fig. 5. Card buys and sell interface

Each round, player can choose to keep the three cards, sell one card or purchase a new card. Fig. 5 shows these three options. For buying and selling, players can trade up to three cards. Under the card, the button is shown of sell or buy presents as well as a button for full description of each card. However, the card that the player purchased during that round is excluded from further trade until the next round. All cards cost $3 where player gets $1 from selling a card. The remaining money is always visualized at the bottom left of the screen. Each card has different points that will be summed at the end of game to determine the winner. If players would like to learn more about card detail, an explanation of each can be enlarged with more details, as visualized in Fig.6.

To win the game, player has to collect the cards aiming to maximize their total points. As each game round continues, the three contamination scores are decreased, and the game will end when at least one of these three contamination scores reaches zero. Player can use their card to remove the contamination, which delays the game ending for everyone, but player will lose the card and their points will be updated to include the new card.

Fig. 6. Card information interface

Fig. 7. Game ending interface

4.2 GMP game evaluation

The first evaluation measures understanding of GMP through examination. The maximum score is 10. An average test scores, computed from 11 subjects, after using the GPM online game is compared against using the GMP board game. of Comparison of average scores is presented in Table 2. The averaged score after playing the GMP online game is 7.36 which is higher than the scores from using the GMP board game. The result indicates that using the GMP online game (virtual game on mobile platform) as educational tool is better than using the board game. Thus, GMP online game is suitable for teaching GMP in a virtual class or remote setup.

Table 2 Student test score after using educational media

Educational Media	Averaged Scores
GMP board game	4.09/10.00
GMP online game (Proposed)	7.36/10.00

The experimental evaluation of the test scores revealed a marked improvement in student learning outcomes when utilizing the online GMP game. In this study, the average test score increased from 4.09 (after using the traditional GMP board game) to 7.36 following engagement with the online game, indicating a significant enhancement in knowledge acquisition. These findings are in line with previous research

on digital game-based learning, such as that reported by Wouters et al. [19], which demonstrated that interactive and competitive learning environments can lead to substantial cognitive gains, improving test scores in the range of 20% to 40%. Moreover, similar trends have been observed in studies by Hamari et al. (2016), where the incorporation of engaging game mechanics was linked to improved learning outcomes. Such comparisons underscore the efficacy of digital platforms in enhancing educational performance, especially in contexts where traditional in-person interactions are limited.

4.3 GMP game's satisfaction

To evaluate the game design, user satisfactions are measured using criteria listed in Table 3. Overall system design, appropriate background sound and multimedia, and quality of game instruction have a score higher than 4, indicating materials in these categories have high satisfaction scores. All criteria attain scores higher or equal to 3, indicating good satisfaction. No criteria are in the ranges of poor (1) or fair (2) scores.

Table 3 GMP game's satisfaction scores (out of 5)

Criteria	*Averaged Scores (Standard Deviation)*
1) Overall system design	4.33 (0.58)
2) Appropriate text color and size	3.00 (1.00)
3) User experience	3.00 (0.00)
4) Concise language usage and graphics	3.33 (1.15)
5) Appropriate background sound and multimedia	4.00 (1.00)
6) Quality of game instruction (sound recording)	4.33 (1.15)
Total	3.67 (0.45)

The evaluation of user satisfaction provided valuable insights into the overall acceptance and quality of the GMP online game. With an average overall satisfaction score of 3.67 out of 5, the game was particularly well-regarded in areas such as system design, quality of game instruction, and multimedia integration. These results are consistent with the findings of Siu and Kai [20], which highlighted the importance of intuitive design and engaging multimedia in achieving high satisfaction levels among users. Furthermore, the positive ratings in our evaluation mirror trends observed in other research that emphasize the role of user-centered design in enhancing educational outcomes. Together, these comparisons not only validate the design choices made in the development of the GMP online game but also reinforce its potential as a robust educational tool in modern remote learning environments.

5. Conclusion and Future work

This research presents the development of an online game for teaching Good Manufacturing Practices (GMP), addressing the challenges of transitioning hands-on learning to virtual platforms during the COVID-19 pandemic. The GMP game adapts the interactive and competitive nature of a board game into a mobile application, enabling students to practice GMP rules in a simulated environment. Evaluation results demonstrate that the online game improves students' understanding of GMP compared to the traditional board game, making it an effective educational tool for remote learning.

It is important to note that the findings are based on a small sample size (n=11). While the results are positive, this limits the generalizability. Future work should involve evaluating the game with a larger and potentially more diverse student population to further validate its effectiveness. Another possible future work includes expanding its functionality. Currently, the game is supported only on the Android platform; future developments will include support for iOS devices to enhance accessibility. Future versions of the game may include AI-driven adaptive learning features to dynamically adjust gameplay difficulty based on individual performance, enhancing personalized learning experiences and improving cross-platform accessibility. Additionally, long-term assessments and real-world application studies will help validate the efficacy of the GMP game. The Agile methodology proved effective for rapid development, but further experimentation is required to refine the game mechanics and educational impact.

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REFERENCES

[1] C. Muangmee, S. Kot, N. Meekaewkunchorn, N. Kassakorn, S. Tiranawatananun, and B. Khalid, "Students' Use Behavior towards E-Learning Tools during COVID-19 Pandemics: Case Study of Higher Educational Institutions of Thailand," International Journal of Evaluation and Research in Education, vol. 10, no. 4, pp. 1166-1175, 2021.

[2] V. Chen, A. Sandford, M. LaGrone, K. Charbonneau, J. Kong, and S. Ragavaloo, "An exploration of instructors' and students' perspectives on remote delivery of courses during the COVID-19 pandemic," British Journal of Educational Technology, vol. 53, no. 3, pp. 512-533, 2022.

[3] D. Serhan, "Transitioning from Face-to-Face to Remote Learning: Students' Attitudes and Perceptions of Using Zoom during COVID-19 Pandemic," International Journal of Technology in Education and Science, vol. 4, no. 4, pp. 335-342, 2020.

[4] C. Rapanta, L. Botturi, P. Goodyear, L. Guàrdia, and M. Koole, "Online university teaching during and after the Covid-19 crisis: Refocusing teacher presence and learning activity," Postdigital science and education, vol. 2, pp. 923-945, 2020.

[5] L. Sun, Y. Tang, and W. Zuo, "Coronavirus pushes education online," Nature materials, vol. 19, no. 6, pp. 687-687, 2020.

[6] Zahra, I. Neo, M. and Hew, S.-H (2022). Online Game-Based Learning to Enhance Student Engagement, Motivation and 21st-Century Skills, Proceedings of the 2nd International Conference on Creative Multimedia 2022 (ICCM 2022). Atlantis Press. pp. 192-202.

[7] Nadeem, M., Oroszlányová, M., & Farag, W. (2023). Effect of digital game-based learning on student engagement and motivation. Computers, 12(9), 177.

[8] E. Boyle, T. M. Connolly, and T. Hainey, "The role of psychology in understanding the impact of computer games," Entertainment computing, vol. 2, no. 2, pp. 69-74, 2011.
[9] C. B. Hodges, S. Moore, B. B. Lockee, T. Trust, and M. A. Bond, "The difference between emergency remote teaching and online learning," Educause Review, 2020.
[10] L. Mishra, T. Gupta, and A. Shree, "Online teaching-learning in higher education during lockdown period of COVID-19 pandemic," International journal of educational research open, vol. 1, p. 100012, 2020.
[11] Statista, "Market share of mobile operating systems worldwide from 2009 to 2024, by quarter." [Online]. Available:
[12] Food, A. Organization, and W. H. Organization, "Good manufacturing practices for food safety and quality," FAO and WHO, 2022. [Online]. Available:
[13] U. Food and D. Administration, "Current good manufacturing practice (cGMP) regulations for drugs and biologics," US Food and Drug Administration, 2023. [Online]. Available:
[14] C. A. Commission, "General principles of food hygiene CXC 1-1969," FAO and WHO, 2023. [Online]. Available:
[15] E. M. Agency, "Good manufacturing practice (GMP) for medicinal products," European Medicines Agency, 2023. [Online]. Available:
[16] C. Proaño et al., "Serious 3D game over a cluster computing for situated learning of traffic signals," in 2019 IEEE/ACM 23rd International Symposium on Distributed Simulation and Real Time Applications (DS-RT), 2019: IEEE, pp. 1-10.
[17] O. Verenych and M. Semenov, "Agile and Waterfall Approaches Hybridization in the Hyper-Casual Games Projects," in 2023 IEEE 12th International Conference on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications (IDAACS), 2023, vol. 1: IEEE, pp. 477-480.
[18] I. A. Pratomo and Y. Widyani, "Development of Simulator for Learning Scrum," in 2023 IEEE International Conference on Data and Software Engineering (ICoDSE), 2023: IEEE, pp. 73-78.
[19] Wouters, P., van Nimwegen, C., van Oostendorp, H., & van der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. Journal of Educational Psychology, 105(2), 249–265.
[20] Siu Y. & Kai Y. (2021). Application of the educational game to enhance student learning. Frontiers in Education, 6,