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Gamification Approach for Interactive Learning of Lean Manufacturing Activities

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ABSTRACT

The gamification approach is popular method in education as it has been widely utilized in many fields. The project focuses on designing a game for interactive learning of lean manufacturing activities to create an alternative learning method that would gain interest and efficiency in learning. Integration of gamification approach and interactive learning method was used to illustrate a virtual lean manufacturing education and training by means of users' interaction towards provided interactive learning materials and participation in playing the designed game. Input of the project which is learning materials was developed by analysing numerous articles regarding common lean manufacturing tools and practices. Interactive elements such as animation, sound effects, lecture voice, and videos were applied in each learning material to deliver an adequate understanding of each topic. Construction of the game platform is being developed using ActivePresenter software which includes simulation videos of the production line using FlexSim software to visualize a real production floor which provides a clearer picture of the production system for users. The game should include a basic assessment of lean manufacturing practices by considering its complexity and difficulty level for users with inadequate or does not have experience in the field. The outcome of the project is expected to successfully design a basic game platform for lean manufacturing education by means of interactive learning. Users will be able to learn lean manufacturing systems using the designed interactive learning materials included in the games and self-assess themselves as the game publishes the correct and best answer option in case they answer wrongly.

Keywords: Gamification; Interactive learning; Lean Manufacturing; Education; Asynchronous learning

INTRODUCTION

The gamification approach has been widely utilized since the last decade due to the emerging era of digitalization and technological advancement has urged society to implement technology in various fields. Traditionally, various physical games were designed to reflect a real-world situation which enables basic assessment or practice regarding the player's adaptation of the game values and enhances their interest in learning the intended values. Interactive learning is the right stance for the gamification approach, where it could attract learners' interest to enjoy learning sessions and assess their skills based on games. Especially with the current generation of so-called digitally native students who are strongly dependent on technology.

In recent years, interactive learning has become a more common learning method, especially during the pandemic COVID-19 outbreak that forces society to utilize digital platforms. This learning method was initially merely accepted by the community as they had doubts regarding the effectiveness of the method. However, their acceptance

level has increased significantly due to Online Distance Learning (ODL) being implemented by numerous countries, especially during the pandemic which directly proves that interactive learning is efficient and very relevant to technological access alignment towards society.

Interactive learning requires learning materials that allow users to have control over the learning session. Learning media is a definite example of learning material that supports interactive learning in which it emphasizes user interaction towards features attached to the learning material such as audio, video, action buttons, and pop-ups. Integrating a gamification approach in an interactive learning platform would enhance the learning experience for learners as they can learn based on learning materials and self-assess themselves regarding a particular topic through the developed games (Anunpattana et al. 2021).

Moreover, the gamification approach would help to gain learners' interest to undergo interactive learning sessions as the games act as enjoyable practices about the topic (Hursen & Bas 2019). This approach is undoubtedly more interesting compared to paper and pencil tests. Hence, it would indirectly affect learner behaviour and feedback towards education.

Interactive learning has been implemented in primary, secondary, and tertiary education. Several interactive learning platforms have been developed to support education for these groups such as *Kahoot* and *Google Classroom*. Numerous learning materials regarding academic syllabus have been developed by educators and published as learning media (Mimouni 2022) Unfortunately, the gamification approach for interactive learning about industrial knowledge and skills has not been widely applied in industry.

In this new era of technological advancement, the manufacturing industry is expected to be the key instrument in supporting economic growth. Hence, adequate exposure and knowledge regarding lean manufacturing towards the industry workforce, community, and future graduates are undeniably important to ensure prolonged improvement in the manufacturing industry.

Teaching industry workforces and people in middle age or higher might be more difficult compared to full-time students due to commitments and capability to cope education with career. Thus, utilizing interactive learning with a gamification approach would help them to learn better, and faster and make learning more enjoyable which indirectly retains their focus on learning about lean manufacturing. Lean manufacturing-based games should be developed that enable them to sharpen lean practices and skills in virtual reality before adapting them to real-world industry.

Moreover, manufacturing companies commonly encounter lack of production efficiency regardless they are doing well in their business. Inefficient productivity often occurs due to wastes that may be present in production lines that are not adding value to the product. In order to achieve lean manufacturing system, production managers and future engineers should acknowledge lean tools implementation and techniques to be adapted in the industry. However, most industry workforces including future graduates are still lacking lean manufacturing knowledge.

Lean manufacturing is often taught at lectures and training sessions using theoretical approaches and not practical implementation. A clear explanation and guideline to define each lean tool and its implementation technique would strengthen future lean practitioner skills to adapt lean approaches in the industry (Ijaz et al. 2023). Considering the whole world is affected by the pandemic COVID-19, it is very challenging for future lean practitioners to sharpen their skills in lean tool implementation as restrictions on workplace and workforce limitations are being held. Hence, this project aims to provide an interactive learning platform that includes basic games or known as gamification to enhance students understanding. reported gamification not only improves engineering students' performance, but students also enjoy and feel positive about it and increases their collaboration attitude.

In addition, studies about the effectiveness of gamification in engineering courses are limited (Díaz-Ramírez 2020). The gamification approach in this study is equipped with self-assess modules for students to rate themselves regarding their understanding of lean manufacturing activities. Two objectives are highlighted in this study. The main objective is to design and simulate an interactive learning platform of lean manufacturing using a gamification approach. The second objective is to develop lean manufacturing-based games that enable self-assessment for users.

The project covers developing a virtual lean manufacturing education platform that utilizes the integration of a gamification approach with an interactive learning method for learning and skill development purposes. Interactive learning is supported by learning media that is designed using *ActivePresenter* software. The development of the learning material or contents is based on literature review and lean manufacturing concepts.

Basic lean manufacturing-based games are also developed using *ActivePresenter* software. The game consists of a few virtual production lines that are simulated using *FlexSim* software. These production lines are developed based on theoretical aspects that are considered satisfactory to act as reflections of real-world production lines for learners to gain clear visualization of production flow and practice line observation.

LITERATURE REVIEW

INTERACTIVE LEARNING

A simple definition of interactive learning is a pedagogical technique that engages students by having them actively participate in learning activities. In this study, interactive learning refers to interactive learning technology as a learning method that requires students to enrol in a learning process through virtual platforms such as digital classrooms and software to conduct learning sessions and discussions (Sanders et al. 2016). Hadiana et al. (2021) contended that this method of learning supports distance learning, especially during the recent pandemic COVID-19 that urged society to emphasize virtual learning. A broader perspective has been adopted by Tuma (2021) who stated that due to the increasing pervasiveness of computer technology, education technology is undergoing substantial changes. Several aspects such as communication, information storage and transport, audio-visual media consumption and production, and sharing mainly utilize technology. Technology's role in education has evolved from a simple instrument for research and inquiry to an approach and integrated application.

Online and distance learning are divided into two subsequent categories: synchronous and asynchronous learning. While a variety of definitions of the term synchronous and asynchronous learning have been suggested, this paper will use the definition that was suggested by Shahabadi & Uplane (2015) who saw synchronous learning as real-time interaction of learners with an instructor through the virtual platform while asynchronous learning as an interactive learning method that does not constraint learners and instructors by time, place, or classroom. As mentioned by Skulmowski & Rey (2020), interactive learning is strongly supported by learning media that enables user control over the learning materials such as simple control such as start and stop media player in which users can manipulate the materials published on their screen.

Previous studies have reported that the existence of an interactive learning module will help to develop a communicative, creative, and effective learning process for users and instructors. In addition, it helps in encouraging students' enrolment with high motivation due to their interest in the displayed multimedia system in terms of text, images, videos, sounds, and animations that act as a source of learning for users. The interactive learning media may be able to give responses and feedback to them (Hermita et al. 2020). Xia (2020) stated that learners' preferences for participating in learning interaction activities might be reflected in their learning behaviour feedback towards the learning method. Because of the vast number of learning interaction activities in a continuous time, a course will represent the underlying tendency of the teaching and learning process.

GAMIFICATION

Gamification can best be described as the process of creating systems, services, organizations, and activities that have similar experiences and motivations to games, with the added purpose of influencing user behaviour. This is commonly accomplished by taking cues from game design and incorporating game mechanics or other game-like ideas into the target environment. Legaki et al. (2020) contended that the gamification approach in education carries the same meaning but aligns the statement with the added educational purpose of changing user behaviour.

Several elements are needed to be considered as mentioned by Mullins & Sabherwal (2020), game design elements such as points, leader board, stages, badges, and challenges may be needed to design a game. Either utilizing them individually or in combination, these game design features may trigger various emotions and cognitions in the user, promoting desired outcomes from the gamified experience.

A previous study by Rodrigues et al. (2019) found that if websites do not include game features, younger generations will not pay attention to them. This urges society to believe that game elements and mechanisms have a strong impact on human behaviour and that the intention of gamification plays a significant role in persuading users. He then added gamification is a new way of thinking about software development, design, and deployment that aims to influence users' attitudes and actions.

As stated by Zainuddin et al. (2020), the educational effectiveness of digital games has validated the benefits of gamification in favour of its ability to enhance motivation, engagement, and social influence while allowing students to immerse themselves in experiential learning. Moreover, gamification has sparked significant attention among academics and research networks in recent years which encourages them to investigate the entire range of gamified components to be utilized in the instructional design process to offer engaging experiences and improve programmes.

METHODOLOGY

The project employed design and development research which consists of three phases: need analysis, design and development, and final draft of the learning platform.

PHASE I: NEED ANALYSIS - CAUSAL RELATIONSHIP MODEL

The design is utilized based on the Causal Relationship Model (CSM) which considers several factors of gamification science based on an article by Landers et al. (2018). The CSM agrees with the findings regarding a systematic mapping study by Rodrigues et al. (2019) that illustrates the indirect connection between gamification and learning through game design's applications, design, and game as illustrated in Figure 1.

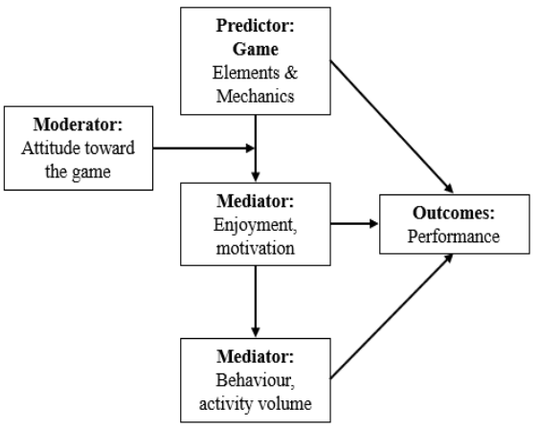


FIGURE 1. Causal Relationship Model

PHASE II: DESIGN AND DEVELOPMENT

FLOW OF INTERACTIVE LEARNING AND GAMIFICATION PLATFORM

The platform for interactive learning and gamification was designed according to the operational flow illustrated in Figure 2. The operation starts with the topic selection that is provided on the platform. Upon choosing the topic, users will have to choose which option they intend to use either interactive learning or gamification.

The first option is 'Tutorial' which indicates an interactive learning session. An interactive learning media that includes learning material of the chosen topic will be published to their screen when the user chooses this option. The concept of each learning material is practically similar which includes short notes, lecture audio, animation, and pop-ups. These features will appear during the interactive learning session that promotes interactivity.

Users can insert their input to move to previous or skip lecture slides via the interactive button provided and rewind or forward the learning material media player. Moreover, the platform enables them to jump backward or forward slideshow by clicking the slide number. Upon finishing the interactive learning session, the user may proceed to 'Practice' for the game session or end the learning session.

Meanwhile, the second option is a gamification platform. There are 8 games provided that assess users on different topics. Upon selecting the game, an interactive game instruction by means of text and audio will be published. Users may move forward or backward in the slideshow via the interactive button provided. During the game session, the user needs to choose their input. As soon as they click the submit button provided, the correct, best option, and the incorrect answer will be published on their screen.

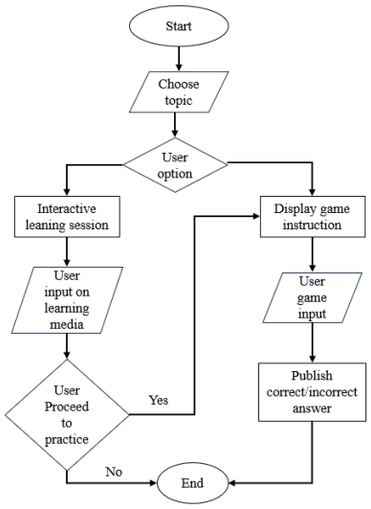


FIGURE 2. Operation of Interactive Learning and Gamification Platform

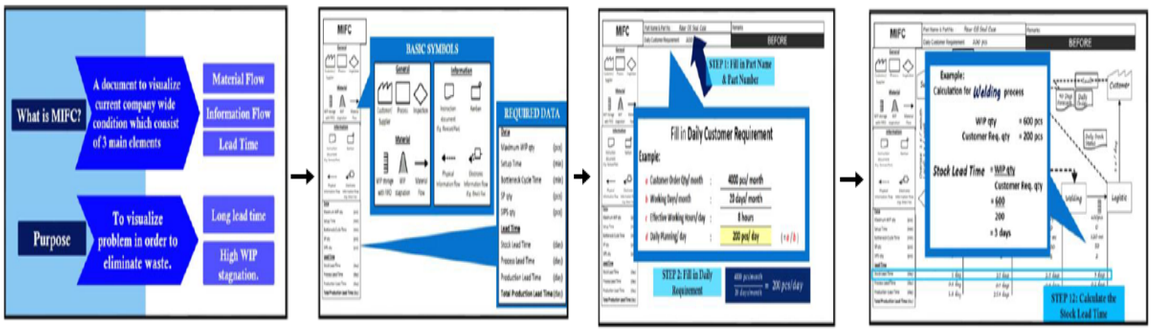
DEVELOPMENT OF LEARNING MATERIAL

Learning materials were developed using *ActivePresenter* software. Numerous lean manufacturing topics and practices were developed that contain short notes, explanations, and examples. Interactivity aspects such as lecture audio, action buttons, learning material media player, and pop-ups were included in each learning material. The learning materials covered common lean manufacturing activities along with its tutorial to utilize

several lean tools that were referred to literature review and industrial lean training tutorial.

Several common lean manufacturing topics were chosen to be included in the learning platform, which focused on basic lean manufacturing understanding and its common tools which are Material and Information Flow Chart (MIFC), time study, Process Capacity Sheet (PCS), Yamazumi Chart, Standardized Work Chart (SWC), and Standard Work Combination Table (SWCT). These common tools were defined briefly and step-by-step on how to utilize these tools were shown in the learning platform. Contents of the learning materials were referred to numerous articles and industrial lean training notes.

The approach in developing learning modules is practically the same in that it focuses on each tool's definition, the purpose of utilizing the tool, basic information regarding the format of the tool, requirements, and step-by-step tutorials on how to utilize the tool. To illustrate the approaches in learning module development for each lean tool, consider the MIFC learning module as an example. Development of the learning module for MIFC is shown step-by-step as follows as shown in Figure 3.



Step 1: Provide definition and purpose of the utilizing the tool with its development stage (if any).

Step 2 : Provide information for standard format of the tool.

Step 3 : Provide step-by-step explaination on how to utilize the tool. Highlight the important points.

Step 4: Include formulas and calculation steps (if any).

FIGURE 3. MIFC Learning Module 2

INTERACTIVITY FEATURES OF LEARNING MODULE

Several interactivity features are designed to improve the learning experience of users throughout the module. Features such as lecture voice, working steps tutorial pop-ups, and action buttons. These features do have their parameters that can be adjusted accordingly. Audio files were inserted on each page of the learning module that acts as a tutor to guide the user through the module. Rewind or skip learning modules are enabled using action buttons that are set to previous or skipped slides in the learning module.

SIMULATION OF PRODUCTION LINE

Virtual production lines were simulated using *FlexSim* software to visualize the virtual environment of production which helps in providing clearer illustration for users to observe and understand processes involved in a production line. Three different layouts of production lines were simulated that represent an initial production system, production system after the kaizen approach was implemented, and a one-piece flow production system. These layouts are included as videos in the gamification platform in which the user will need to observe these productions and answer the question attached in the game platform. Moreover, a production line was designed, and the user needed to apply MIFC based on the simulation video provided.

An initial production layout was simulated to visualize a production floor before implementing any lean tools to reduce non-value-added activities. The initial production line is equipped with three operators and one forklift for stock transporting from inventory to processing and finished goods to be delivered.

Based on the initial production layout, the kaizen approach was implemented to improve the productivity of the production line. The workstations are rearranged into a line to reduce manufacturing wastes such as inventory, unnecessary movement, and transportation. Figure 4 shows the production layout after the kaizen approach was implemented.

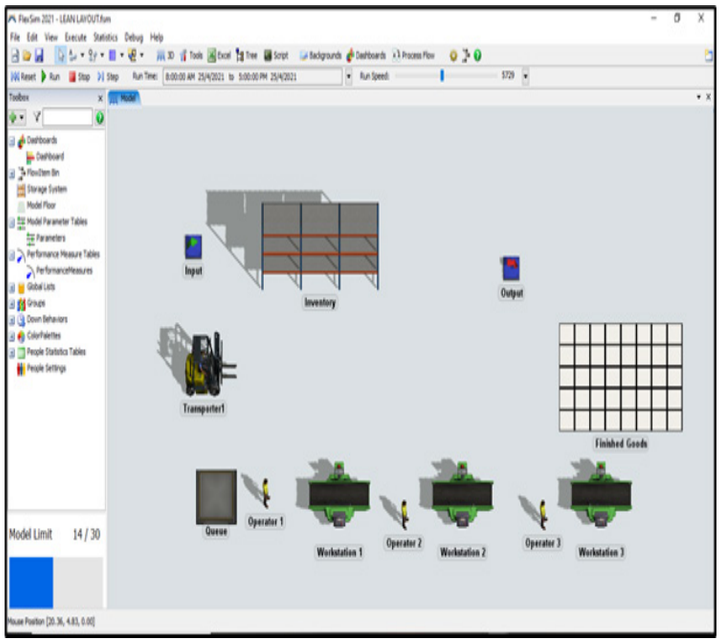


FIGURE 4. Production System After Kaizen Approach

GAME DEVELOPMENT

*ActivePresente*r software was utilized to develop the games that consist of drag-and-drop features, quizzes, and multiple-choice questions. These games were designed for the lean manufacturing concept in which the games act as an assessment of the user. Users are required to choose their game topic, listen to the interactive game instructions, and provide their input in the game. Upon completing the game, users are required to click on the 'submit' button which then publishes the correct, incorrect, and best answer. They may review their answer based on the published feedback which is considered a self-assessment.

DRAG-AND-DROP BASED GAME

In several topics of the designed game, drag-and-drop features were included as the game base which requires the user to drag the answer option to their desired area. This method is the simplest yet most effective game feature as it can be utilized in filling blank charts, mapping, and definition matching games.

MULTIPLE-CHOICE QUESTION

In the line observation game, three different production line simulation videos were provided to users for them to observe. Three sets of multiple-choice questions will be asked to the user and the answer feedback will be published when the users submit their answers.

ANSWER FEEDBACK AND RESPONSES

Feedback and responses for users' submitted answers are necessary for them to self-assess themselves upon playing the games. To create feedback and responses, a feedback layer and responses must be designed to correctly publish the best answer option or correct answer compared to users' answer input.

PHASE III: FINAL DRAFT PROTOTYPE

The completed design of the interactive learning platform is considered as the final draft prototype which was planned to be distributed among students to obtain a user acceptance test. Users are provided with the files of the interactive learning platform in HyperText Markup Language (HTML) format to be obtained in the cloud *(Google Drive)* and a survey form to acquire their feedback.

RESULTS AND DISCUSSION

LEARNING MODULE

A total of 7 topics of interactive learning materials were successfully developed by including several interactivity features such as action buttons, media player, lecture audio, and pop-ups. These topics are named using the module which the module consists of learning material and games

related to its topic. The topics covered in the interactive learning platform are listed as follows: Module 1: Lean Manufacturing Basic Principle, Module 2: MIFC, Module 3: Time Study, Module 4: PCS Module 5: Yamazumi Chart, Module 6: SWC and Module 7: SWCT.

The materials were exported via HTML, which enables users to open both interaction and game platform via the Internet browser. The raw files of these platforms will not be distributed and published to users which ensures originality of the platform. Users will only need the HTML files to open these platforms. These learning materials were tested before being published, and each of them operates well. All notes, audio, and pop-ups attached to each learning material were displayed correctly during the testing of the interactive learning session.

GAME DESIGN WITH FEEDBACK AND RESPONSES

A total of 8 lean manufacturing-based games were successfully developed by referring to lean manufacturing concepts. These games were also exported via HTML which is the same method as an interactive learning platform. Every designed feature in each game was operating and displayed correctly. The drag-and-drop feature and multiple-choice questions were correctly operated after several times of testing. Feedback on each game was also displayed correctly in which the correct, incorrect, and best answer options were displayed as designed. The outcome of this feedback would allow the user to self-assess their understanding and skills by reviewing their answer to the respective feedback.

Module 1 focuses on lean manufacturing basic principles. In this module, several games were designed that are related to the contents which are wastes definition, lean tool definition, 5S concept training, and line observation game. The waste definition game is designed using drag-and-drop features in which the user will have to drag the type of waste on the left-hand side into its definition provided in boxes on the right-hand side. After the user has completed dragging each answer, they are required to click on the 'Submit' button to reveal the correct answer using the 'Responses' feature. A 'Tick' symbol appeared upon correct answer input and number symbols appeared upon wrong answer input that indicates the number symbols should match to define the correct answer.

Module 2 focuses on the MIFC game which is designed to assess learners' understanding based on the MIFC tutorial provided in the learning media of the topic. A production line simulated using *FlexSim* software is provided where users are required to watch the simulation video and MIFC based on the video accordingly. The game utilized a drag-and-drop feature where users are required to drag the symbols provided. The correct answer feedback will be displayed once the user clicks on the 'Submit' button.

Module 3 focuses on the time study topic which is designed to assess users' understanding of the Time Study tutorial in the learning session of the topic.

Module 4 game focuses on a PCS tutorial that intends to assess users' understanding of how to utilize the tool. It is a drag-and-drop-based game in which the concept is similar to Module 2 and 3.

Module 5 focuses on the Yamazumi chart tutorial in which the game is designed for users to fill the chart according to a case study provided. The game utilized drop-and-drop features where users are required to drag each content provided. The correct answer feedback layer of the Yamazumi chart will be published once the user clicks on the 'Submit' button.

Module 6 focuses on the SWCT tutorial in which a game on this topic is designed to illustrate the utilization of the tool. Job details and process details such as takt time, operation steps, and recorded time are provided in the game. Users are required to draw a time graph based on the provided details. The game utilizes a drag-and-drop feature where users are required to drag the line graph provided into the time graph (drop area) which is designed to be blank in the SWCT sheet. Upon completing the time graph, the user may click on the 'Submit' button to reveal the correct answer feedback layer.

USER ACCEPTANCE TEST

The learning platform and survey form were distributed to 58 users which stands from students and lecturers from College of Engineering, Universiti Teknologi MARA Shah Alam. These users are required to test the interactive learning platform and provide feedback on the *Google Form* based on their perspectives. All users are familiar with lean manufacturing and have used online platforms for learning activities previously.

The survey consists of four sections which are feedback on flow experience, learning input, technical, interest, and motivation. Another part of the survey acquires users' suggestions for improvement. The survey consists of a Likert scale with a scale of 1 'Strongly Disagree' up to a scale of 5 that is 'Strongly Agree'. The results of these feedback are shown in Table 1.

TABLE 1. User Acceptance Test Results

No	Sections	Items	Users' Feedback (%)				
			Strongly disagree				Strongly agree
			1	2	3	4	5
1	*Feedback on Flow Experience*	Assessment of User Focus	1.7	6.9	27.6	44.8	19.0
		The usefulness of Interactive Learning Platform	0.0	3.4	10.3	53.4	32.8
		Enjoyment During Platform Utilization	0.0	5.2	27.6	46.6	20.7
		Environment Shut Out Upon Using the Platform	3.4	17.2	31.0	29.3	19.0
2	*Feedback on Learning Input*	Understanding of Lean Manufacturing Topics	0.0	0.0	3.4	44.8	51.7
		Lean Tools Utilization	0.0	0.0	3.4	48.3	48.3
		Basic Concepts of Lean Manufacturing	0.0	0.0	1.7	51.7	46.6
		Understanding of Lean Manufacturing Wastes	0.0	0.0	12.1	50.0	37.9
		Lean Tools Clarification	0.0	0.0	13.8	55.2	31.0
3	*Technical Feedback*	Display Quality of Learning Notes	0.0	0.0	5.2	50.0	44.8
		Audio Quality	0.0	1.7	13.8	39.7	44.8
		Action Buttons Functionality	0.0	6.9	6.9	50.0	36.2
		Pop-Ups Appearance	0.0	0.0	13.8	46.6	39.7
		Game Instructions	0.0	0.0	6.9	44.8	48.3
		Smoothness of Drag-And-Drop Features	1.7	6.9	12.1	46.6	32.8
		Multiple-Choice Question	0.0	0.0	5.2	50.0	44.8
		Publishment of Answer Feedback	0.0	0.0	1.7	58.6	39.7
4	*Interest and Motivation Feedback*	Interest in Lean Manufacturing	0.0	0.0	5.2	39.7	55.2
		Comparison Between the Approach and Conventional Method	0.0	1.7	22.4	39.7	36.2
		Game Enjoyment	1.7	0.0	13.8	46.6	37.9
		Impact of Platform Towards Learning Lean Manufacturing	0.0	0.0	13.8	48.3	37.9
		Motivation to Learners	0.0	1.7	12.1	48.3	37.9
		Feedback on the Gamification Approach	0.0	0.0	6.9	39.7	53.4
		Interest in Becoming a Lean or Industrial Improvement Practitioner	0.0	0.0	19.0	34.5	46.6
		Idea of Gamification Approach for Interactive Learning	0.0	0.0	6.9	43.1	50.0

FEEDBACK ON FLOW EXPERIENCE

In Table 1, users' focus on using the interactive learning platform was assessed. Most of the users agreed that they tend to focus on utilizing the platform, while 27.6 percent of users felt content, and a minority of the users disagreed with the statement. It indicates that a very low percentage of users are unable to focus on utilizing the platform so it can be considered that the platform can gain users' focus and attention in learning. On the usefulness score of the interactive learning platform, most of the users 86.2 percent agreed to the statement that they do not feel that using the platform is a waste of time or in other words not useful. This score remarks the interactive learning platform is useful for most people.

On the users' enjoyment level of using the platform for several hours without losing focus, 67.3 percent of the users enjoyed utilizing the platform for long hours, and only 5.2 percent disagreed with the statement. Hence, it can be considered that the platform is enjoyable even for long hours of usage and manages to maintain users' attention. Based on the environment shut out upon using the platform, 48.3 percent of the users strongly agreed and

agreed. Meanwhile, a minority of the users disagreed with the statement which shows that the platform can gain most user attention until they can forget about their environment. Those with disagreements may find that the platform does not meet their expectation.

FEEDBACK ON LEARNING INPUT

Users' feedback on learning input is important to determine the quality of learning material content that helps to ensure information about the topics covered is well explained (Alfoudari et al. 2023). Based on Table 1, most of the users agreed that using the platform indeed helped them to understand better the topics in the learning modules while only a minority of the users, only 2 out of 58 users felt content. To summarise the issue, the platform does help most users understand better about lean manufacturing topics.

The platform did help most of the users to understand lean tools utilization while only two users felt neutral. It can be assumed that almost every user agrees that the platform helps them understand how to utilize lean tools. It can be summarized that most of the users can understand well on basic concepts of lean manufacturing and only one of them felt content about the issue after they had tested the interactive learning platform.

Thus, it shows that the interactive learning platform does help people to understand lean manufacturing topics. Only seven users felt neutral while other users agreed that they could clarify each type of waste involved in the manufacturing system after they had tested the platform. It illustrates that the platform can make people understand and clarify lean manufacturing wastes.

A minority of the user felt content about their ability to clarify suitable lean tools to be utilized in the manufacturing system to achieve lean production. However, most of the users agreed with the statement which they can clarify well after learning through the interactive learning platform. Since most of the users gave positive feedback, those who felt content about the issue may undergo the interactive learning session again as it might help them to get a better understanding.

TECHNICAL FEEDBACK

Technical feedback from users is very useful to determine any possible technical issue that occurred and identify the quality of technical features of the platform that promotes interactivity for both learning material and the game. Based on Table 1, most of the users gave positive feedback regarding the display quality of the learning material with which 26 users strongly agreed and another 29 users agreed on the issue while a minority of the user felt content. It can be considered that the display quality is adequate for users to see the learning contents displayed on their screen.

Most of the users found that the lecture audio of learning media was very clear and concise while eight users felt neutral towards the issue. Since only one user disagreed with the statement, the audio quality is considered adequate and those who felt content are suggested to their audio setting on their device to find in case if there is any technical issue.

Most of the users stated that action buttons in learning media were operating efficiently and only four users disagreed while another four users felt content with the statement. To support this issue, every action button was tested to operate well by the developer before the interactive learning platform was distributed among users.

Table 1 shows that most of the respondents agreed that the pop-ups included in the learning media were displayed accurately while only eight users felt content about it. It might be due to their expectation to design the pop-ups to be more interactive and precise in alignment with lecture audio.

Most of the users found that the game instructions provided by the platform before each game session started were clear and easy to understand while only four users felt content regarding the statement. There is no negative feedback which indicates the instructions given in the text display on the screen are precisely aligned with audio instruction that helped them to understand well how to play the games.

Most users gave positive feedback on drag-and-drop games functionality while a minority felt content, four users disagreed and only one user strongly disagreed on this issue. However, the developer found that drag-and-drop games can be slightly insensitive if the user drops the answer option not precisely at the drop area. To reduce the tendency of this issue to happen, the developer has prepared a guideline along with an interactive learning platform document that highlights user should drop the answer option precisely at the drop area.

Most of the users gave positive feedback on multiple-choice question functionality while only three users gave neutral feedback. There is no negative feedback on this issue which is believed due to the multiple-choice questions operation being tested numerous times by the developer to ensure that the tick boxes can operate as designed.

Most of the users agreed that answer feedback for each game were published correctly after they submitted their answer input while only one user gave a neutral response towards the answer feedback publishment. Since there is no negative feedback on this technical aspect, it is assumed that every answer feedback was published accordingly.

INTEREST AND MOTIVATION FEEDBACK

The fourth section of the survey form was intended to acquire feedback from the user regarding how the platform improves their interest and motivation in several aspects. As shown in Table 1, the platform has successfully gained users' interest in manufacturing topics despite a minority of the users feeling content about the statement. The author believed that this is due to lean manufacturing education in interactive learning method being a new approach to the topic that has encouraged current and future lean practitioners to learn about lean manufacturing using a more technological approach.

Most of the users found that learning the topic using the interactive learning platform is much better than the conventional method which is a physical lecture session while 13 users felt content and only one user disagreed with the statement. This may be due to the platform being more interesting compared to the conventional method of tutoring the topic which is only based on theoretical aspects. Unlike this platform, it enables learners to have control over the learning media and sharpen their skills on lean tools utilization using games.

Most of the users agreed that they enjoyed playing the games provided in the interactive learning platform while eight users felt content and only one user strongly disagreed with the statement. This indicates that successfully gained most users' interest in learning lean manufacturing topics and might motivate them to explore more about the topic. Those who felt content and disagreed with the statement might prefer face-to-face lecture sessions compared to interactive learning.

Most of the users gave positive feedback that indicates the platform does help them to understand better about lean manufacturing topics despite only eight users feeling content but there is no negative feedback towards the statement. The reason behind their feedback may due that the platform does give a better illustration of lean manufacturing activities and tool utilization toward users.

The platform has successfully motivated most users to learn more about lean manufacturing topic despite only seven users gave neutral feedback and one user disagreeing with the statement. This indicates interactive learning does help to motivate learners in terms of learning as this method enhances user control and interaction towards learning media according to their preferences which ensures versatility in learning.

Results in Table 1 have proved that the gamification approach for interactive learning is indeed relevant and successful as most of the users agree with the statement while only four users gave neutral feedback. This is because the gamification approach brings enjoyment to learning and delivers the necessary learning inputs along with enjoyment. By tapping into learners' interests and incorporating them into the learning experience, gamification can help to increase motivation, engagement, and ultimately, learning outcomes (Ghai & Tandon 2023).

The platform has successfully gained most of the users' interest in becoming lean or industrial improvement practitioners. Meanwhile, a minority of the users gave neutral feedback which assumes that different people have different main interests in pursuing their future careers. However, there is no negative feedback regarding the statement that indicates the platform can encourage people to know more about the lean manufacturing field but does not discourage anyone at all.

Most of the users showed their agreement towards utilizing the gamification approach for interactive learning to learn about lean manufacturing topics while four of them felt neutral and there was no negative feedback towards the statement. It is proven that using this new approach does help in acquiring users' attention and enjoyment to learn about lean manufacturing topics.

CONCLUSION

The development of an interactive learning platform with gamification features has been designed according to the planned operational flow that starts with the user option of selecting to undergo interactive learning media or play lean manufacturing games directly. Despite both learning materials and games being designed according to selected topics, these materials are not combined as a single learning media. Both materials are classified according to the chosen topic home page in HTML which is more organized as learners can choose 'Tutorial' for interactive learning session and 'Practice' to play games of the selected lean manufacturing topic.

Each interactive learning media was tested to perform accordingly, every interactive feature included in the learning media are action buttons, audio, and pop-ups were working successfully as designed including the attached production line simulation video. Meanwhile, for games, the drag-and-drop games tested to be working accordingly but with minor issues regarding the sensitivity of dropping the answer into the drop area. However, the multiple-choice answer game works successfully as designed. The feedback and responses for user answer input as designed but with a tolerable issue regarding the publishment of the state of game progress for the user. These issues may be prevented by designing each game slide separately to distinguish variations of feedback and response design layout.

Most importantly, the interactive learning platform has been successfully designed which would be helpful for

people to learn lean manufacturing activities and assess themselves on their basic understanding via the games developed.

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DECLARATION OF COMPETING INTEREST

None

REFERENCES

Alfoudari, A.M., Durugbo, C.M. & Aldhmour, F.M. 2023. Exploring quality attributes of smart classrooms from the perspectives of academics. *Education and Information Technologies* 28(10): 1–43.

Anunpattana, P., Mohd Nor Akmal Khalid, Lida, H. & Inchamnan, W. 2021. Capturing potential impact of challenge-based gamification on gamified quizzing in the classroom. *Heliyon* 7(12): 1–22.

Hadiana, A., Leiliawati, L., Muslih, M., Rohmanto, R., Natalia, N. & Sudaryo, Y. 2021. Asynchronous Collaborative and Interactive Learning Support System. *European Journal of Engineering and Technology Research* 6(3): 39-43.

Díaz-Ramírez, J. 2020. Gamification in engineering education: An empirical assessment on learning and game performance. *Heliyon* 6(9): 1–10.

Ghai, A. & Tandon, U. 2023. Integrating gamification and instructional design to enhance usability of online learning. *Education and Information Technologies* 28(2): 2187–2206.

Hursen, C. & Bas, C. 2019. Use of gamification applications in science education. *International Journal of Emerging Technologies in Learning* 14(1): 4–23.

Landers, R.N., Auer, E.M., Collmus, A.B. & Armstrong, M.B. 2018. Gamification science, its history and future: Definitions and a research agenda. *Simulation and Gaming* 49(3): 315–337.

Legaki, N.Z., Xi, N., Hamari, J., Karpouzis, K. & Assimakopoulos, V. 2020. The effect of challenge-based gamification on learning: An experiment in the context of statistics education. *International Journal of Human Computer Studies* 144: 1–14.

Mimouni, A. 2022. Using mobile gamified quizzing for active learning: The effect of reflective class feedback on undergraduates' achievement. *Education and Information Technologies* 27(9): 12003–12026.

Mullins, J.K. & Sabherwal, R. 2020. Gamification: A cognitive-emotional view. *Journal of Business Research* 106: 304–314 .

Hermita, N., Alpusari, M., Astuti Mulyani, E., Paura, A. & Herliana, H. 2020. Enhancing Science Process Skills through Conceptual Teaching and Learning Related to Water-Savings and Natural Events Concept. *Journal of Educational Sciences* 4(1): 146-152.

Rodrigues, L.F., Oliveira, A. & Rodrigues, H. 2019. Main gamification concepts: A systematic mapping study. *Heliyon* 5(7).

Sanders, A., Elangeswaran, C. & Wulfsberg, J. 2016. Industry 4.0 implies lean manufacturing: Research activities in industry 4.0 function as enablers for lean manufacturing. *Journal of Industrial Engineering and Management* 9(3): 1–13.

Shahabadi, M.M. & Uplane, M. 2015. Synchronous and asynchronous e-learning styles and academic performance of e-learners. *Procedia - Social and Behavioral Sciences* 176: 129–138.

Skulmowski, A. & Rey, G.D. 2020. Subjective cognitive load surveys lead to divergent results for interactive learning media. *Human Behavior and Emerging Technologies* 2(2): 149–157.

Ijaz, T., Ismail, M., Haider, S.M., Rafique, M.Z. & Jamshaid S.H. 2023. Production Enhancement through Integration of Lean, Life Cycle Assessment & Industry 4.0. Jurnal Kejuruteraan 35(3): 755–766.

Tuma, F. 2021. The use of educational technology for interactive teaching in lectures. Annals of Medicine and Surgery 62: 231–235.

Xia, X. 2020. Learning behavior mining and decision recommendation based on association rules in interactive learning environment. *Interactive Learning Environments* 31(2): 593-608..

Zainuddin, Z., Chu, S.K.W., Shujahat, M. & Perera, C.J. 2020. The impact of gamification on learning and instruction: A systematic review of empirical evidence. Educational Research Review 30: 1-23..