Enhancing Occupational Health and Safety Education: A Mobile Gamification Approach in Machining Workshops

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***Abstract*—This study explores the results of developing mobile gamification technology as a cutting-edge educational tool for occupational health and safety that aims to foster a safe and healthy work environment and increase student awareness of potential hazards in the machining workshop. This study engages 64 students from the Department of Mechanical Engineering at Universitas Negeri Padang. The research follows a comprehensive 4D development model encompassing the define, design, develop, and disseminate stages. The findings underscore the robustness of the developed technology, with media validation scoring (*M* = 4.40) and material validation (*M* = 4.39) both achieving "very valid" ratings. The practicality test yielded promising responses, with lecturers rating the application (*M* = 4.38) as "very practical" and students acknowledging its practicality (*M* = 4.18). Subsequently, effectiveness testing revealed a significant N-gain score of 0.65, categorizing it as moderate/effective in enhancing learning outcomes. In brief, this study demonstrates the successful development of mobile gamification in occupational health and safety education, specifically in terms of validity, practicality, and effectiveness criteria. The implications transcend academia, offering the prospect of a safer and more conducive community environment in the future.**

***Keywords*—educational technology, gamification, mobile learning, occupational health and safety, training, quality education, industry, innovation, and infrastructure**

I. Introduction

Integrating gamification technology in education represents a contemporary approach to leveraging game elements to enhance student engagement and motivation [1–3]. Remarkably, within the context of machining workshops and the industrial sector [4], mobile gamification emerges as a promising tool for Occupational Health and Safety (OHS) education, fostering heightened awareness of workplace risks [5–7].

Defined by the World Health Organization (WHO), occupational health and safety endeavors to cultivate skills conducive to safe and healthy work practices, encompassing adherence to workplace regulations and a positive safety culture [8, 9]. Central to OHS management is identifying, assessing, mitigating hazards, and prioritizing risk prevention to minimize work-related accidents [10, 11].

Notably, recent data from the Social Security Administration in Indonesia for 2022 reveal a concerning trend, with a significant increase in work accident cases compared to previous years [12, 13]. This escalation underscores the urgent need to address low awareness levels among workers regarding OHS protocols and practices [14]. With companies bearing the brunt of costs associated with workplace accidents, early dissemination of OHS education becomes imperative, underscored by regulations and Policies [15].

In response to these challenges, there is a pressing need to enhance educational provisions for OHS training within machining workshop environments, aiming to cultivate competent graduates equipped for the rigors of the industrial landscape [16]. In the ever-evolving educational landscape, technology-mediated learning solutions play a pivotal role in fostering students' critical, creative, and collaborative thinking skills [17, 18]. Integrating innovative tools in lectures, from e-modules to virtual reality, presents Indonesian universities, including Universitas Negeri Padang, with opportunities to enhance learning experiences and competitiveness [19, 20]. These technologies provide opportunities and benefits for Indonesian universities to compete with other developed countries to gradually improve the quality of their training and learning, which is immersive, creative, and innovative [21, 22].

Within this context, the development of mobile gamification-based learning media represents a significant endeavor. This research emphasizes that mobile gamification can revolutionize learning outcomes by offering a novel and engaging approach, prioritizing occupational health and safety in training and work environments [23]. Leveraging mobile applications, both lecturers and students can engage in independent training and learning activities [24–26].

This study endeavors to devise a robust learning and training model for OHS education using mobile gamification. Initial analyses underscore OHS learning as a semester-long endeavor characterized by educational models designed to stimulate student engagement and furnish them with OHS

knowledge essential for the industrial landscape [27, 28]. Moreover, as evaluated by experts, the study seeks to ascertain this approach's validity, practicality, and effectiveness. Ultimately, the implications, conclusions, and recommendations of this study can provide the necessary information to reduce workplace accidents in the future.

In order to accomplish the goals of this research, it is necessary to address the following research questions:

RQ1. What is the process of developing a Gamification mobile app for occupational health and safety education?

RQ2. What are the validity test results for mobile gamification in work safety, particularly in machining workshops and the industrial sector?

RQ3. What are the results of the practicality test for using mobile gamification in occupational health and safety education?

RQ4.What is the effectiveness level of mobile gamification in learning and training for occupational health and safety in machining workshops?

II. Methodology

This research aims to develop mobile gamification as an innovative educational medium explicitly designed for Occupational Health and Safety (OHS) training in machining workshops. This novel approach will be meticulously tested for its validity, practicality, and effectiveness, leveraging gamified elements to foster interactive learning of OHS material. This type of research uses a Research and development (R&D) design using the 4D development model, which consists of four stages: define, design, develop, and disseminate [29]. Specifically, the Mobile Gamification development stage was modified to 3D. It is essential to realize that this study was limited to the effectiveness testing stage (development), a pivotal milestone in the iterative development process.

Define. Fig. 1 illustrates the pedagogical process of developing mobile gamification for occupational health and safety content, from initial analysis to final assessment. This process aims to identify learning challenges and ascertain the initial needs of students. The initial step involves defining clear and specific learning objectives achievable through gamification technology [30]. Additionally, content design should align with these objectives, considering relevant pedagogical principles and individual trainee needs. Accordingly, gamification elements like points, levels, challenges, and rewards should be integrated to engage trainees appropriately [31]. Ultimately, rigorous content testing and evaluation are conducted to ensure effectiveness and suitability to trainee needs, identifying areas for improvement. These steps correlate with the core competencies outlined in the semester curriculum for occupational health and safety at Universitas Negeri Padang in the Department of Mechanical Engineering. This curriculum underscores a holistic approach encompassing fundamental knowledge and preventive education across all phases of workplace accidents within machining workshops and broader industrial settings. Consequently, adhering to this methodology aims to render the Mobile Gamification application development outcomes more educationally focused and productive in augmenting awareness and behaviors about occupational health and safety [32, 33].

Design. The design phase of the 4D model development was adapted to the formulation of semester learning plans and specific learning objectives focusing on occupational health and safety [34, 35]. Furthermore, this design process was aligned with the learning objectives, considering the pedagogical procedures outlined in the defining phase. Afterward, points, levels, challenges, and rewards provide users with an engaging and motivating learning experience customized to their mobile devices to encourage user engagement in the virtual environment [36, 37]. Subsequently, in building the 3D objects and animations were designed in the Blender App, and the user interface design was further developed in Unity 3D carefully for user accessibility and dance to facilitate users' participation. In addition, interactive features allow users to engage directly with the content, such as simulating emergencies in the work environment. Through this application, it is expected to hone students' cognitive and practical skills in dealing with risks and increase awareness of dangers in work safety.

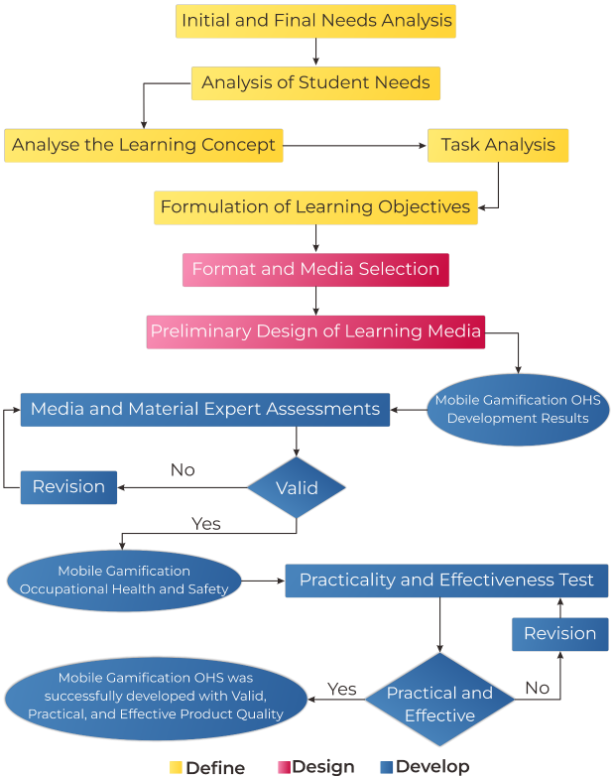

Fig. 1. Research procedure 4D development model.

The app evaluation process involved several comprehensive steps in ensuring its smooth use in occupational health and safety in machining workshops [38, 39]. The first step in evaluating this application after obtaining validation results is a practicality test to measure how easy it is for users to use the application and how well it can be integrated into the learning environment. Furthermore, an effectiveness test will be conducted to evaluate how this application improves users' understanding and occupational health and safety skills. Typically, the effectiveness test will be conducted by comparing the test results before and after using the application and by considering the level of user engagement and feedback provided [40].

Develop. This stage encompasses several critical facets.

To begin with, the blueprint design, once established, undergoes development based on the user interface concept, integrating an aesthetically pleasing visual presentation comprising colors, imagery, animations, typography, buttons, and interactive elements [41]. Simultaneously, User Experience (UX) plays a vital role in the development of health and safety educational media, which includes designing interfaces and interactions that ensure usability, accessibility, and satisfaction for users, as well as ensure alignment with user preferences and needs and encourage an engaging and enjoyable learning journey for students.

On the other hand, the validation and reliability testing phase employs Cronbach's alpha assessment, facilitated by three material experts and three media experts—esteemed Doctors and Professors boasting 30–40 years of research and teaching tenure at Universitas Negeri Padang [42]. This rigorous evaluation ensures the credibility and robustness of the developed educational tool.

Subsequently, conducting the practicality test involved assessing the ease of use of the OHS Mobile Gamification Application based on feedback from both lecturers and students. To begin with, participants engaged in this study were given access to the app and asked to utilize all available features. Moreover, it ensures the app's features function as expected in an actual usage scenario. Subsequently, participants filled out a questionnaire measuring dimensions such as Correctness of Material, Media Presentations, Quality in UI/UX Design, Ease of Media Use, and Expediency of the app in facilitating OHS learning. The data from this questionnaire was then analyzed to assess whether the app is easy to use and practical in OHS learning.

Ultimately, the effectiveness test of this study measured student learning outcomes through a pre-test and post-test that measured their cognitive ability towards occupational health and safety before and after receiving the mobile gamification learning application treatment. This analysis is measured through questionnaires and objective tests, including multiple-choice, true/false, or essay questions designed to see their improvement or change after learning the material taught, particularly on occupational health and safety in the machining workshop, using the normalized gain metric [43].

III. Data Collection

This study involved 64 participants aged 19–21 with a background as active students in the Department of Mechanical Engineering at Universitas Negeri Padang, who are currently taking or have finished taking Occupational Health and Safety (OHS) courses and must have an Android-based mobile device. Recruitment was done through Email and WhatsApp, providing details on the study's purpose, procedures, benefits, and participant requirements. Students interested in participating may be asked to fill out a participation consent form containing information about their rights and responsibilities as participants in the study. Finally, after participation in the study, the researcher can provide rewards or incentives to participants as a token of gratitude for their contribution.

This study concludes by creating educational instruments rooted in Occupational Health and Safety (OHS) principles, utilizing advancements in mobile gamification technology. These tools encompass diverse resources such as instructional videos, e-modules, and interactive game animations, collectively serving as an educational arsenal to augment students' understanding of workplace hazards prevalent in machining workshops and mitigate the risks of fatal accidents within industrial settings.

The research instrument employed a questionnaire meticulously evaluated by experts to ascertain its validity, practicality, and effectiveness, utilizing a Likert Scale methodology outlined by Nieveen [44]. Data collection centered on assessing the questionnaire's validity, meticulously evaluated by six experts specializing in educational technology and occupational health and safety. Each item within the questionnaire was scrutinized to ensure linguistic validity, emphasizing precise measurements and linguistic accuracy [45, 46]. The Likert scale method meticulously scrutinized all facets of the developed application through a series of positively and negatively framed statements.

The development process involved successfully creating a mobile gamification system, which underwent rigorous validation, reliability, revision, and evaluation procedures to ensure its efficacy. The nuances of the validity and practicality assessments are delineated in Table 1.

Table 1. Determination of the validity and practicality category

Validity		**Practicality**	
Score range (X)	Criteria	Score range (X)	Criteria
$4.2 < X \leq 5.0$	Very valid	$4.2 < X \leq 5.0$	Very practical
$3.4 < X \leq 4.2$	Valid	$3.4 < X \leq 4.2$	Practical
$2.6 < X \leq 3.4$	Quite valid	$2.6 < X \leq 3.4$	Practical enough
$1.8 < X \leq 2.6$	Less valid	$1.8 < X \leq 2.6$	Less practical
$1.0 < X \leq 1.8$	Very Invalid	$1.0 < X \leq 1.8$	Very Impractical

Table 2 outlines the assessment criteria for N-gain, providing a comprehensive framework for evaluating the effectiveness, cognitive prowess, and enhancements in learning outcomes observed among students [47]. This evaluative framework draws upon the formulation proposed by Meltzer [48].

Table 2. N-gain criteria and interpretation of effectiveness

Percentage (%)	**N-gain (normalized gain)**	**Criteria**
70–100	$(g) \geq 0.70$	High/Very Effective
0.31–0.69	$0.31 \leq (g) \leq 0.69$	Medium/Effective
0–0.30	$(g) < 0.30$	Low/Less Effective

The concluding stage in the development of mobile gamification for Occupational Health and Safety (OHS) education entails the revision and assessment of the application, incorporating feedback garnered from comments, suggestions, and validator input. The practicality examination assesses the initial responses of both educators and learners to the application through a trial conducted with a restricted group. Following this, the efficacy evaluation quantifies the improvements in students' learning outcomes and cognitive capacities by scrutinizing pre-test and post-test outcomes utilizing tests for normality, paired sample t-tests, and evaluations employing normalized gain analysis.

IV. Research and Development Results

A. *Results of the Initial and Final Needs Analysis*

Developing an Occupational Health and Safety (OHS)

application is paramount for ensuring the safety and well-being of students in the workplace. The initial and final needs analyses are pivotal in developing OHS mobile gamification. The needs analysis phase initially entails delineating the fundamental principles for implementing OHS correctly, aligning with pertinent laws and regulations, and addressing prevalent OHS concerns. This involves understanding various types of work, associated risks, and potential threats within the machining workshop environment. Additionally, it is imperative to scrutinize past work accidents involving students in the Department of Mechanical Engineering at Universitas Negeri Padang to ascertain adherence to established OHS protocols and identify any disparities between current and desired conditions in the application.

During the final needs analysis stage, OHS experts evaluate the potential and incorporate OHS material into the application to ensure alignment with predetermined needs. Establishing a priority scale based on the urgency and impact of occupational health and safety outcomes initiates the process of designing the user interface, application workflow, and necessary database. Ultimately, the OHS application becomes poised for user implementation by subjecting the developed media to validation and verification tests, ensuring adherence to initial and final analysis requirements.

The initial and final needs analyses are indispensable in OHS mobile gamification development, facilitating effective application development to enhance occupational safety and health, cater to user needs, and address OHS challenges in the machining workshop environment. The initial design of the OHS mobile gamification workflow is depicted in Fig. 2.

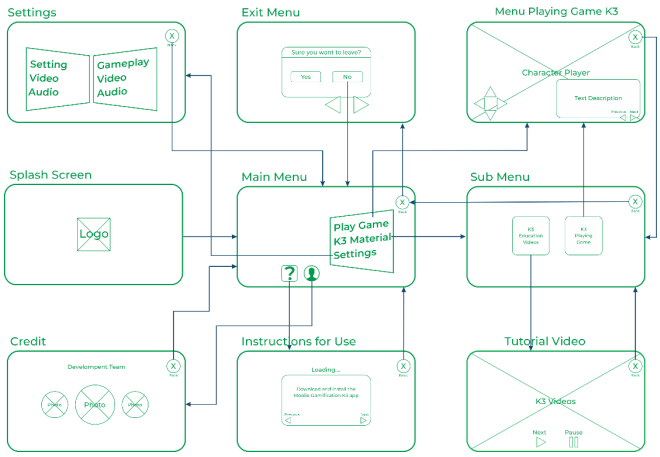

Fig. 2. Workflow for OHS mobile gamification.

Fig. 2 illustrates the workflow of the OHS mobile gamification blueprint, delineating the sequential activity process of the application's usage flow in a distributed manner.

Here is an elucidation of the workflow of the mobile gamification application concerning OHS. The initial screen, the splash screen, serves as a visual introduction upon launching the application. Users then access the main menu, which acts as a central hub for navigating various features and options available on the platform. Users can customize preferences and configurations within the settings section according to their requirements. Additionally, a user manual provides comprehensive instructions for effectively utilizing the application, guiding users through its functionalities. Transparency regarding the application's development, including developer details and contact information, is provided in the application developer information section. The OHS play game menu encourages users to engage in OHS games set in the machining workshop, facilitating indirect learning about potential work-related risks and hazards. Users are presented with two options in the sub-menu: accessing either OHS gamification or OHS videos, catering to different learning preferences. Supplementary resources in the form of video tutorials offer instructional simulations highlighting the significance of adhering to OHS practices while working. Finally, a designated exit menu button enables users to exit or close the application smoothly, ensuring user convenience and ease of navigation.

B. The Development of Mobile Gamification of Occupational Health and Safety

The results of developing mobile gamification-based learning media for occupational health and safety education are multifaceted. This research endeavors to harness mobile gamification as an educational tool for enhancing occupational health and safety in machining workshops, leveraging game elements to foster interactivity and enhance users' comprehension of OHS principles. The software used to craft the OHS gamification application includes Blender, Android Studio, and Unity 3D, each contributing to the application's development process.

Blender is utilized to construct 3D objects capable of dynamic animation. At the same time, Android Studio facilitates the creation of user-friendly applications with intuitive interfaces [49]. Unity 3D, on the other hand, serves as the primary platform for visualizing 3D objects within the gamification framework, focusing specifically on replicating the machining workshop environment and integrating safety protocols using various programming systems such as C#, JavaScript, and boot script. The resulting output is an APK format application compatible with students' mobile devices, enabling them to engage in OHS training through simulated gameplay.

Gamification features include game points, levels, achievements, competitions, challenges, and rewards to boost user engagement and motivation. The interface design undergoes meticulous adjustment to optimize accessibility and foster user engagement, encouraging active involvement and facilitating the understanding of theoretical concepts and the practical application of OHS training [50].

The visual display of the mobile gamification design exemplifies the culmination of these efforts, showcasing a user-friendly interface and immersive environment conducive to effective OHS education. Through the integration of gamification principles and innovative technology, this research endeavors to revolutionize occupational health and safety training in machining workshops, empowering users to acquire and apply essential safety knowledge for a safer working environment.

A growing trend in e-learning, mobile learning, is revolutionizing the educational paradigm by utilizing media that can be accessed through Android devices with minimum specifications of Android 4.4 KitKat or higher), sufficient

RAM (at least 2 GB), and a compatible graphics processing unit (GPU) to render graphics smoothly [39]. This research capitalizes on mobile learning as its platform of choice, recognizing the prevalence of mobile devices among students and their capacity to facilitate independent learning. The visualization in Fig. 3 depicts how the application of mobile gamification technology in the learning process can engender a virtual learning experience, augmenting learning motivation through the seamless integration of game elements and workplace safety education.

Fig. 3. a) main menu mobile application, b) play mobile gamification OHS.

Fig. 3 illustrates the critical role of testing in using mobile gamified OHS applications in fostering an engaging and immersive learning environment, empowering users to identify workplace hazards, and actively reinforcing safety protocols. The first step requires users to install the app on their mobile device, after which they can "play the game" by moving the avatar using the console feature available in the app so that the avatar within the app can move within the machining workshop providing users with an authentic experience, allowing students to receive educational OHS knowledge in an easy-to-use virtual work environment.

The simulation depicted in Fig. 4 offers users an immersive experience within a virtual machining workshop, melding real-life scenarios with game elements to foster active engagement in applying OHS principles. Users navigate the virtual environment, managing workflows akin to real-world scenarios encountered in machining workshops. For instance, upon interacting with a lathe equipped with sharp objects, users are prompted to don personal protective equipment before commencing work.

Fig. 4. Utilizing mobile gamification to implement OHS learning and training.

The mobile gamification platform offers students a learning experience to prioritize understanding workplace safety principles, identify potential risks, learn how to deal with emergencies and understand the importance of following correct safety procedures in a carefully crafted virtual workspace with detailed models of equipment, rooms, and specialized work areas. Moreover, it is targeted at increasing their awareness of hazards in the work environment and acquiring cognitive abilities and practical skills relevant to the student's future employment.

The game elements are designed with simulated models of potentially hazardous situations, allowing trainers to intervene virtually, guide users to adhere to safety protocols, and reinforce positive safety practices. Users can maneuver 3D avatars using controllers on Android devices, freely navigating according to their OHS learning objectives, honing their ability to identify and mitigate potential hazards. Notifications encourage users to enforce safety measures, such as wearing helmets and gloves, foster an understanding of OHS concepts, and allow them to test their responses in simulated risky scenarios.

Furthermore, integrating interactive posters within the

virtual workshop enriches the learning experience, augmenting traditional educational methods with dynamic game elements to enhance worker safety and health in high-risk industrial settings. Mobile gamification technology allows students to access learning materials at their convenience, facilitating anytime, anywhere learning tailored to individual schedules.

By meticulously assessing the application's design, content, and impact, it is an invaluable tool for early education, equipping users with the insight to effectively identify and mitigate workplace hazards. With a profound understanding of OHS principles, students emerge as adept professionals poised to enhance safety and productivity in future work environments. Evaluation of the application's ease of use, alongside pre-test and post-test assessments, offers insights into students' cognitive development and the efficacy of OHS mobile gamification, underscoring its role in shaping a safer and more productive workforce: https://bit.ly/OHSMobileGamification.

C. Result of the Validity Test

The results of the validation test in the development of OHS mobile gamification involved several aspects of questionnaire assessment containing statements and questions validated by six experts: three people for each aspect of media and material. Table 3 outlines the results of the media aspect validation, which contains the following dimensions: User Interface Quality, Responsive Navigation, Creative, and Progressive.

Table 3. Media aspect validity and reliability test results

Aspect	Validity	Criteria	Reliability	Criteria
User Interface Quality	4.19	valid	0.70	High Reliability
Responsive Navigation	4.56	very valid		
Creative and Progressive	4.44	very valid		
Overall Average	4.40	very valid	0.70	High Reliability

Table 3 displays the results of the media aspect validation, indicating an average score of 4.19 for the user interface quality aspect, 4.56 for the responsive navigation aspect, and 4.44 for the creative and progressive elements. The overall assessment yielded an average score of 4.40, falling within the "very valid" category. Additionally, the material validation achieved a Cronbach's alpha of 0.70, meeting the criterion of >0.70, indicating high reliability [51].

The validation conducted by media experts aimed to evaluate the effectiveness of the newly created mobile gamification components as a tool for Occupational Health and Safety (OHS) education, with particular attention to the integration of UI/UX design principles on the creation of an intuitive and engaging platform that facilitates a more effective learning experience. The assessment primarily targeted the navigational features of the application to guarantee its usability before broader adoption by users. The insights from the validators unveiled recommendations for specific enhancements despite the meticulous crafting of the application. These suggestions entail adjusting the luminance levels of specific font hues and rectifying glitches within the mobile gamification functionality. Consequently, developers have the opportunity to optimize the effectiveness of educational media, thereby fostering improved outcomes in health and safety training.

The OHS gamification technology developed in this study aims to enrich training and education by ingraining safe practices into work habits through a heightened interactive and cooperative learning method focusing on workplace safety. Through mobile gamification technology, learners can participate in educational activities that promote advancement in comprehension and motivation by consistently implementing OHS principles in work environments, notably within machining workshops.

Based on the presentation of Table 4, the material aspect validation test results demonstrate the effectiveness of the developed materials. The average scores indicate a high level of validity across critical dimensions: the learning design aspect received an average score of (M = 4.58), showcasing the robustness of the instructional framework. Additionally, the quality of the learning materials aspect garnered an average rating of (M = 4.27), highlighting the meticulous attention to detail in content development. Moreover, the presentation of the material element achieved an average score of (M = 4.39), indicating clarity and coherence in content delivery.

Table 4. Material aspect validity and reliability test results

Dimension	Validity	Criteria	Reliability	Criteria
Learning Design	4.58	very valid	0.69	Moderate Reliability
Quality of Learning Materials	4.27	very valid		
Presentation of Material	4.33	very valid		
Overall Average	4.39	very valid	0.69	Moderate Reliability

Overall, the comprehensive evaluation yielded an impressive average score of (M = 4.39), placing the assessment firmly within the "very valid" category. This underscores the overall effectiveness and reliability of the material aspect validation. While Cronbach's alpha obtained from material validation is 0.69, meeting the criterion of < 0.70, indicating moderate reliability, it still signifies a respectable level of internal consistency [51].

The validation conducted by subject matter experts aims to assess the caliber, pertinence, and precision of Occupational Health and Safety (OHS) instructional materials incorporated within mobile gamification. This validation process entails scrutinizing the delivery of OHS content, focusing on its thoroughness and suitability for the machining workshop setting. While the feedback from the validators suggests that the OHS content meets the minimum criteria for completeness, some areas necessitate further refinement, particularly regarding the comprehensive coverage outlined in the Semester Learning Plan.

Furthermore, involving OHS experts in the educational process facilitates the application of OHS principles in real-world work settings. Their participation ensures that the OHS materials effectively correspond to the demands of the industrial realm and machining workshops, thereby augmenting the practical significance and applicability of the educational materials.

D. Practicality Test Results of the Lecturer and Student Responses

Experts in media and material have effectively confirmed the advancement of mobile gamification for Occupational Health and Safety (OHS). A practicality trial was administered involving educators and students in OHS education within the machining workshop to assess its usability further. This assessment sought to collect initial perceptions regarding the application's user-friendliness.

The practicality assessment included disseminating surveys through Google Forms to three professionals/educators knowledgeable in occupational health and safety and 64 students engaged in machining workshop training. Users' responses after using OHS mobile gamification were systematically gathered and evaluated. The examination concentrated on two viewpoints: 1) Instructors/practitioners involved in OHS education and facilitation, and 2) students, the primary recipients of OHS mobile gamification.

The results of the practicality test delineated in Table 5 provide insights into the application's usability and effectiveness in facilitating OHS learning experiences for both instructors and students.

Table 5. Practicality test results of lecturer and student responses

Dimension	Lecturer Response		Students Response	
	Average	Criteria	Average	Criteria
Correctness of Material	4.17	Practical	4.09	Practical
Media Presentations	4.52	Very practical	4.20	Very practical
Quality in UI/UX Design	4.25	Very practical	4.32	Very practical
Ease of Media Use	4.33	Very practical	4.10	Practical
Expediency	4.62	Very practical	4.23	Very practical
Overall Average	4.38	Very practical	4.18	Practical

The practicality test results indicate that lecturers found the OHS mobile gamification highly practical, with an average score of (M = 4.38), categorizing it as "very practical." Similarly, students rated the application as "practical," with an average score of (M = 4.18). These findings demonstrate the overall effectiveness of the OHS mobile gamification in facilitating learning experiences for both lecturers and students.

Table 5 illustrates the positive impact of work safety education media on both lecturers and students. The diagram indicates that users using OHS gamification technology reported positive experiences, highlighting its convenience in applying occupational health and safety principles effectively. Some user suggestions include enhancing gamification performance for more excellent stability and optimizing application size to improve usability and reduce computing loads, aiming for a size below 100 MB.

E. Effectiveness of the Mobile Gamification and Student Learning Outcomes

The Shapiro-Wilk normality test assessed whether the statistical data adhered to a normal distribution [45]. The data are normally distributed if the obtained significance level (*Sig.* > 0.05 or 5%) indicates significance. IBM SPSS Statistics 26 software facilitated the normality test, paired sample *t*-test, and *N*-gain value analysis. Table 6 displays the results of the descriptive analysis of the normality test.

Table 6. Results of descriptive analysis of the normality test

Test	Mean	Std. Dev	Shapiro-Wilk Statistics	Sig.	Criteria
Pre-Test	50.67	9.156	0.976	0.704	Normal
Post-Test	83.00	6.801	0.937	0.077	Normal

The results of the descriptive analysis of learning outcomes in the machining workshop after using OHS mobile gamification are presented in Table 6. The pre-test average value was 50.67, with a standard deviation of 9.156. In contrast, the post-test average was 83.00, with a standard deviation 6.801 These values indicate increased learning outcomes, with the post-test showing a lower standard deviation than the pre-test. This suggests that after receiving the OHS mobile gamification treatment, the scores obtained by students became more consistent.

As shown in Table 6, the normality test results indicate normal distribution for both the pre-test and post-test data. The pre-test yielded a Shapiro-Wilk value of 0.976 with a significance of 0.704. Conversely, the post-test yielded a Shapiro-Wilk value 0.937 with a significance of 0.077. Due to the data above showing a normal distribution, we conducted the paired sample t-test analysis.

Table 7 shows that the paired sample t-test results have a significant result of [*t*-count = 19.018 > *t*-tabel = 2.045; *df* = 29; *Sig*. (2-tailed) < 0.05 = 0.000]. These results prove an average difference between the pre-test and post-test learning outcomes, which means that the OHS mobile gamification influences occupational health and safety learning outcomes in the machining workshop. To determine the influence and effectiveness resulting from the treatment, we continued with the N-gain (normalized gain) value test.

Table 7. Paired sample t-test results for learning outcomes

Test	Descriptive statistics		95% confidence interval		Paired *t*-test		
	Mean	Std. Dev	Lower	Upper	*t*	*df*	*Sig.* (2-tailed)
Pre-test	50.67	9.156	−35.812	−28.857	−19.018	29	0.000
Post-test	83.00	6.801					

Normalized gain, utilized to gauge the effectiveness of OHS mobile gamification, is a crucial metric in assessing the treatment's impact within a one-group pre-test and post-test design [52]. This assessment calculates the disparity between pre-test scores obtained before the treatment and post-test scores recorded after applying specific interventions. The results of the *N*-gain score test are presented in Table 8.

Before the students used the application, they generally showed varying levels of understanding of occupational health and safety concepts. Based on subjective observations, some may have firmly understood the basic principles. In contrast, others may have difficulty identifying potential risks in the work environment. However, after using the app, there was a significant improvement in their understanding and skills. These results are shown through the visualization of Fig. 5.

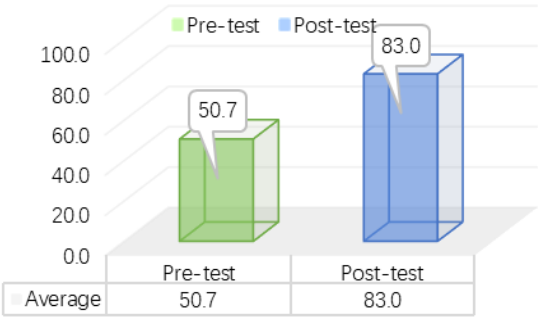

Fig. 5. Comparison results of the learning outcomes of one group.

Table 8. Results of the analysis of the N-gain on learning outcomes

Test	N	Min.	Max.	SD	N-gain Score	N-gain (%)	Criteria
Pre-test	30	0.20	0.92	0.154	0.65	65.3	Effective
Post-test	30						

Table 8 presents the students' performance post-exposure to the OHS mobile gamification intervention. Scores vary from 0.20 to 0.92, with a standard deviation of 0.154. Notably, the N-gain value stands at 0.65, corresponding to 65.3%, placing it within the moderate to effective range. This outcome suggests that students, previously challenged in grasping certain OHS concepts, have improved in risk identification and response to emergencies. Such progress aims to equip graduating students with the competency required in the industrial sector. Additionally, they demonstrated heightened motivation in the learning process, which is evident through heightened participation and engagement, positively affecting the efficacy of mobile gamification applications in enhancing student performance concerning occupational health and safety.

Fig. 6 provides a visual representation of the comparative analysis between pre-test and post-test scores, highlighting the enhancement in learning outcomes facilitated by the effectiveness of OHS mobile gamification. The comprehensive assessment yielded an average N-gain score of 0.65, positioning it within the moderate/effective category. This depiction underscores the significant impact of OHS mobile gamification in fostering improved learning outcomes among students undergoing occupational health and safety training in machining workshop settings.

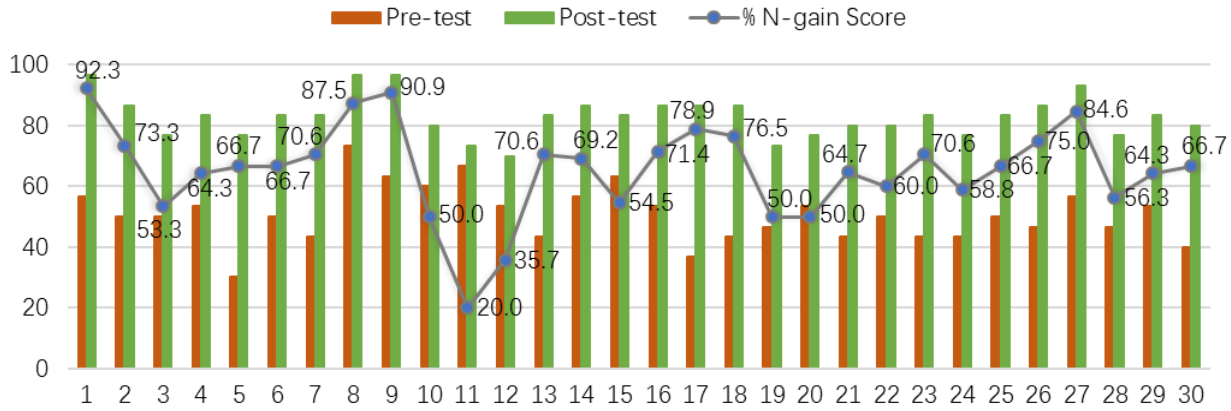

Fig. 6. The analysis results of the N-gain analysis on learning outcomes.

V. Discussion

In prior scholarly works, a study by Ofosu-Ampong *et al.* [53] underscores the significance of addressing students' psychological needs by integrating gamification technology to enhance their educational achievements. Nonetheless, it is observed that the areas covered are restricted to motivational and psychological facets, thereby failing to grasp gamification's influence on all aspects of learning comprehensively. On the one hand, the research conducted by this research group focuses more on exploring the results of the development and application of gamification technology in the field of Occupational Health and Safety (OHS). Additionally, this research examines gamification technology's validation, practicality, and effectiveness in augmenting student outcomes in Occupational Health and Safety (OHS) education.

Additionally, the research findings by Ismara *et al.* [54], particularly, the significant role of OHS application development in facilitating flexible and interactive learning experiences, enabling active participation in fostering safety awareness within a virtual work environment. The study categorizes mobile OHS gamification as effective, highlighting its crucial function as an educational tool in augmenting students' knowledge and capacity to identify OHS hazards [55, 56]. On the contrary, our study aligns with the above research; nonetheless, our investigation exhibits distinct characteristics, notably in the selection of media and subsequent research findings, with a concentrated emphasis on the phase of efficacy aimed at trainees in health and safety to mitigate occupational accident risks. Consequently, this methodology can be regarded as more quantifiable and targeted within the framework of developing and evaluating the efficacy of mobile gamification technology.

Furthermore, previous research conducted by Rauh *et al.* [57] is grounded in a study employing mixed reality technology for occupational health and safety training to incentivize industrial employees. However, the outcomes of this innovation underscore the hurdles associated with the utilization of relatively costly mixed reality hardware. Conversely, our investigation using gamification technology through applications that can be accessed anytime, anywhere through Android mobile devices is one of the advantages of its ease of use compared to using mixed reality technology with costly devices. The findings were substantiated by usability data showing positive reactions from both lecturers

and students regarding the practicability and availability of OHS mobile gamification [58].

This research is distinguished by its investigation into the role of mobile gamification as an educational tool, promoting an initial focus on occupational health and safety within machining workshops and industrial environments [59]. A pivotal innovation of this research is using gaming dynamics and gamification technology to augment understanding and behaviors toward work safety. Moreover, the study provides evidence on the efficacy of mobile gamification, corroborated by comprehensive evaluations from an expert panel and practical assessments with educators/practitioners and students. By integrating pre-test and post-test analyses, we further clarify OHS mobile gamification's substantive influence on students' learning outcomes.

In summary, this study significantly advances educational and industrial sectors by underscoring the efficacy of gamification in OHS education and enhancing graduate competencies. Validated by empirical evidence and corroborated by prior research on gamification in OHS training, this approach is user-friendly and an essential pedagogical tool for instilling workplace safety priorities among students. Consequently, this research aims to serve as a pivotal resource for academics and practitioners eager to incorporate gamification into educational strategies, thereby fostering safer and more optimistic future work environments.

This research holds implications for various stakeholders directly involved in the study. By focusing on occupational health and safety (OHS) through mobile gamification tools, the findings underscore the significance of leveraging mobile technology to enhance workplace safety awareness in the industrial sector. Consequently, industries and educational institutions are urged to prioritize the development of engaging and relevant OHS mobile applications to educate and train their workforce effectively.

Moreover, the study emphasizes the transferability of skills acquired through OHS mobile gamification to real-world scenarios, empowering users to make informed decisions in machining workshops and similar settings. The integration of game design elements into training initiatives not only enhances learning experiences but also fosters interactive and exciting educational environments.

This research has important ethical implications in the long term as it integrates safety and knowledge culture to reduce accidents and prioritize worker well-being. The interactive learning experience equips users with the necessary knowledge and skills to comply with higher safety and health standards, aiming to reduce the negative impact of workplace accidents.

While the cited literature lacks direct emphasis on ethical concerns in research or the interplay between science and society sufficiently [60], we recognize that it is essential to address moral issues and the interaction between science and culture, including occupational health and safety (OHS), education, and technology.

Furthermore, this research has the potential to inspire the younger generation in Indonesia to elevate their living standards and education levels. However, it is essential to note that this study is limited to evaluating the effectiveness of mobile gamification in OHS learning. Future research endeavors should focus on disseminating the findings to educational institutions and companies fostering collaborations to enhance OHS education through sustainable integration of mobile gamification technology.

Additionally, future research can explore advanced OHS training and learning content by integrating gamification technology with artificial intelligence, thereby automating the identification of user needs and providing more tailored learning experiences. By embracing such advancements, organizations can better prepare their workforce and cultivate a safer work environment for all stakeholders.

VI. Conclusion

This research culminates in successfully implementing a mobile gamification tool for Occupational Health and Safety (OHS) education, marking a significant stride in enhancing workplace safety awareness and practices. The developed gamification technology leverages 3D-based game elements, intricately simulated to replicate real-world scenarios within machining workshops. This technological advancement augments productivity and fosters active engagement among students and workers in adhering to OHS protocols.

The gamification simulation approach yields tangible improvements in student performance, facilitating sustainable occupational safety and health learning. The robustness of the developed application is underscored by the high validity ratings from material experts (M = 4.39) and media experts (M = 4.40), categorizing it as "very valid." Moreover, practicality tests reveal favorable responses from both lecturers (M = 4.38) and students (M = 4.18), affirming its usability and effectiveness in OHS learning contexts.

The effectiveness test further reinforces the impact of the gamification technology, with an N-gain score of 0.65 in the moderate/effective category. Henceforth, the research objectives are accomplished: the developed application showcases stability and responsiveness across user mobile devices. Moreover, the validity, practicality, and effectiveness tests substantiate its appropriateness for OHS education and the potential for sustainable business ventures, encompassing training, OHS consulting, and technology development, underscores this innovation's broader applicability and long-term viability.

This study significantly contributes to OHS education and awareness in work environments. The immersive simulation scenarios and challenges create an engaging learning environment, enabling workers to internalize OHS concepts effectively. Ultimately, the positive changes in workplace safety culture catalyzed by this technology promise enduring benefits, ushering in a new era of improved occupational safety and health practices.

This research offers valuable insights into OHS mobile gamification's validity, practicality, and effectiveness in enhancing student learning outcomes. However, it is fundamental to acknowledge the study's limitations, notably resource and time constraints, which restricted the sample size to 64 participants. Despite efforts to ensure optimal sample selection, the findings may only capture specific variations in participants' technological aptitude, motivation, gaming interest, and learning inclinations. Moreover, while

the Mobile Gamification development phase transitioned to 3D, it is imperative to recognize that this study was confined to the effectiveness testing stage (develop).

Further investigation is warranted to explore the broader implementation of OHS gamification mobile technology as an educational tool across various industrial sectors. Future research endeavors could focus on integrating technology into OHS practices, fostering a safety culture, and enhancing workers' adherence to safety protocols and procedures. Such initiatives hold the potential to significantly improve productivity and efficiency in machining workshop environments while promoting safer working conditions.

Moreover, by providing a detailed description of the treatment administered through OHS mobile gamification, future studies can address anticipated challenges more effectively. Ultimately, the widespread adoption of gamification technology in OHS education has the potential to reduce workplace accidents and injuries, thereby creating safer and more conducive work environments for workers and students alike.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

R.A.N. corresponding author; A.F. and A.R.S. conducted the research; A.F., W.A., and R.A.N. wrote the original draft; H.C., M.C., and S.A. app assessment validator and reviewed the paper; F.P. and A.D.S. supervised the research; (W.A.); (S.R.); responsible for the grammar of the article; all authors had approved the final version.

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