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Elemental Fusion : Unlocking the Science Lab (A Game-Based Mobile Learning Application about Chemistry Subject for Form 4 and Form 5 Students)

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Abstract

Chemistry is one of the subjects that can be taken in Malaysia Certificate of education (SPM). There are several topics that are causing difficulty to remember and feel more challenging to learn Chemistry. Therefore, an educational mobile game learning application named Elemental Fusion: Unlocking The Science Lab with gamification approach is developed to help Form 4 and Form 5 students improve their chemistry skills that combines the immersive experience of an escape room with interactive chemistry quizzes. Elemental Fusion application has three modules including Recap module, Game module, and Quiz module. Besides, Multimedia Mobile Content Development (MMCD) methodology is used to develop the Elemental Fusion: Unlocking The Science Lab application. System Usability Scale (SUS) method is used to obtain the results of a user acceptance test. It gets 78.08 positive feedback through this testing. In conclusion, Elemental Fusion is an application that is suitable for learning Chemistry.

1. Introduction

Science serves as the foundation for numerous technological and industrial breakthroughs that influence today's society. For students, knowing fundamental scientific subjects such as chemistry is critical, not just for academic performance but also for understanding the principles that govern the universe. This subject is critical in secondary school because it establishes the foundations for many STEM (Science, Technology, Engineering, and Mathematics) fields. Research from the National Science Teaching Association (NSTA) highlights that proficiency in subjects like chemistry not only increases problem-solving abilities but also prepares students for advanced studies in these fields[1]. As knowledge of science becomes more essential in today's technology environment, students want more interesting and practical approaches to understanding these subjects.

However, in the current education system, chemistry is usually taught through traditional methods such as textbooks, exercises, and lectures. Many secondary schools already teach science subjects in the classroom, with teachers discussing them while students follow along in their textbooks [2]. Hands-on experiments in the lab are occasionally used to teach key principles; however these sessions are frequently time and resource limited [3]. These challenges come from the abstract nature of some scientific concepts, which are difficult to visualise or relate to real-world applications. Furthermore, this typical teaching technique does not effectively accommodate various learning styles or stimulate active problem-solving, leaving students disengaged.

To solve this challenge, “Elemental Fusion: Unlocking The Science Lab” is developed as an educational mobile game that targets secondary school Form 4 and Form 5 students who are learning chemistry. The game relates to

the syllabuses of these courses, providing an interactive, immersive learning experience in which players must solve questions and find a key and hidden hint in order to escape from a virtual science lab. Moreover, by combining the thrill of an escape room with instructional information, the game provides an innovative approach to learning that is both exciting and educational. Additionally, by combining learning with an exciting escape room theme, the game seeks to make science more appealing to young learners. While students frequently attend science seminars and workshops, these sessions may lack the dynamic and engaging features that keep students interested, making it difficult for them to recall vital information.

The objective of this project is to develop an interactive educational 3D game called Elemental Fusion: Unlocking The Science Lab, which focuses on fundamental chemical principles for Form 4 and Form 5 students, to develop the game on the Android platform and test its usability and user acceptance with the target audience using System Usability Scale (SUS) method. Elemental Fusion: Unlocking The Science Lab was developed for students who struggle to understand chemistry through standard teaching techniques, providing a fun and engaging alternative through escape room-style gameplay. Madam Siti Nur Hidayah binti Sahari, a chemistry teacher at Sekolah Menengah Kebangsaan Tanjung Puteri Resort, serves as the project's Subject Matter Expert (SME). The game was created utilizing the Multimedia Content Development (MMCD) process, which ensures an organized and engaging approach.

The Multimedia Content Development (MMCD) technique is a systematic instructional design strategy for creating interactive learning materials by incorporating multimedia elements such as text, audio, video, graphics, and animation [4]. It consists of five major phases: analysis, design, development, implementation, and evaluation. MMCD focusses on user engagement and learning effectiveness by connecting multimedia components with educational objectives [5]. This concept is commonly utilized in educational game development to increase learner interest, particularly in science and technology disciplines. Recent research indicates that MMCD provides a structured yet flexible framework for building digital learning aids that adapt to different learning styles [6]. MMCD-based applications have been shown to improve students' comprehension and memory of complicated subjects. Therefore, Elemental Fusion: Unlocking. The Science Lab is designed utilizing the MMCD methodology to provide Form 4 and 5 chemistry students with an interactive, engaging, and curriculum-aligned learning experience.

The rest of this paper is organized as follows: Section 2 covers the study domain, the technologies used, and the results of the comparative analysis. Section 3 describes the Multimedia Mobile Content Development (MMCD) methodology that has been chosen to be used in this project, as well as the outputs from the analysis and design phases of this project. Next, Section 4 demonstrates the result and discussion of the developed application, while Section 5 presents the conclusion of the project.

2. Literature Review

This section discusses the study domain related to developed applications and existing applications similar to the developed applications. The purpose is to analyze the comparison between existing applications and developed applications so that improvements to the applications can be implemented.

2.1 KSSM Chemistry

KSSM Chemistry is a core science subject provided in the Sijil Pelajaran Malaysia (SPM) and plays an important role in developing scientific literacy among Malaysian secondary school students. The course provides students with foundational knowledge and abilities in atomic structure, the periodic table, chemical bonding, and atomic structure, which are required for higher education in subjects such as medicine, engineering, pharmacy, and environmental science [7]. In 2017, the Ministry of Education (MOE) changed the KSSM syllabus, emphasizing inquiry-based learning, higher-order thinking skills (HOTS), and real-world applications of chemical ideas [8]. Despite these improvements, many students continue to struggle with abstract chemical concepts, resulting in a drop in interest and performance in the subject [9]. As a result, the use of digital resources and interactive learning methodologies, such as instructional games, has become critical to students' comprehension and engagement with the KSSM Chemistry curriculum.

2.2 Game Technology

This project utilised two key technologies: the Multimedia Content Development (MMCD) methodology and game-based learning methodologies, in particular the escape room concept. First, the MMCD model was used to arrange the production of this instructive mobile game. MMCD promotes the development of multimedia learning resources by incorporating features such as interactive animations, music, video, graphics, and simulations to help students understand complicated concepts [1]. This methodology helps developers to plan, design, and create

high-quality multimedia educational material that is consistent with curricular standards and student learning goals.

Secondly, game-based learning, especially the escape room technique, has been used to increase students' engagement and motivation while learning chemistry. The escape room concept replicates a problem-solving environment in which participants must accomplish educational tasks in order to "escape" a virtual scenario. This strategy improves learning by using timed exercises, questions, and instant feedback to promote higher-order thinking and reinforce material mastery [10]. To make abstract concepts more concrete and entertaining, this game uses chemistry-based questions on topics such as the periodic table, chemical bonding, and atomic structure.

Furthermore, the game incorporates use of mobile technologies to enable students to learn at any time and from any location via interactive simulations and multimedia information. The game format promotes student autonomy and accommodates a wide range of learning preferences, especially when linked with the VARK learning styles (visual, auditory, read/write, and kinaesthetic) [6]. Visual learners, for example, profit from colourful diagrams and animations; auditory learners gain from narrations and sound cues; read/write learners engage with in-game notes and quizzes; and kinaesthetic learners interact through touch-based challenges and hands-on virtual experiments. Overall, these integrated technologies aim to make chemistry education more accessible, interactive, and interesting for secondary school students.

2.3 Comparison Of Existing Application

Several educational games on the market have included chemistry-related content, however the majority lack systematic Form 4 and Form 5 syllabus alignment and fail to incorporate effective gamification for deeper involvement. Figure 1 (a) – (c) shows Chemistry Masters in Roblox, Chemistry Lab: Compounds Game, and Periodic Table Quiz are examples of applications that use interactive aspects to teach chemical principles,respectively. However, these games frequently emphasise surface-level memorisation or generalised gaming rather than providing defined educational pathways associated with national curriculum. A comparison was made between these existing applications and the game Elemental Fusion: Unlocking the Science Lab. Table 1 includes a review of eight features: game modules, platform compatibility, gamification methodologies, multimedia integration, syllabus coverage, strengths and shortcomings.

Based on the comparison, it was discovered that the reviewed applications lacked curriculum-specific information or did not use structured gamification strategies to promote learning. For example, Chemistry Masters in Roblox provides exploratory gameplay but does not closely correlate with the Form 5 syllabus. The Periodic Table Quiz focusses on factual recall with little interactivity, whereas Chemistry Lab: Compounds Game delivers simple compound creation without deeper conceptual learning. To solve these constraints, Elemental Fusion: Unlocking the Science Lab employs a more immersive escape room-style gamification approach, mixing interactive questions with chemistry subjects like the periodic table, chemical equations, and atomic structure [10].

Fig.1 ***(a)*** *Chemistry Masters in Roblox [11],* ***(b)*** *Chemistry Lab : Compounds Game [12],* ***(c)*** *Periodic Table Quiz [13]*

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Table 1 *The comparison of three existing application and proposed applications*

Criteria	Chemistry Masters in Roblox	Chemistry Lab : Compounds Game	Periodic Table Quiz	Elemental Fusion: Unlocking The Science Lab
Technology	3D multiplayer game using built Roblox Studio platform	Mobile App using Unity	Mobile quiz app built using Android Studio	Mobile game application developed using Unity engine
Methodology	Multimedia Content Development (MMCD)	Multimedia Content Development (MMCD)	Multimedia Content Development (MMCD)	Multimedia Content Development (MMCD) and Escape Room Game Technique
Module	Lab experiments, reaction challenges	Virtual experiments, bonding puzzles	Multiple-choice quizzes	Recap module, game module has 3 room level (easy, medium, and hard), quizzes
Multimedia Elements	3D environments, animated interactions	High-quality 2D/3D simulations	Text and static visuals	2D and 3D graphic, animations, video. audio and sounds, interactive UI, 3D environments
Accessibility	Requires Roblox platform and stable internet connection	Mobile application, no internet required after download	Works offline	Mobile application and works offline after installation
Advantage	Promotes collaboration and creativity	Visualizes abstract chemistry concepts effectively	Improves memory retention of facts	Combines syllabus-aligned chemistry content with immersive gamification and multimodal learning (VARK)

3. Methodology/Framework

Elemental Fusion: Unlocking The Science Lab will use Multimedia Mobile Content Development (MMCD) as a methodology. The Multimedia Mobile Content Development (MMCD) methodology is a comprehensive framework established exclusively for mobile application and content development. It consists of well-structured phases that guide the development team through creation of ideas, structure analysis, process design, fundamental development, and testing. MMCD was chosen as the project's methodology because of its systematic and flexible approach, which keeps the development process organised and adaptive to changes while lowering development risks. Its emphasis on user-centered design and content optimisation is consistent with the goals of this educational endeavour. Furthermore, MMCD prioritises providing high-quality material that is useful, interactive, and entertaining, which is critical for an educational game like Elemental Fusion: Unlocking the Science Lab.

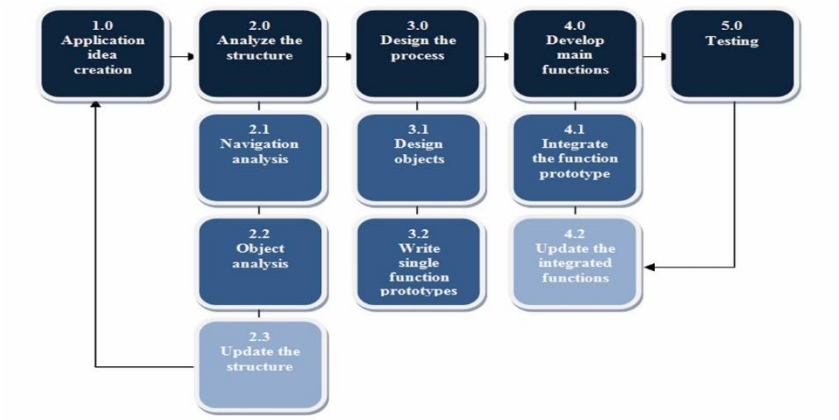


Fig. 2 *Multimedia Mobile Content Development (MMCD) [16]*

3.1 Application Idea Creation Stage

The first stage of the MMCD (Multimedia Content Development) methodology identified two categories of requirements for the Elemental Fusion: Unlocking the Science Lab application: user requirements and application requirements. Two strategies were used to collect information about user requirements. First, an interview was conducted with a Subject Matter Expert (SME), Cikgu Nurul Hidayah binti Sahari, a Chemistry teacher at SMK Tanjung Puteri Resort. Meanwhile, a survey was distributed to selected Form 4 and Form 5 students to gain an understanding of their preferences and expectations for mobile-based chemistry learning applications. According to the data, the majority of students have never used game-based chemistry applications, but they are interested in utilising one that has interactive and escape room aspects to promote engagement and understanding of the subject.

Furthermore, many students preferred multimedia components like photos, animations, and audio to aid in their learning process. Interactive components like quizzes and storyline-based tasks were particularly popular since they make learning more fun and effective. The SME emphasized the significance of matching the application with the curriculum and employing gaming dynamics to pique interest. Table 2 presents a summary of the user analysis from both the SME and students' viewpoints.

Table 2 *User Analysis*

Stakeholder Category	Role in product	Design implications	actions needed
Subject Matter Expert	Content consultant expert in the related field	Based on interview Simple user interface design	Choose fonts type and sizes that are readable to the users such as Flatory Slab with a font size bigger than 30pt
		Easy to navigate	Consistency of buttons and icons. Simple navigation buttons that can lead users to the selected interfaces.
		Reliable content and simple word choice	Content should follow the syllabus in Form 4 Chemistry.
General user (Form 4)	End-user of the system	Through questionnaire conduct by blast Google Form	The application should be developed on mobile devices. The application should be developed on the Android platform.

3.2 Analyze the Structure Stage

At this stage, navigation and object analysis have been completed. The application contained selected syllabus-related content from the Form 4 and Form 5 Chemistry textbooks. Chemical bonding, the periodic table, and atomic structure were among the topics covered, and three major modules were created: the lesson recap module, the game module, and the quiz module. Figure 3 illustrates the content structure, which consists of the title, objectives, modules, lessons, and subjects, while a more detailed application structure is shown in the system flowchart in Appendix A. Tables 3 and 4 include both functional and non-functional needs.

Table 3 *Functional requirements*

Functional Requirements	Module	Description
User Interaction	Main Interface	• The system shall provide users with the ability to start the application.
	Main Menu	• The system shall provide users with the ability to navigate between levels.
	Setting Interface	• The system shall provide users with the ability to edit sound and volume.
Game Level Modules	Module 1: Periodic Table	• The system shall provide interactive quizzes on elements
	Module 2: Atomic Structure	• The system shall provide users with interactive questions for Atomic structure.
	Module 3: Chemical Bonding	• The system shall provide users with the ability to balance chemical equations.
Progress Tracking	Progress Module	• The system shall display scores and progress for each level.
3D Environment	3D Simulation Module	• The system shall provide users with an immersive 3D science lab environment.
Feedback and Hints	Hint Module	• The system shall provide users with hints if they struggle with questions.
	Feedback Module	• The system shall provide real-time feedback on quiz and game performance.

Table 4: Non-functional requirements

Non-functional Requirements	Description
Performance	The application shall operate fully offline. Any interaction between the user and the system should not exceed three seconds for an Android mobile phone.
Operational	The application shall be able to operate on any Android device with Android version 12 and above.
Legal	Users only can review the information displayed in the application but they cannot modify any information in it
Usability	The application shall be user-friendly and easy to bring anywhere at any time.

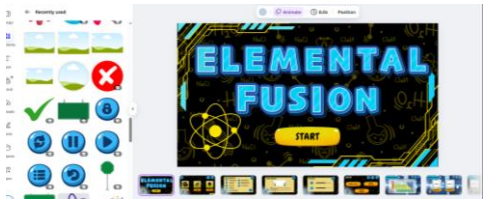
3.3 Design The Process Stage

At the process design stage, the main focus is on designing user interactions with the application through a task flow that involves an engaging storyline. Students learn chemistry topics through challenging games and quizzes. Gamification, multimedia, and narrative elements are combined to ensure a fun and effective learning experience. The assets for the escape room game were created using Blender, while all elements in the Recap module and Quizzes were designed using Canva. The objects that were designed are buttons, backgrounds, assets, and images. Subsequently, the Unity software is used to compile the assets with scripting. Table 11 shows the button design attached in Appendix B.

3.4 Develop Main Functions Stage

This phase focuses on creating and integrating all of the game components. Unity is used to design game mechanics such as completing challenge questions in escape room games and quizzes, ensuring that they are in line with educational objectives. 3D elements, such as lab equipment, chemical models, and settings, are designed to offer an immersive and realistic science lab experience. The development stage also entails combining all materials, game mechanisms, and storylines into a unified, playable experience. Audio features, such as sound effects for activities like walking, as well as background music, are used to keep players engaged and immersed throughout the game. It included the development of assets for the application using software and integration using C# scripting in Unity software. The assets developed for these applications are 2D graphics, audio, animation, and videos as tabulated in Table 5.

Table 5 *Development of Asset in Application*

Types of Assets	Development View	Description
2D Graphics		Canva are used to design the background interfaces, buttons, icons, and images for the application. All of the Elements are imported into Unity by PNG file.

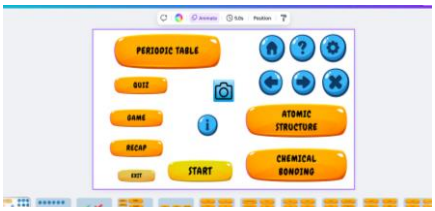
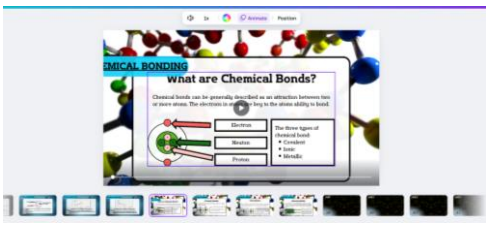
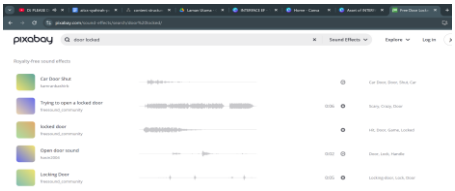
2D Button and Icons		In addition, Canva elements like Icon and Buttons are imported from Canva into Unity, and can be used to form buttons that can be used in different scenes in an application.

Table 5: *Development of Asset in Application (continued)*

3D Models		Blender is used to develop assets for 3D escape room games, like a science lab table, a key, and a science lab environment.
Video And Animation		Video and animation are created by using Canva.
Audio		The audio files are downloaded from free online resources such as “Pixabay” . Its format MPEG Audio Layer 3 (MP3).

Subsequently, the C# scripting is applied to ensure the main functions of the application can be operated properly. The main functions involve player movement, hint manager, change scenes, background music, quiz manager, question and answer, and answer script are tabulated in Table 7 that attached in Appendix C.

3.5 Testing Stage

Finally, the testing stage allows the developer to evaluate the application's operation, find bugs, and guarantee the system is in good condition. To resolve defects, the developer should review the coding and update the integrated functions to correct the flaws. Table 6 describes functional testing. It is used to determine whether the buttons perform as planned. In addition, user acceptance testing is done to verify whether this program is available and has market value.

Table 6: *Functional Testing*

Test	Expected Result	Actual Result	Corrective Action
Start button	Navigate to main menu	Works well as expected	Not needed
Exit button	Pop-up to exit panel	Works well as expected	Not needed
Manual button	Navigate to manual page	Works well as expected	Not needed
Setting button	Navigate to setting page	Failed to function in recap and quiz page	Reset the button and use the correct script onClick()
Home Button	Navigate to home page	Works well as expected	Not needed

Table 6: *Functional Testing (continued)*

Test	Expected Result	Actual Result	Corrective Action
Next button	Navigate to next scene	Works well as expected	Not needed
Back button	Navigate to the previous scene	Works well as expected	Not needed
Quiz button	Navigate to Quiz page	Works well as expected	Not needed
Recap button	Navigate to Recap page	Works well as expected	Not needed
Periodic table button	Navigate to Periodic table page	Works well as expected	Not needed
Atomic structure button	Navigate to Atomic structure page	Works well as expected	Not needed
Chemical bonding button	Navigate to Chemical bonding page	Works well as expected	Not needed
Answer option button	Identify the correct or wrong answer	Failed to identify the correct answer	Reset the correct answer button, and assign correct answer at the inspector
Room level button	Navigate to each level	Works well as expected	Not needed
Replay button	Replay the game/quiz	Works well as expected	Not needed
Menu button	Pop-up menu panel	Works well as expected	Not needed
Quiz score system	Track the current and record the score quiz	Failed to record previous score	Set the public integer variable for the point
Game score system	Track the current and record the score for the game	Failed to record previous score	Set the public integer variable for the point

According to functional testing, a few issues were found. The default behaviour of the setting button to open the volume settings panel was caused by a Unity system problem and a missing file in the onClick() code. To resolve this problem, a new button was added. The Answer Option Button has the same bug as the Setting Button; thus the developer reset and tested the button. Users cannot win the game in the Quiz module despite not collecting scores due to a scoring error. As a result, the approach is to set a public integer variable for the score at each game level. Same to game score system, that the countdown system did not detect well the game progres, that make users win stats easily. For answer option button, there are error with failed identify the correct answer, that make user did not get answer right in the score scene user are failed to answer all. Meanwhile, user acceptance testing was undertaken to gather feedback from target users on the application. This testing took place once the application was entirely developed. The questionnaire comprises ten questions. The selected statements accurately measure system usability, including assistance, training, and complexity.

4. Result and Discussion

During user acceptance testing, the System Usability Scale (SUS) [14] was used to assess application acceptance and usability. To accomplish this, all respondents must download and install the Elemental Fusion: Unlocking The Science Lab apk file from the link provided in Google Forms. The app is compatible with at least Android version 12. The SUS questionnaire had ten statements that alternated between positive and negative elements, such as ease of use, system integration, and the need for technical support. The findings revealed that the majority of students answered favourably to phrases like "I thought the system was easy to use" and "I felt very confident using the system," indicating a high level of comfort and familiarity with the video games interface. Fewer students

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agreed with unfavourable statements such as "I found the system unnecessarily complex" or "I needed to learn a lot of things before I could get going," indicating that the application is generally simple and user-friendly.

Table 7 *Respondent's Score(System Usability Scale (SUS)*

Responden	Skor Item										Skor Ganjil	Skor Genap	Jumlah Skor
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10			
R01	4	2	4	3	3	3	4	2	3	4	13	11	60
R02	5	2	5	2	5	2	5	1	5	4	20	14	85
R03	5	4	5	3	4	1	4	2	5	3	18	12	75
R04	4	2	5	1	3	3	5	2	4	4	16	13	72.5
R05	5	2	5	4	5	1	4	1	5	3	19	14	82.5
R06	4	4	4	3	3	3	4	3	4	3	14	9	57.5
R07	5	1	5	4	4	1	5	1	5	4	19	14	82.5
R08	4	4	5	2	4	4	4	1	4	5	16	9	62.5
R09	5	1	5	3	4	2	5	1	5	3	19	15	85
R10	2	2	4	1	3	3	4	3	2	3	10	13	57.5
R11	4	2	4	2	5	2	5	1	5	1	18	17	87.5
R12	5	1	5	1	5	1	5	1	5	1	20	18	95
R13	5	2	5	2	5	2	5	2	5	2	20	15	87.5
R14	5	5	5	5	5	5	5	5	5	5	20	20	100
R15	5	2	5	2	4	2	4	2	3	3	16	14	75
R16	5	5	5	5	5	5	5	5	5	5	20	0	50
R17	5	3	4	4	3	2	4	3	3	3	14	10	60
R18	4	2	4	3	4	2	4	2	4	2	15	14	72.5
R19	4	2	4	2	4	2	4	2	4	2	11	15	65
R20	5	1	4	2	5	2	4	1	4	3	20	16	67.5
R21	5	1	5	1	5	1	5	1	5	1	18	20	95
R22	4	2	4	2	4	2	4	2	4	2	15	15	75
R23	5	2	5	2	4	2	4	1	5	2	18	16	85
R24	5	1	4	2	5	1	4	2	5	1	18	18	90
R25	5	1	5	1	5	1	5	1	5	1	20	20	100
R26	4	2	4	2	4	2	4	2	4	2	15	15	75
R27	4	2	5	1	4	2	5	1	4	2	17	17	85
R28	5	1	4	2	5	1	4	2	5	1	18	18	90
R29	5	1	4	2	5	1	4	2	5	1	18	18	90
R30	5	2	4	1	5	3	4	3	5	3	18	13	77.5
												Skor Purata	78.08

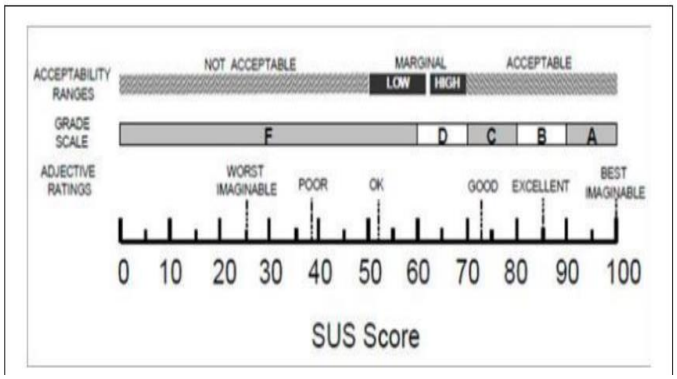

Fig.3 *Scale of SUS Score [14]*

The application's average SUS score was 78.08, placing it in the "Good" to "Excellent" usability category according to the SUS grading scale. This score corresponds to a Grade B, indicating that the system is well-liked by users and has a high degree of usability. Multiple students rated the application in the upper 80s and 90s, with some calling it the "best imaginable." These findings indicate that the game design successfully balances instructive content with compelling gameplay, and that students will likely continue to use the application independently to supplement their chemistry learning. The mix of gamified elements, straightforward navigation, and curriculum-based content helped to increase user adoption among the target audience. To conclude, the average score of the respondents using the System Usability Scale (SUS) was 78.08 which falls in the acceptable range based on Figure 3 that shows average of SUS Score. Therefore, the application with a gamification approach is acceptable.

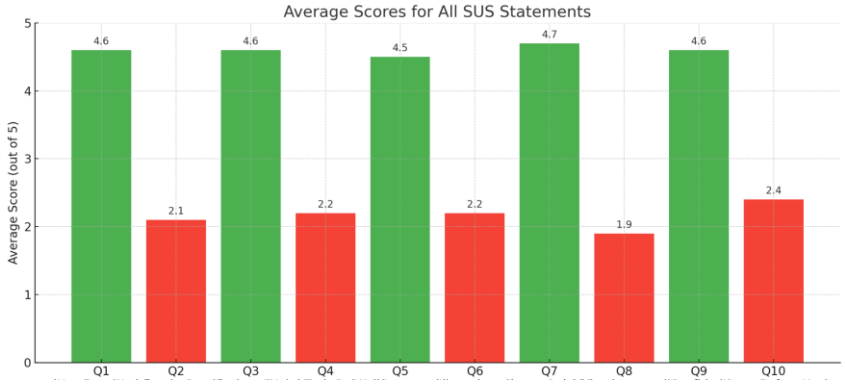

Fig.4 *Graph of average SUS Score*

The graph shows the average scores for all ten System Usability Scale (SUS) statements based on feedback from Form 4 and Form 5 chemistry students. The positive statements (Q1, Q3, Q5, Q7, and Q9) are highlighted in green and achieved high average scores (all greater than 4.5). This demonstrates high user satisfaction in important areas such as simplicity of use, confidence, and system integration. In contrast, the negative assertions (Q2, Q4, Q6, Q8, and Q10), shown in red, scored much lower between 2.0 and 2.4 which is a desired conclusion because more agreement with these items would indicate usability issues. The clear separation between high-scoring positive and low-scoring negative items demonstrates that the program is extremely usable, intuitive, and well-received by its intended audience.

5. Conclusion

In conclusion, Elemental Fusion: Unlocking the Science Lab mobile application was partially developed to support the learning of the Chemistry concepts (Periodic table, Atomic structure, Chemical bonding) among students. Approximately 70% of the intended features were successfully implemented, focusing on simple interactions, colorful visuals, and age-appropriate content to make the application engaging and easy to understand for primary school students. Usability testing was conducted using the System Usability Scale (SUS), with responses collected from the target users. The results indicate that the application is generally usable and well-received, though there is still room for improvement in both functionality and user experience. This project demonstrates the potential

of mobile applications as educational tools for young learners, particularly in promoting environmental awareness. Future work will focus on completing the remaining modules, refining user interface design, enhancing interactivity, and incorporating feedback from usability testing to further improve the learning experience

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design**: Nurul Syahirah Abu Bakar, Muhammad Fakri Othman; **data collection**: Nurul Syahirah Binti Abu Bakar, Muhammad Fakri Othman; **analysis and interpretation of results**: Nurul Syahirah Binti Abu Bakar, Muhammad Fakri Othman; **draft manuscript preparation**:Nurul Syahirah Binti Abu Bakar, Muhammad Fakri Othman; All authors reviewed the results and approved the final version of the manuscript.

Appendix A: Content Structure And Flowchart

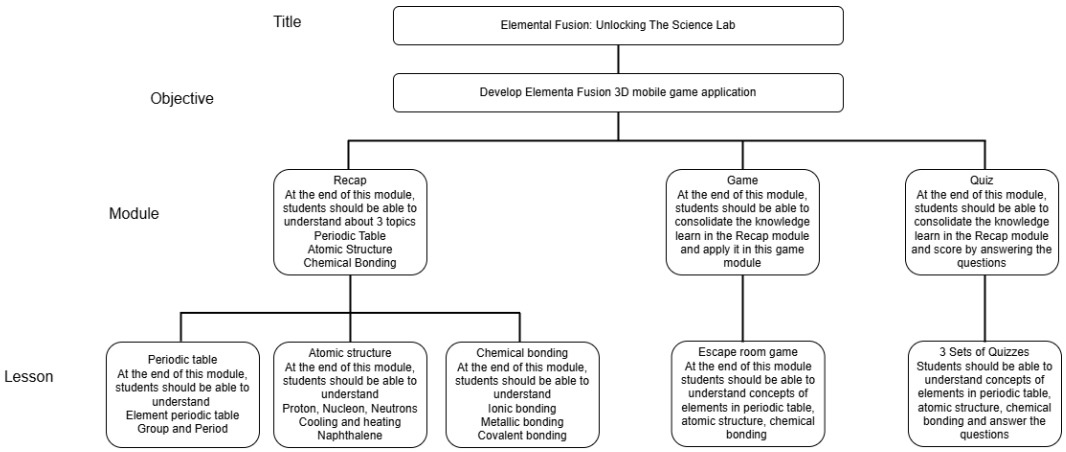

Fig.5 *Content Structure*

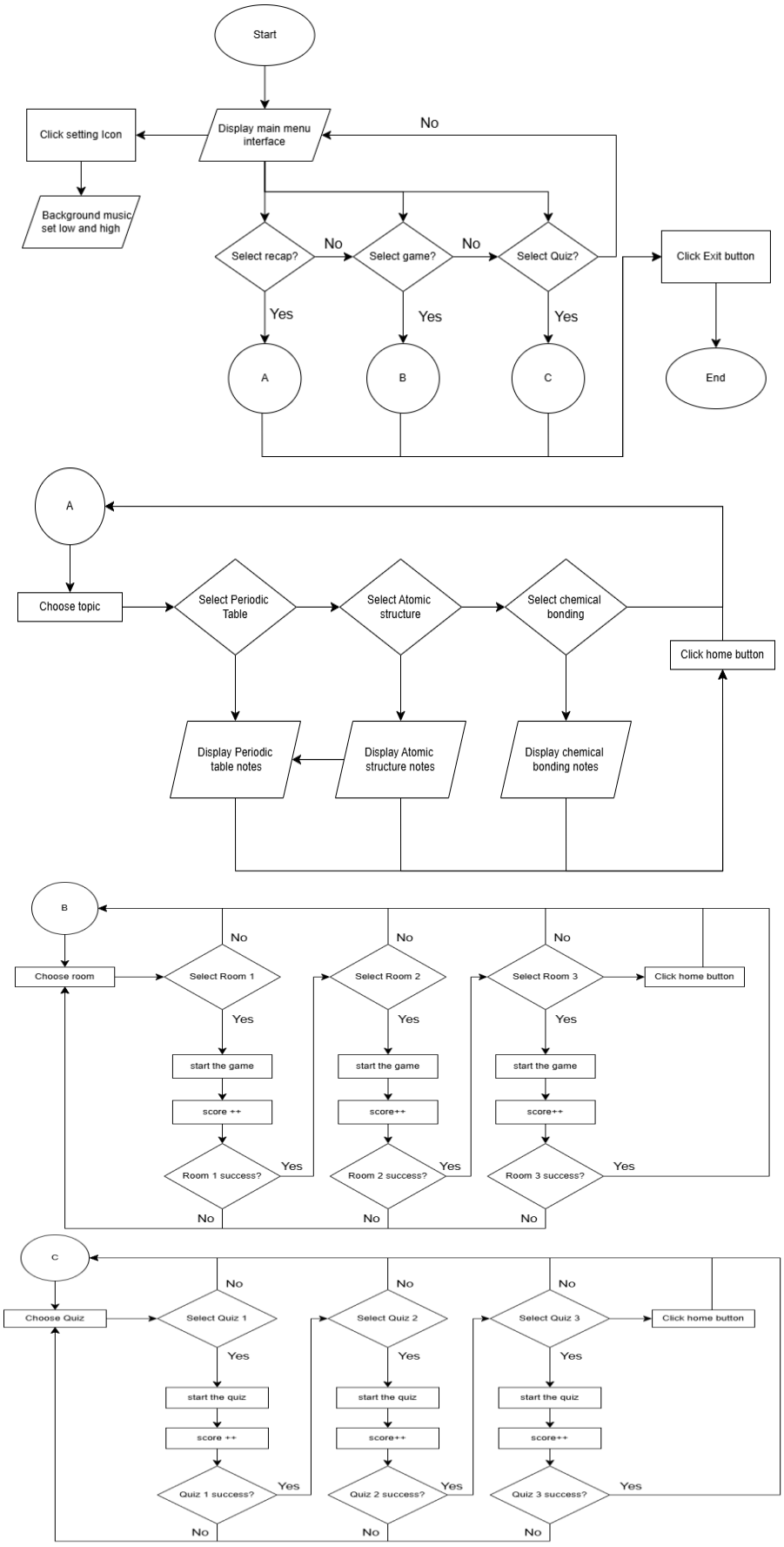

Fig.6 *System Flowchart*

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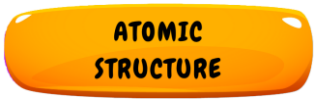
Appendix B : Button design

Table 8 *Button Design*

Button	Description	Button	Description
	"Start" button		"Home" button to return to the main menu
	"Recap" module button		"Setting" button
	"Game" module button		"User manual" button
	"Quiz" module button		"Replay" button
	"Exit" button		"Next" button
	"Periodic table" button		"Back" button
	"Atomic structure" button		"Exit menu" button
	"Chemical bonding" button		"Menu" button
	"Room 1" button		"Quiz 1" button
	"Room 2" button		"Quiz 2" button
	"Room 3" button		"Quiz 3" button

Appendix C

Table 9 *C# Scripting for integration in Unity*

Functions	C# Scripting

Switch scene (switch scene between scene)	using System.Collections;
	using System.Collections.Generic;
	using UnityEngine;
	using UnityEngine.SceneManagement;
	public class SwitchScene : MonoBehaviour
	{
	public void LoadScene(string sceneName)
	{
	SceneManager.LoadScene(sceneName);
	}
	}

First person controller (Game module)	using System.Collections;
	using System.Collections.Generic;
	using UnityEngine;
	public class FirstPersonController : MonoBehaviour
	{
	// References
	[SerializeField] private Transform cameraTransform;
	[SerializeField] private CharacterController characterController;
	// Player settings
	[SerializeField] private float cameraSensitivity;
	[SerializeField] private float moveSpeed;
	[SerializeField] private float moveInputDeadZone;
	[SerializeField] private float gravity = -9.81f;
	//jump detection
	private float verticalVelocity;
	private bool isGrounded;
	// Touch detection
	private int leftFingerId, rightFingerId;
	private float halfScreenWidth;
	// Camera control
	private Vector2 lookInput;
	private float cameraPitch;
	// Player movement
	private Vector2 moveTouchStartPosition;
	private Vector2 moveInput;
	// Start is called before the first frame update
	void Start()
	{
	// id = -1 means the finger is not being tracked
	leftFingerId = -1;
	rightFingerId = -1;
	// only calculate once
	halfScreenWidth = Screen.width / 2;
	// calculate the movement input dead zone
	moveInputDeadZone = Mathf.Pow(Screen.height / moveInputDeadZone, 2);
	}
	// Update is called once per frame
	void Update()
	{
	// Handles input

Table 9: *C# Scripting for integration in Unity (continued)*

```
    GetTouchInput();
    if (rightFingerId != -1)
    {
      LookAround();
    }
    Vector3 move = Vector3.zero;
    if (leftFingerId != -1)
    {
      move = GetMoveDirection();
    }
    // Apply gravity
    isGrounded = characterController.isGrounded;
    if (isGrounded && verticalVelocity < 0)
    {
      verticalVelocity = -2f;
    }
    verticalVelocity += gravity * Time.deltaTime;
    // Combine move direction and gravity
    move.y = verticalVelocity;
    characterController.Move(move * Time.deltaTime);
  }
  Vector3 GetMoveDirection()
  {
    if (moveInput.sqrMagnitude <= moveInputDeadZone)
      return Vector3.zero;
    Vector2 movementDirection = moveInput.normalized * moveSpeed;
    Vector3 move = transform.right * movementDirection.x +
transform.forward * movementDirection.y;
    return move;
  }
  void GetTouchInput()
  {
    // Iterate through all the detected touches
    for (int i = 0; i < Input.touchCount; i++)
    {
      Touch t = Input.GetTouch(i);
      // Check each touch's phase
      switch (t.phase)
      {
        case TouchPhase.Began:
          if (t.position.x < halfScreenWidth && leftFingerId == -1)
          {
            // Start tracking the left finger if it was not previously being
tracked
            leftFingerId = t.fingerId;
            // Set the start position for the movement control finger
            moveTouchStartPosition = t.position;
          }
          else if (t.position.x > halfScreenWidth && rightFingerId == -1)
          {
            // Start tracking the rightfinger if it was not previously being
tracked
            rightFingerId = t.fingerId;
          }
          break;
        case TouchPhase.Ended:
        case TouchPhase.Canceled:
          if (t.fingerId == leftFingerId)
```

Table 9 *C# Scripting for integration in Unity (continued)*

```
            {
                // Stop tracking the left finger
                leftFingerId = -1;
                Debug.Log("Stopped tracking left finger");
            }
            else if (t.fingerId == rightFingerId)
            {
                // Stop tracking the right finger
                rightFingerId = -1;
                Debug.Log("Stopped tracking right finger");
            }
            break;
        case TouchPhase.Moved:
            // Get input for looking around
            if (t.fingerId == rightFingerId)
            {
                lookInput = t.deltaPosition * cameraSensitivity *
Time.deltaTime;
            }
            else if (t.fingerId == leftFingerId)
            {
                // calculating the position delta from the start position
                moveInput = t.position - moveTouchStartPosition;
            }
            break;
        case TouchPhase.Stationary:
            // Set the look input to zero if the finger is still
            if (t.fingerId == rightFingerId)
            {
                lookInput = Vector2.zero;
            }
            break;
      }
    }
  }
  void LookAround()
  {
    // vertical (pitch) rotation
    cameraPitch = Mathf.Clamp(cameraPitch - lookInput.y, -90f, 90f);
    cameraTransform.localRotation = Quaternion.Euler(cameraPitch, 0, 0);
    // horizontal (yaw) rotation
    transform.Rotate(transform.up, lookInput.x);
  }
  void Move()
  {
    // Don't move if the touch delta is shorter than the designated dead
zone
    if (moveInput.sqrMagnitude <= moveInputDeadZone) return;
    // Multiply the normalized direction by the speed
    Vector2 movementDirection = moveInput.normalized * moveSpeed *
Time.deltaTime;
    // Move relatively to the local transform's direction
    characterController.Move(transform.right * movementDirection.x +
transform.forward * movementDirection.y);
  }
}
```

Table 9 *C# Scripting for integration in Unity (continued)*

Simple Quiz manager (Quiz module)	using UnityEngine;
	using UnityEngine.UI;
	using System.Collections.Generic;
	using UnityEngine.SceneManagement;
	using System.Linq; // For shuffling the list
	using TMPro;
	[System.Serializable]
	public class QuizItem
	{
	public Sprite questionImage;
	public Sprite[] answerImages = new Sprite[4];
	public int correctAnswerIndex;
	}
	public class SimpleQuizManager : MonoBehaviour
	{
	public Image questionImage;
	public Button[] answerButtons;
	public GameObject feedbackCorrect;
	public GameObject feedbackWrong;
	public Button nextButton;
	public TMP_Text timerText;
	// UI Text to show countdown
	public List<QuizItem> allQuestions;
	private List<QuizItem> quizQuestions;
	private int currentQuestion = 0;
	private int score = 0;
	private float timePerQuestion = 30f; // seconds
	private float currentTime;
	private bool timerRunning = false;
	private bool questionAnswered = false;
	void Start()
	{
	PlayerPrefs.SetString("CurrentQuiz",
	SceneManager.GetActiveScene().name);
	quizQuestions = allQuestions.OrderBy(q =>
	Random.value).Take(10).ToList();
	nextButton.gameObject.SetActive(false);
	ShowQuestion();
	}
	void Update()
	{
	if (timerRunning)
	{
	currentTime -= Time.deltaTime;
	timerText.text = "Time: " + Mathf.CeilToInt(currentTime).ToString();
	if (currentTime <= 0)
	{
	timerRunning = false;
	if (!questionAnswered)
	{
	TimeUp(); // Auto mark as incorrect if time's up
	}
	}
	}
	}
	void ShowQuestion()
	{
	QuizItem q = quizQuestions[currentQuestion];

Table 9: *C# Scripting for integration in Unity (continued)*

```
        questionImage.sprite = q.questionImage;
        for (int i = 0; i < answerButtons.Length; i++)
        {
            answerButtons[i].interactable = true;
            answerButtons[i].image.sprite = q.answerImages[i];
            int index = i;
            answerButtons[i].onClick.RemoveAllListeners();
            answerButtons[i].onClick.AddListener(() => CheckAnswer(index));
        }
        feedbackCorrect.SetActive(false);
        feedbackWrong.SetActive(false);
        nextButton.gameObject.SetActive(false);
        currentTime = timePerQuestion;
        timerRunning = true;
        questionAnswered = false;
    }
    void CheckAnswer(int index)
    {
        questionAnswered = true;
        timerRunning = false;
        bool isCorrect = index ==
quizQuestions[currentQuestion].correctAnswerIndex;
        if (isCorrect)
        {
            feedbackCorrect.SetActive(true);
            score++;
        }
        else
        {
            feedbackWrong.SetActive(true);
        }
        foreach (Button btn in answerButtons)
            btn.interactable = false;
        nextButton.gameObject.SetActive(true);
    }
    void TimeUp()
    {
        feedbackWrong.SetActive(true);
        foreach (Button btn in answerButtons)
            btn.interactable = false;
        nextButton.gameObject.SetActive(true);
    }
    public void NextQuestion()
    {
        currentQuestion++;
        if (currentQuestion < quizQuestions.Count)
        {
            ShowQuestion();
        }
        else
        {
            QuizScoreManager.score = score;
            QuizScoreManager.totalQuestions = quizQuestions.Count;
            SceneManager.LoadScene("ScoreScene");
        }
    }
}
```

Table 9: *C# Scripting for integration in Unity (continued)*

Persistent Music (Background music loop in background application)	using UnityEngine;
	public class PersistentMusic : MonoBehaviour
	{
	  private void Awake()
	  {
	  // Only allow one instance
	  if (FindObjectsOfType<PersistentMusic>().Length > 1)
	  {
	  Destroy(gameObject); // Destroy duplicates
	  return;
	  }
	  DontDestroyOnLoad(gameObject);
	  }
	}

Score Scene Manager (Score scene for quiz module)	using UnityEngine;
	using UnityEngine.UI;
	using UnityEngine.SceneManagement;
	using TMPro;
	public class ScoreSceneManager : MonoBehaviour
	{
	  public TextMeshProUGUI scoreText;
	  public TextMeshProUGUI unlockMessageText;
	  public Button rightButton;
	  void Start()
	  {
	  int score = PlayerPrefs.GetInt("LastScore", 0);
	  string currentQuiz = PlayerPrefs.GetString("CurrentQuiz", "q1");
	  scoreText.text = "Score: " + score + "/10";
	  // Determine next quiz
	  string nextQuiz = GetNextQuiz(currentQuiz);
	  if (score >= 5)
	  {
	  PlayerPrefs.SetInt(nextQuiz + "_unlocked", 1);
	  unlockMessageText.text = nextQuiz.ToUpper() + " Unlocked!";
	  rightButton.onClick.AddListener(() => {
	SceneManager.LoadScene("quiz"); });
	  }
	  else
	  {
	  unlockMessageText.text = "Score too low. Try again!";
	  rightButton.interactable = false; // Disable right button
	  }
	  }
	  string GetNextQuiz(string currentQuiz)
	  {
	  // Assumes your quizzes are named q1, q2, q3, ...
	  string prefix = currentQuiz.Substring(0, 1); // 'q'
	  int num = int.Parse(currentQuiz.Substring(1));
	  return prefix + (num + 1); // return "q2" if current is "q1"
	  }
	}

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