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DEVELOPMENT OF A GAME-BASED LEARNING: AIRFIELD LIGHTING SYSTEM SIMULATOR USING VIRTUAL REALITY AND AUGMENTED REALITY

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ABSTRACT
This study aimed to develop an innovative learning tool, AIRLIT, as an alternative practical system to enhance the learning of Airfield Lighting System (ALS) among Diploma IV Airport Engineering Technology (DIV-TRBU) cadets. The motivation behind this research stemmed from the necessity to address the challenges faced in ALS practical learning due to limited access to airport facilities. The research methodology is Waterfall Model, encompassing phases: analysis, design, implementation, system testing, and maintenance. User needs were thoroughly analyzed, particularly those of DIV-TRBU cadets, through observations and interviews with subject matter experts. The resulting AIRLIT application offers immersive simulations of ALS operations, including AR recognition of lighting tools/materials and VR visualization of airport layouts. This research succeeded in developing the AIRLIT application, and system testing revealed positive outcomes, with the significant value for pair 1 is 0.000 < 0.05, so there is a difference in the average learning outcomes of cadets for the experimental class pre-test and the experimental class post-test. The significant value of pair 2 is 0.000 < 0.05, so there is a difference in the average learning outcomes of cadets for the control class pre-test and the control class post-test. The Independent sample test shows a difference in cadet learning outcomes between the learning model using AIRLIT and the conventional model, and this result indicates the effectiveness of AIRLIT in improving cadets' learning experiences and outcomes. Overall, this research underscores the significance of incorporating innovative technologies into educational practices, paving the way for enhanced learning experiences and outcomes in airport engineering training programs. The theoretical implication of this study lies in its contribution to integrating AR technology into educational settings, enhancing engagement and experiential learning. Practically, AIRLIT provides a valuable tool for ALS learning, addressing the limitations of traditional practical training methods.
Keywords : *AIRLIT, Virtual Reality, Augmented Reality, Airfield Lighting, Experimental Class*

1. Introduction

Education promotes creativity within national innovation systems and is crucial for sustainable development. The quality of education must keep up with the technological advances brought about by the digital transformation caused by these technologies as developed economies enter the mature stages of the fourth industrial revolution (Shenkoya & Kim, 2023). Digital transformation has become an inseparable part of education (Du Toit & Verhoef, 2018) and it employs a methodical and selected strategy that leads to resource savings by utilizing resources as effectively as possible while avoiding typical budget limits. Digital transformation is used to improve the student experience and accessibility, deliver excellent instructional resources, and offer blended learning to draw enough and upper-class students (Hashim, 2018). In addition, it impacts students' motivation, autonomy in learning, competency, and literacy (Engelbertink et al., 2020). Global phenomena like the development of the internet, information exchange, digitalization, virtualization, and social media have made it necessary for higher education to implement a digital transformation strategy to enhance student experience, particularly education delivery. As a result, going digital has increasingly become a reliable platform to create, cultivate, and maintain competitive advantages. Simulators, in particular, replace unavailable laboratories, as was the case during the COVID-19 epidemic when access to laboratory techniques was restricted (Amalia & Nugraha, 2021). An online simulator aims to facilitate an interactive understanding of abstract or complex subjects by providing compelling images that may be challenging to attain through solely theoretical learning activities.

In contemporary education, integrating emerging technologies has become increasingly prevalent, revolutionizing traditional teaching methods and reshaping learning experiences (Qolamani & Mohammed, 2023). Among these technologies, augmented reality (AR) and virtual reality (VR) have garnered significant attention for their potential to enhance student engagement, facilitate immersive learning environments, and foster deeper conceptual understanding across various disciplines (Shaukat, 2023). Augmented reality (AR) and virtual reality (VR) will also grow in educational media. These technologies can increase students' interest in their studies by making learning more interactive and engaging (Motejlek et al., n.d.; Pelargos et al., n.d.). In many fields, including education, AR and VR are now more feasible and desirable thanks to recent technological advancements and the spread of affordable gear and software. They have also been relaunched with fresh promises that were before unthinkable. Because VR and AR technologies offer immersed multimodal experiences enhanced by many sensory elements, they are an effective tool to improve learning and memory (Papanastasiou et al., 2019). The use of VR in education, as mentioned by (Saab et al., 2021) suggests that virtual reality technology can enhance present educational methods and facilitate learning. According to research by (Zamar & Segura, 2020), there has been an increase in interest in studying how virtual reality used in higher education, particularly over the past three years. Approximately 80% of students are more likely to attend an AR-based class, according to (Khan et al., 2019), about 72% of them are eager to participate, and 70% said the AR-enhanced their learning and sped up the process of understanding the material. AR-based learning increases student interest by making the learning experience enjoyable and welcoming. According to a current study by ARtillery Intelligence, by 2023, there will be 2.4 billion mobile augmented reality users worldwide, and the market will grow to $72.7 billion by 2024. The sharp increase is evident when you consider that there were only 200 million users in 2015. It is increasing not only its influence in the entertainment business but also in the educational industry.

An issue to raise that Airfield Lighting System (ALS) as one of the competencies that must be mastered by Diploma IV Airport Engineering Technology (DIV-TRBU) cadets, aiming to ensure their understanding and ability to explain lighting system settings in airport airside. However, the challenge lies in the fact that the total mandatory practical activities in this course reach 70% of the total learning hours, where practical sessions usually rely on field trips to airports, which are carried out only once or for eight hours in one semester, which is not enough to meet the requirements. percentage of required practical activities. Apart from that, in the DIV-TRBU program itself, currently there are no laboratory facilities available that support learning about airfield lighting systems, in contrast to conditions at airports which greatly affect the increase in cadets' knowledge because they can only carry out practicums at predetermined hours. Even though it is one of the main competency courses, ALS currently does not have a laboratory to use, which hinders a comprehensive learning experience. As stated in the learning plan document, the final achievement of the subject is to explain the characteristics and categories of airfield lighting systems. To overcome this gap, digital-based learning that utilizes various media capabilities and encourages active learning methods such as independent observation, creation, demonstration, and evaluation is essential. AIRLIT allows cadets to practice what lecturers have given in theory independently, create creativity through independent learning, build cadets' self-confidence in a fun independent learning atmosphere, and instantly present learning evaluation results to lecturers.

This research aims to 1) give an alternative practical system to accommodate the ALS course, 2) build an Airfield Lighting System (AIRLIT) application, an online simulator made with Unity 3D Game Developer and developed with the convenience of Unity 3D game development for VR or AR environments (Kim et al. 2021), 3) conduct an experiment class and functional suitability testing using ISO standard 25010 by expertise in media and ALS.

By developing and implementing AIRLIT, we allow students to learn about the lighting system on a runway by visiting an airport that digitally replicates it through VR. The application of AR allows students to observe and study the structure of each airfield lighting system. In addition, these technologies can also assist students and lecturers in dealing with complex learning problems. The benefit of this research is the availability of online simulator products for Airfield Lighting System learning, which presents simulations with VR and AR accompanied by learning support menus such as digital teaching materials. This product is accessible to all cadets, and we hope it can help cadets achieve learning outcomes in their studies. This product is used in visual aids for navigation courses that comply. The product is developed on Android and Windows Systems, designed with a self-built programming architecture considering course learning plans and outcomes.

In the learning of visual aids for navigation, previous research found that there was a development of learning media application. Fajar in 2019 designs for visual studio-based landing aid facilities. Luwihono in 2019 designs to determine the layout and circuit configuration on the airside of the airport, and also in designs for monitoring computer-based airside lighting systems (Zhang et al., 2010). Literature research by (Cevikbas et al., 2023) showed the positive impact of AR/VR in learning mathematics, especially in geometry. Apart from that, there is research that analyses and reviews the latest trends in the application of Augmented Reality in the education sector (Gomez & Medina, 2023; Perifanou et al., 2023) and the application of AR and Virtual Reality (VR) in the health sector to improve the skills of health workers (Gasteiger et al., 2022). Also, some studies focus on applying medical image visualization using AR and VR, considered a breakthrough for medical professionals (Izard et al., 2020). Research was also found regarding immersive implementation using AR architecture on 5G networks (Morin et al., 2022). (Davis et al., 2022) recommend Unity 3D in building AR/VR games due to its familiar interface, code, and realistic image results. However, researchers have not found an airfield lighting system learning media product that presents VR and AR from AFL facilities built using the Unity game developer application and the Vuforia Software Development Kit (SDK) to create Augmented Reality (AR) and sketch up for 3-dimensional model graphic design and 3ds MAX to animate the graphic.

We found other research results related to the use of AR and VR in learning contexts, such as designing virtual geometric model prototypes in mathematics learning using augmented reality (Syafril et al., 2021), as well as research related to integrated augmented reality learning to increase knowledge of Covid-19 prevention in the post-pandemic (Putra et al., 2022). Other research we discovered includes the application of multimedia design principles in augmented reality learning environments (Krüger & Bodemer, 2022), as well as the use of virtual and augmented reality technology in the design of modern library media spaces (Horban et al., 2023). Moreover, we also found two exciting studies it is research on the development of augmented reality-assisted learning media to improve understanding of concepts on the topic of physics concepts (Silfiani et al., 2022), as well as research on improving geometric thinking skills through augmented reality-based learning media (Widyasari & Mastura, 2020).

(Edl et al., 2022; Morales et al., 2022; Poonja et al., 2023) develop an learning media with only AR-based using Unity 3D. (Fotia & Barrile, 2023) develop AR and VR applications using geomatics and survey method. (Masud et al., 2023) discusses the development methodology within the Unity 3D framework, focusing on continuous testing methodologies and Python API integration, but we in AIRLIT utilizes the Waterfall Model for software development, emphasizing phases such as analysis, design, implementation, system testing, and maintenance. Based on these previous studies, we believe that integrating AR and VR in ALS learning can increase cadets' interest and quality of learning.

2. Literature Review

Since the 1990s, virtual reality has developed for about 30 years, although access has been limited due to high equipment costs. Research by (Segarra et al., 2022) conducted a bibliometric analysis of 1074 articles on using virtual reality in education from 1990 to early 2021. In their research, (Bower et al., 2014) noted the benefits of letting students create augmented reality (AR) experiences to enhance higher-order thinking skills with a case study of "learning by design" in middle school visual arts. (Hanid et al., 2020) conducted a meta-analysis showing that the most common AR teaching methods are experiential, collaborative, game-based, and interactive learning. AR technology allows users to interact with virtual objects inserted into real environments in real time. Advances in virtual reality (VR) technology make learning more realistic, increasing mobility and physical and sensory interactions, as stated by (An et al., 2020).

With virtual reality (VR) and augmented reality (AR) technologies, learning can be expanded by placing students in a realistic three-dimensional world, enabling them to learn independently and generate output after engaging with 3D learning materials and gaining real-world experiences. For example, Google Expeditions (VR) is a VR-based learning program that allows teachers to take students on virtual tours to exotic and historical locations worldwide, (Cardullo & Wang, 2022; Ebadi & Ebadijalal, 2022; Parmaxi et al., 2021). Additionally, zSpace (AR) is an AR device used in education, allowing students to visualize objects immersively (Aljumaiah & Kotb, 2021; Yu et al., 2024; Zhou et al., 2022), such as visualizing natural science concepts about tornado phenomena. Wonderscope (AR) is an AR application designed specifically for children, combining interactive stories with AR elements to enable interaction with characters in the story and visual understanding of complex concepts. (Yi et al., 2022) use it to perform distinct surfaces of different materials in a museum show. Both AR and VR are digital learning technologies that utilize the full capabilities of media and encourage students to learn through various activities, showing potential to enhance the quality of learning (Vijay et al., 2019).

However, integrating AR and VR into ALS learning presents several challenges. These include difficulties in AR development, such as marker adaptation in different environments, application performance influenced by model complexity and device strength, and compatibility issues with various devices, particularly Vuforia (Chaudhary et al., 2023). Additionally, concerns concern accurate camera calibration and seamless integration between UI elements and AR experiences. Thorough testing, model, texture optimization, marker selection, and adherence to official guidelines help overcome these challenges. In VR development using Unity, challenges include application performance disruptions due to VR environment complexity and ensuring user comfort to prevent discomfort (Jangra et al., 2023). Thorough testing, immersive technology like teleportation, and careful adjustments to hardware integration and interface design address these challenges effectively.

(Cheliotis, 2021) since game engines frequently support 3-D graphics and offer a programming back-end for coding model logic, they are a viable candidate platform for creating many systems of interest that might greatly benefit from being emulated in three dimensions. (Wang & Zeng, 2019) mentioned that to address the issues of poor stability and constrained application conditions in conventional AR, Unity 3D software is used in conjunction with Vuforia SDK and EasyAR SDK to create AR (Software Development Kit) (Chaudhary et al., 2023). The findings can be used with Hololens AR glasses and mobile devices.

The execution of AIRLIT in Unity3D involves a list of plans for how AIRLIT will be. It is about the limitations of the AIRLIT scope, the system's flow, the interface design, the airport 3D design, and the figure of each lighting system. We also designed a figure for each lighting system using SketchUp software. AIRLIT was designed to be an effective learning tool that can assist in understanding the Airfield Lighting System (ALS). This application replicates existing ALS systems at airports by using technology that allows users to experience experiences similar to field situations without needing to be physically at that location. By using augmented reality (AR) and virtual reality (VR) features, users can directly interact with various ALS components such as runway lights, taxiway lights, and PAPI (Precision Approach Path Indicator). In addition, AIRLIT also comes with additional learning materials and maintenance guides to increase user understanding of ALS. Feedback from cadets who have used AIRLIT shows that their learning experience has improved significantly as the app combines learning and play elements, making learning more educational and fun. They also felt more involved in the learning process and were able to understand ALS concepts better through the interactive experiences provided by AIRLIT. In this way, AIRLIT is an effective ALS learning tool that provides users with a more enjoyable and immersive learning experience.

3. Research Methods

This research aims to develop a mobile application for the Airfield Lighting System (ALS) course using Unity 3D which fits the context and objectives set. To ensure that quality standards for information system development are achieved, this study adopts a linear sequential approach known as the waterfall model (Saravanos & Curinga, 2023).

Fig 1. Waterfall Model

The purpose of this AIRLIT development is to produce products that are prepared for use in learning activities that are ready for use in classroom activities, and we limit this research to the 4th step, called system testing. This research focuses on developing the Airfield Lighting System (AIRLIT) application learning media software in Android and Windows for DIV-TRBU cadets of 1st and 2nd grade.

In the first stage, we analyze user needs, taking a sample test of 24 cadets (1 class) in the second grade in DIV-TRBU. In this stage, observations are made of the lesson plan document and the teaching and learning process. ALS is one of the core competency courses, but it presently lacks a lab for use, which makes it difficult to provide a thorough learning environment. The explanation of the traits and classifications of airport lighting systems is the subject's ultimate accomplishment, as indicated in the learning plan document. Digital-based learning is crucial to closing this gap because it makes use of a variety of media capabilities and promotes active learning strategies like self-directed creation, observation, demonstration, and assessment.

The second stage is the design. This step consists of instruments that describe data flow and system involvement in an information system. The Use Case Diagram and flowchart of AIRLIT are built in this stage. It is determining the use of Unity3D as a platform for developing AIRLIT, selecting the airport that will be used as a 3D mockup, and determining category I ALS, 3D Light Images, etc., regarding the overall material presented in AIRLIT.

The third stage is implementation, which is Android-based media development. The created application design is implemented into a program and then made into an Android-based application. It is easy for personnel to use under any circumstances. The runway mockups are Juwata Airport-Tarakan Aerodrome, taken from Google Earth and converted to 3dsmax format to help visualize ideas. We utilize the Sketchup program to create the graphical representations of each lighting system.

The fourth stage, system testing, is carried out to test the effect of implementing AIRLIT as a learning media. Two kinds of tests are carried out: experiment test and functional suitability. The experiment test is carried out using a pre-test and post-test. Two groups of cadets are divided for the experiment. Twenty junior cadets who have not yet accepted ALS content at their class level make up the second group. The first group consists of 24 senior cadets who have already accepted ALS material in their class, which we have dubbed a controlled class. It has the moniker "experiment class". Pre- and post-tests were administered to all cadets concerning the ALS material, and we then put together the results to undertake a classic assumption test analysis, which includes the tests for normality, paired sample tests, and homogeneity of variance. We also conducted an independent samples test to check the validity of the hypothesis. The classic assumption test and hypothesis test are then processed in SPSS. As a result of the test, we discovered that the cadets in the experimental class using AIRLIT had made substantial progress.

Functional suitability aspect testing was adopted from the ISO/IEC 25010 standard (Mulyawan et al. 2021). ISO 25010 is an international standard used to evaluate the quality of software and systems, also known as the SQuaRE (Systems and Software Quality Requirements and Evaluation) model, which has undergone three essential updates in 2007, 2011, and 2017.

Although there is a specific model for evaluating a specific software product, most software quality models are general and can be applied to all software products. Therefore, this study adapts ISO 25010 to assess the quality of application usage systems. The functional suitability testing conducted to the material expert and media expert. The material expert assessment uses a questionnaire consisting of content quality, purpose, and learning quality, whereas each aspect represents six indicators. For the media expert assessment, we have 12 question that defines the accessibility of each page of AIRLIT, such as the open page, main menu page, play page, material page, guidance page, cadets evaluation, reference page, quit button, compatibility on various device how the program is easy to operate, there does not have to be a specialist/expert in its operation, useable, sound effect, layout design, typography, and colors.

The data collection in this research uses questionnaires (Sugiyono, 2013) for media testing and material testing. The material experts are the lecturer who teach airfield lighting system material, and the media expert is a professional software developer. Expert respondents performed functional appropriateness testing on test cases incorporating application functions based on needs analysis using a checklist technique. The outcomes of the feasibility validation of AIRLIT's learning media are some recommendations that can be used to enhance AIRLIT quality. To determine which features of the learning media are compelling and which are not, this test is conducted using a customized questionnaire. Functional appropriateness for media professionals contains the two sub-characteristics of suitability and accuracy. The word "suitability" refers to the question of whether the program is capable of carrying out the necessary duties. The accuracy sub-characteristics require that the results match the initially predicted goals. This instrument assesses the information in learning media and checks its usability and can be accomplished by knowing which functions are active and which are not (errors). The X value will be calculated from the formula and used as the test result. The data obtained from each instrument will be calculated as an average using a formula, $\bar{x} = \sum x/n$, where $\bar{x}$ = average score, x = total item score, n = the number of items. In the descriptive section that follows, the conclusion, value conversion is discussed by converting the quantitative data to qualitative data. The score-to-value conversion table is shown below:

Table 1 – Conversion Table

Interval Score	Grade	Category
$X > Mi + 1{,}8\ SBi$	A	Excellent
$Mi + 0{,}6\ SBi < X \leq Mi + 1{,}8\ SBi$	B	Good
$Mi - 0{,}6\ SBi < X \leq Mi + 0{,}6\ SBi$	C	Fair
$Mi - 1{,}8\ SBi < X \leq Mi - 0{,}6\ SBi$	D	Poor
$X \leq Mi - 1{,}8\ SBi$	E	Very Poor

X = actual score (empiric), Mi = ideal mean, calculate with the formulas: Mi = ½ (ideal maximum score + ideal minimal score), Sbi = ideal standard deviation, determined by the formula: Sbi = 1/6 (ideal maximum score - ideal minimal score).

For media experts, the ideal maximum score is 1, so that the Mi and Sbi values are obtained as follows: Mi = ½ (1+0) = 0.5 Sbi = 1/6 (1-0) = 0.167. Because the material aspect uses a scale of 5, the calculation of Mi and SBi is as follows, MI = ½ (5+1) = 3, and SBi = 1/6 (5-1) = 0.67. The analysis technique used in the functionality aspect is descriptive analysis using the following calculations from (Sari, 2016):

$$\text{Value X} = \frac{\textit{Score obtained}}{\textit{Expected score}} \times 100\%$$

4. Results and Discussions

Use case diagrams are always helpful for large and complex projects so developers can readily comprehend the system's needs. Use case diagrams are always helpful for large and complex projects so that developers can readily comprehend the system's needs. The use case diagram represents some interactions between the components in the AIRLIT introduced by the developed system. Actor/user can access the main menu which consists of five menus: *airlit play, airlit material, airlit guidance, cadet evaluation, and airlit reference.*

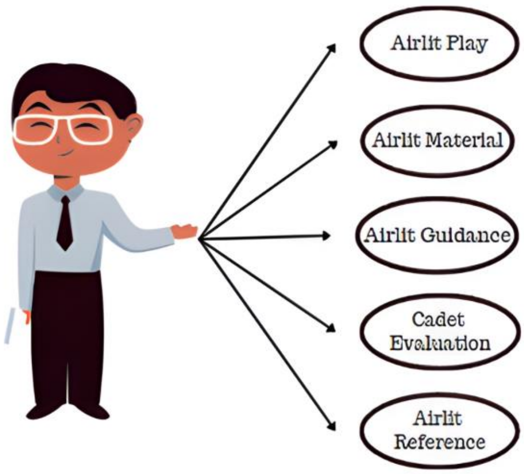
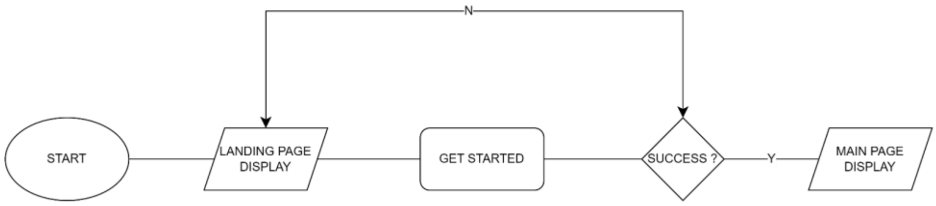


Fig 2. Use Case Diagram of AIRLIT

From the use case diagram, we determined it to be a workflow diagram that shows the system's activity as a series of actions. At the first-time, users will find an initial interface that displays the AIRLIT logo created by researchers, on a yellow background. There is also a "GET STARTED" button that redirects users to the next page. On this page, users will be greeted with a dominating purple gradient. The color purple is often associated with luxury and high quality, reflecting the expectation that the learning experience presented in this application will be of a high standard.

a)

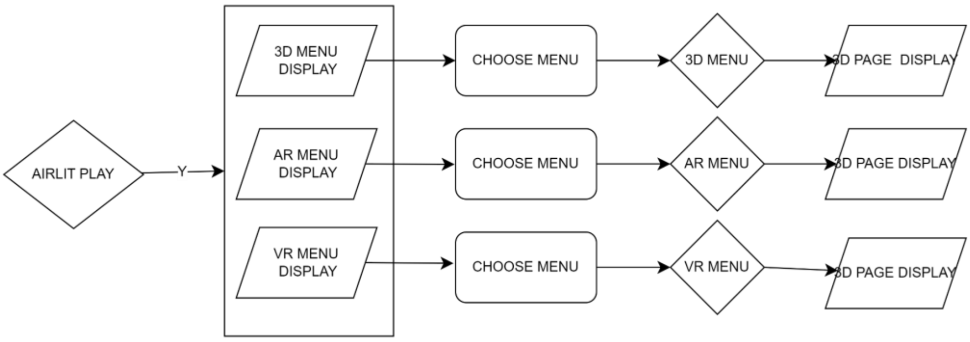


b)

Fig 3. *Landing Page* Diagram and Interface

The next page will show whole menu Access diagram *Airlit Play* offers the user an access 3 main menu 3D floor plan, Augmented Reality, Virtual Reality. The background of this page displays an image of a plane landing at night, intending to allow users to feel the atmosphere of the Airside area at the airport, which is surrounded by beautiful runway lighting system lights and can be seen clearly at night.

a)

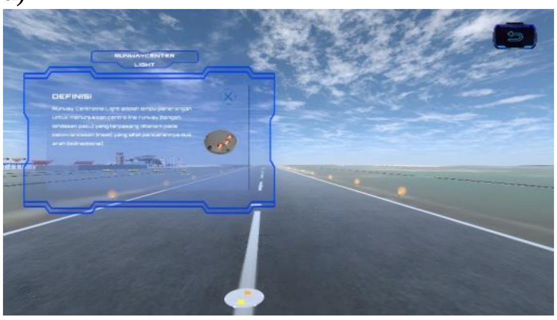


b)

Fig 4. *Airlit Play* Diagram and Interface

Airlit play is the main menu of AIRLIT. In airlit play we can find the AR and VR simulators, AR recognizes an image and displays the lighting tools/material, VR of the airport area, which reveals the true position of each lighting system, and 3D floor plan. Students can examine surfaces in an augmented reality environment using webcam devices like smartphones, tablets, or notebook computers from various angles thanks to developed settings. When a user clicks on a lighting system graphic in the mockup, an explanation appears, allowing for a thorough examination of each lighting system which can be seen in Figure 5 part c).

a) b)

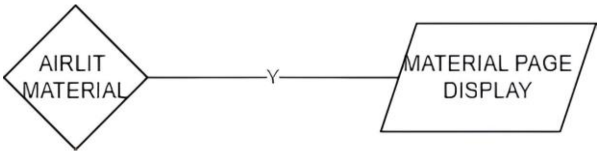


c) d)

Fig 5. VR and AR Display

Go to the next page, it is *airlit material* that contains technical informations and maintenance procedure related to each ALS that can help increase user insight regarding ALS.

a)

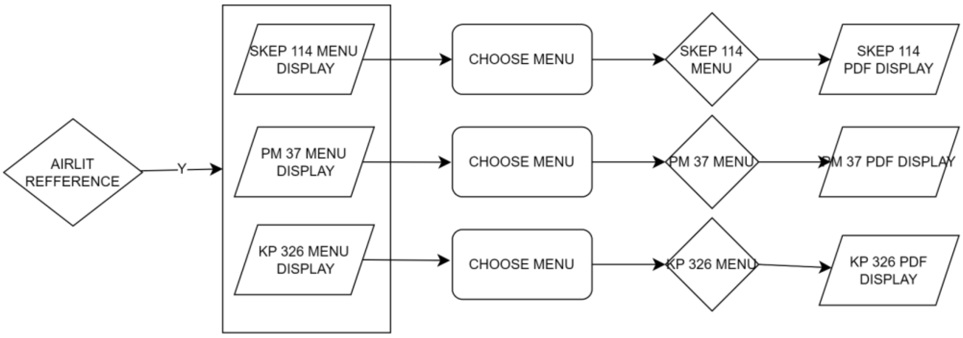


b)

Fig 6. *Airlit Material* Diagram and Interface

Airlit Reference, that contain Indonesia regulations to implementation of Airfield Lighting System.

a)



b)

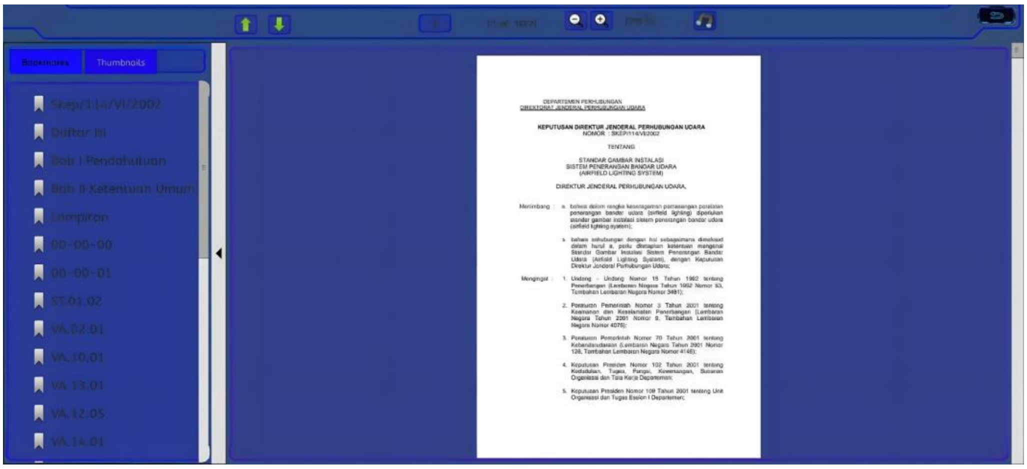
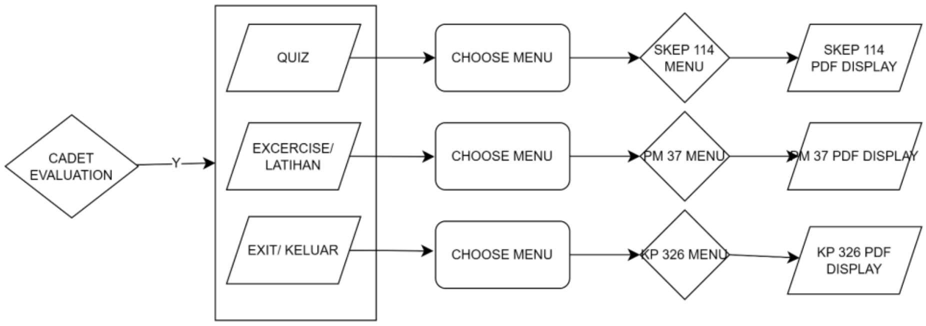


Fig 7. *Airlit Reference* Diagram and Interface

Cadets Evaluation contain quiz and exercise to measure the learning result, this menu also linked to quizziz. Additionally, AIRLIT has a guide menu with instructions to help users use it. There is a "back" button in the top right corner of every page in AIRLIT. A thumbnail with "yes" and "no" will show up once the user clicks the back button to ask if they want to exit the page.

a)



b)

Fig 8. *Cadet Evaluation* Diagram and Interface

In AIRLIT, apart from purple, blue also dominates. The color blue was chosen because it symbolizes seriousness and professionalism in aviation education, like the vast blue sky above. Bar menu is designed to provide easy accessibility and navigation for users by providing well-organized options, allowing users to quickly find and use various features and commands within the application. The rectangular shape of the menu bar was chosen to ensure simplicity, precision and blunt angles, following the current style so as not to be too stiff. The placement and size of the bars and pop-up menus are also designed to make it easier for users to see visual elements in the application, with a large enough size and strategic placement to make it easier for users to read and see points in the application.

AIRLIT System Testing

Using a pre-test and post-test, the experiment test is conducted. The cadets are split into two groups for the experiment. The 1st group is made up of twenty junior cadets who haven't yet agreed to the ALS content for their class level. The 2nd group is made up of 24 senior cadets who have already accepted ALS content in their class—which we have labeled a controlled class—and who make up the first group. "Experiment class" is the name given to it.

Table 2 – Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Experiment Pre-test	20	45	85	63.00	10.052
Experiment Post-test	20	60	100	79.25	9.904
Control pre-test	20	60	90	74.50	7.416
Control post-test	20	70	100	88.25	10.422

Valid N (listwise)	20

As we see on the table below, the minimum score of pre-test in experiment class is 45 and maximum score 85, the post-test show a significance change with minimum score 60 and maximum 100. In the control class, that has accepted ALS on their level, have a 60 minimum in score for the pre-test, and 90 in maximum. Post-test control have a minimum score 70 and maximum 100.

Tests of Normality

The choice of central tendency measures and statistical data analysis techniques depends on the results of this test. Parametric tests are employed when our data have a normal distribution; otherwise, nonparametric approaches are utilized to compare the groups (Mishra et al., 2019). The result using Kolmogrov-smirnov can be seen in next table. The data is normally distributed with a significant value of 0.200; 0.088; 0.101; 0.313 > 0.05.

Table 3 – Tests of Normality

		Kolmogorov-Smirnov[a]		
	Class	Statistic	df	Sig.
Result	Experiment Pre-test	.157	20	.200*
	Experiment Post-test	.180	20	.088
	Control pre-test	.177	20	.101
	Control post-test	.170	20	.131

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Paired samples test

(Frey, 2023) The mean of a single group studied at two separate times is compared using a paired-samples t-test, which examines the means of two matched groups of individuals or cases. A repeated measures t-test is what the t-test is known as when the same group is tested on the same measure twice. The data is taken to be interval for nominal groups, much like with the independent-samples t-test. The significant value for pair 1 is 0.000 < 0.05, so there is a difference in the average learning outcomes of cadets for the experimental class pre-test and the experimental class post-test. The significant value of pair 2 is 0.000 < 0.05, so there is a difference in the average learning outcomes of cadets for the control class pre-test and the control class post-test as see below.

Table 4 – Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Experiment pre test - post test	-16.250	11.907	2.662	-21.823	-10.677	-6.103	19	.000
Pair 2	Control pre-test - post test	-13.750	11.684	2.613	-19.218	-8.282	-5.263	19	.000

Test of Homogeneity of Variance

Homogeneity of variance Compare two variants. The mean of the variable under study is frequently not systematically affected by a condition or treatment, but individual subject variability in responses may be greater for one treatment than another, leading to increased variance. Or, more broadly, if two measurements of the same quantity have about the same means, but one has a significantly higher error variance than the other. The significant value is based on mean: 0.391 > 0.05, so it can be concluded that the variance of the experimental class post-test data and the control class post-test data is homogeneous, the result can be shown at the table.

Table 5 - Test of Homogeneity of Variance

Test of Homogeneity of Variance					
		Levene Statistic	df1	df2	Sig.
Result	Based on Mean	1.015	3	76	.391
	Based on Median	.851	3	76	.470
	Based on Median and with adjusted df	.851	3	72.764	.470
	Based on trimmed mean	.997	3	76	.399

Independent Samples Test

(Gerald, 2018) In their research, the t test for independent samples compares the means of two unrelated or independent groups. In other words, we assess if the means of two independent groups differ significantly from one another. The between-groups design, often known as the independent-sample t-test, can be used to examine both a control and an experimental group.

Table 6 - Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Result	Equal variances assumed	.151	.700	-5.150	38	.000	-16.250	3.156	-22.638	-9.862
	Equal variances not assumed			-5.150	37.992	.000	-16.250	3.156	-22.638	-9.862

H_0 = there is no difference in cadet learning outcomes between the learning model using AIRLIT and the conventional model.
H_a = there is a difference in cadet learning outcomes between the learning model using AIRLIT and the conventional model.
The significant value of equal variances assumed is 0.000 < 0.05, then H_0 is rejected and H_a is accepted, so the positive value indicates the positive impact.

Functional Suitability Testing

The material expert assessment uses a questionnaire consisting of content quality, purpose, and learning quality, whereas each aspect represents six indicators. These functional suitability aspects and measurements adopt the standards of ISO/IEC 25010 (Mulyawan et al., 2021). For the media expert assessment, we have 12 question that defines the accessibility of each page of AIRLIT, such as the *open page, main menu page, play page, material page, guidance page, cadets evaluation, reference page, quit button, compatibility on various device how the program is easy to operate, there does not have to be a specialist/expert in its operation, useable, sound effect, layout design, typography, and colors.* Based on the conversion of the value, the data findings transform into the Expert Spec Value Conversion Table.

Table 7 – Functional Suitability Analysis Results

No	Validator	Percentage	Criteria
1	Material Content Aspect	86%	Very Good

2	Material Learning Aspect	82%	Good
3	Media Aspect	96%	Very Good

Based on these results, it can be concluded that all functionality in the AIRLIT learning media application is included in the Very Good criteria for media aspects, Very Good for the content aspect, and Good in the learning aspect, with the results are similar (Sari, 2016). In the test of Homogeneity of Variance, the significant value is based on mean: 0.391 > 0.05, so it can be concluded that the variance of the experimental class post-test data and the control class post-test data is homogeneous. The findings from (Sritan & Phuenaree, 2021) research indicate that Levene's test has evolved into the best test for highly skewed distributions. In the independent sample t-test, the significant value of equal variances assumed is 0.000 < 0.05, then H_0 is rejected, and H_a is accepted. According to research by (Banuwa et al., 2021), this result can be concluded as a good result.

(Morales et al., 2022) In their research discusses the development of the augmented reality prototype and its potential to improve education for university students. At the same time, AIRLIT evaluates the impact of the AIRLIT application on cadets' learning outcomes compared to a conventional learning model, demonstrating a difference in learning outcomes between the two groups. Both of these studies use the waterfall model as a method. Research by (Masud et al., 2023) focuses on the development of a sophisticated data visualization system using AR and VR technologies to enhance data exploration and presentation, while our research focuses on building an AR and VR application called AIRLIT, which serves as a visual aid for navigation in the context of the Airfield Lighting System (ALS) for electrical competition. (Edl et al., 2022) evaluates the competencies required for creating AR environments and outlines further research directions, while in AIRLIT, we evaluate the impact of the AR and VR-based on learning outcomes, demonstrating its effectiveness through statistical analysis. (Fotia & Barrile, 2023) In their study discusses experimentation on a viaduct in Reggio Calabria to test the proposed methodology. Still, in our study, we evaluate the AIRLIT application's effectiveness through pre and post-tests in an experimental class setting. (Poonja et al., 2023) It is similar to our study, in which they developed an AR-based app using Unity3D and assessed the developed applications' effectiveness through user studies or experimental class settings. Still, in our study, we developed AIRLIT with both AR and VR. The application focuses on STEM education and uses Haptics to enhance student engagement, while the AIRLIT application focuses on providing visual aids for navigation in the context of electrical competency.

Our research shows that AIRLIT is accessible to cadets and improves learning outcomes. Based on the recommendations, the discussion analyzes the suitability of content functions, learning, and media aspects. It also shows that AIRLIT is helpful in ALS learning and explains how these results align with the research objectives and contribute to the usability and quality of the AIRLIT application. In the development of AIRLIT, we used AR and VR to provide the complete experience for the aim of Airfield lighting system learning. Using the waterfall model as a research methodologist, we chose Unity 3D as the software developer.

5. Conclusion

This research successfully built an alternative practical system in an online simulator for Airfield Lighting System learning that aligns with the learning lesson plan, AIRLIT, which presents simulations with VR and AR build in Unity 3D game developer and uses a waterfall model as a research method. AIRLIT uses visual aids for navigation courses that comply with and are developed on Android and Windows Systems. AIRLIT is accompanied by learning support menus such as digital teaching materials that comply with lesson plans. This product is accessible to all cadets, and we hope it can help cadets achieve learning outcomes in their studies. An experimental test using pre and post-tests was conducted to learn the effect of AIRLIT on the cadets. The results show a good response and result that approves the implementation of AIRLIT as a learning media. The result of functional suitability testing conducted, with media and material experts as a contributor, the analysis shows excellent results for each aspect. At this time, AIRLIT is still in the system testing steps, so we hope to continue this research until comprehensive implementation. We also continue to improve. In the future, we will continue to add an ALS category to Category 1, 2, and 3 and plan to adjust learning plans to the industry needs. So, in the future, we will continue to do further reviews so that this application can develop and better match the needs of cadets and the industry.

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