Analysis of Computational Thinking Skill Through Technology Acceptance Model Approach Using Augmented Reality in Electronics Engineering Education

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Abstract **– Technological progress has brought about modifications in the educational process. This transformation has led to numerous technological innovations for supporting student learning, with smartphones being one of the prominent tools. Despite the widespread use, students have primarily used smartphones for online gaming and social media, leading to a decline in the effectiveness for educational purposes. Therefore, this study aimed to explore how students in electronics engineering education responded to a novel technology, augmented reality (AR), when integrated into the fundamental learning process, in order to maximize the utility of smartphones. A cross-sectional survey approach with a quantitative methodology comprising 101 students in the field of electronics engineering education in higher education institutions in Indonesia was adopted.**

Data were collected through a questionnaire, which was subsequently analyzed using the Structural Equation Model (SEM) method with SmartPLS 3 software. Additionally, this study used Fuzzy C-Means (FCM) clustering method to examine the influence of each cluster values on the others. The analytical results showed that Computational Thinking Skill (CTS) of students significantly impacted Actual System Use (ASU) of AR. Furthermore, perceived usefulness (PU) and perceived ease of use (PEU) of this technology played crucial roles as mediators in ASU of AR.

Keywords **– Computational thinking skill, technology acceptance model, augmented reality, structural equation model, fuzzy c-means clustering.**

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1. Introduction

Advancements in technology have induced transformative changes within the realm of education [1]. In the current era, technology holds a critical position in the field of education, necessitating a shift in mindset to recognize the importance of blending traditional methods with technology [2]. This is evidenced by the widespread use of electronic devices to support student learning, including computers, laptops, smartphones, and other similar tools.

An example of this integration comprises the development of instructional media designed to improve problem-solving skill among students [3]. Technological innovation becomes important for effectively packaging the learning process in line with the demand for students to acquire problem-solving skill, including computational thinking skill (CTS). Proficiency in problem-solving serves as an indicator of high-level computational thinking skill in students. Additionally, opportunities for socio-cultural learning should be adopted to develop adaptive thinking and social skills, reflecting the real world and preparing individuals for future workplaces [4], [5].

Engineering education is expected to provide students with the essential skill necessary to navigate changing conditions, eventually promoting the development of reliable professional competencies.

Access to various learning technologies, such as computers, laptops, and smartphones, is available to students [6], [7]. In some schools, permission is granted for the use of smartphones in productive learning activities. However, the majority of students tend to use this technology for online gaming and interaction on social media platforms, such as Mobile Legends, Higgs Domino, TikTok, Instagram, etc. This misuse leads to disruptions in study time and negatively affects comprehension of the learning materials. Since the integration of technology becomes crucial for improving student engagement in the learning process [8], [9] teachers are expected to make effort in achieving this goal [10], [11]. Typically, every teacher is expected to have the skill to create media that stimulates student engagement while maintaining consistency with the needs and relevance of the learning materials.

In this study, augmented reality (AR) technology was implemented in basic electronics learning for students pursuing electronics engineering education, with the aid of smartphones. AR is one of the innovative technologies stemming from widespread smartphone usage. The success of using the technology depends on the acceptance and proficiency of students. The evaluation of technology performance in education is essential for upholding standards in the learning environment. Therefore, this study was conducted to analyze how easily students can adopt the use of AR, considering the factors explained in the Technology Acceptance Model (TAM).

1.1. Literature Review-Computational Thinking Skill

Computational thinking skill comprises the application of key concepts from cognitive psychology, metacognition, and problem-solving tendencies as a thinking approach. There are four distinct indicators of students possessing computational thinking skill, namely decomposition, algorithms, pattern recognition, and abstraction [12], [13]. Decomposition is the process of breaking down complex problems into manageable subparts, using strategies built to the problem specific aspects, as there are often multiple approaches [14], [15]. This approach proves valuable when solving large or complex problems, resolving the issues one subproblem at a time.

Algorithm is a crucial skill applicable in computer science as well as in daily life, forming the basis for goal achievement through a sequence of well-defined steps [16], [17]. Algorithm thinking aims to find the most suitable sequence of steps for a given tasks, recognizing that there can be multiple valid approaches.

Pattern recognition is the skill to identify structures and correlations in problems, and also bridge the gap between current information and historical data. This enables students to apply familiar concepts when encountering similar problems in the future.

Abstraction is the art of simplifying complex issues by filtering out extraneous details and focusing on essential components, often aided by appropriate data structures and notations [18]. Mastering abstraction allows students to systematically analyze problem components.

1.2. Technology Acceptance Model (TAM)

TAM was developed from the theory of reasoned action (TRA) in social psychology. Initially, the model focused on the motivations behind individual actions. TAM serves as a framework for investigating factors that influence people's acceptance of new teschnology [19]. Additionally, TAM comprises five key components, namely perceived usefulness (PU), perceived ease of use (PEU), attitude toward using (ATU), behavioral intention (BI), and actual system use (ASU) [20]. Meanwhile, PU denotes individual perception of how beneficial or positively impactful a tool will be in the life [21]. PEU refers to the impression of user about how a system or technology is user-friendly. Simplifying the user experience can increase adoption and enhance work performance efficiency [22].

ATU reflects individual sentiment regarding technology or information systems usage. In Davis theory, a positive attitude significantly influences technology adoption and usage behavior, while a negative attitude can prevent it [23].

BI is the inclination of an individual to continue using a system or technology in the future. It shows the significance of understanding and influencing individual intentions in the design and implementation of technological solutions [24].

ASU occurs when individual finds a system user-friendly and believes it improves productivity, leading to satisfaction [25]. Across various disciplines, it is commonly recognized that perceived value and perceived ease of use represent two distinct factors influencing people decisions to adopt technology.

TAM has been expanded to include external factors, but this study focuses on three specific criteria, namely PU, PEU, and ASU. Furthermore, an external factor was considered, called computational thinking skill among students pursuing electronics engineering education in higher education. The framework proposed by Fred Davis in 1989 is shown below [26].

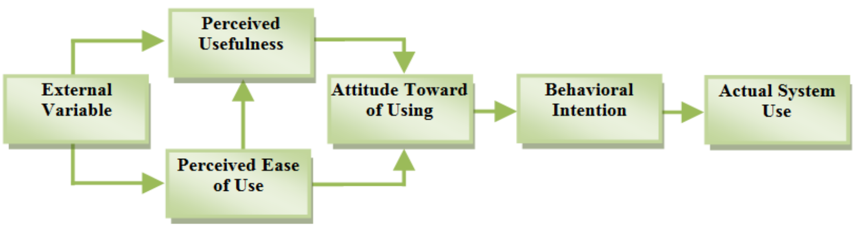

Figure 1. Technology Acceptance Model (TAM)

1.3. Augmented Reality (AR)

AR includes overlaying virtual elements onto the user real-world perspective to offer an enhanced experience using 3D digital graphics to provide various services and functions based on reality [27]. It is a promising technology for educational application [28], and enables the real-time integration of digital and physical data through various technologies, such as computers and smartphones [29]. Jeffri [30], described three primary features characterizing AR, including the presentation of objects in 3D, interactivity, and real-time delivery [31]. This allows students to simultaneously engage with both the virtual and real worlds.

2. Methodology

Research methods are systematic steps or procedures used to collect, analyze, and interpret data in order to answer research questions or achieve research objectives [32].

The purpose of research methods is to assist researchers in designing valid, reliable, and relevant studies. To achieve this goal, the researcher took the following steps:

2.1. Data Collection

This comprehensive study consisted of various elements, including background, sample and population, data collection methods, and investigation. The respondents in this study comprised 101 students pursuing electronics engineering education in higher education, Indonesia. Respondents had previously experienced using an Android application based on AR, specifically designed for learning the basics of electronics. The investigation was conducted by visiting the school directly and overseeing the process of students filling out questionnaires under the guidance of the subject teacher. Consequently, an overview of AR BASIC ELECTRONICS application was presented, including an explanation of its features, usage, and the topics covered.

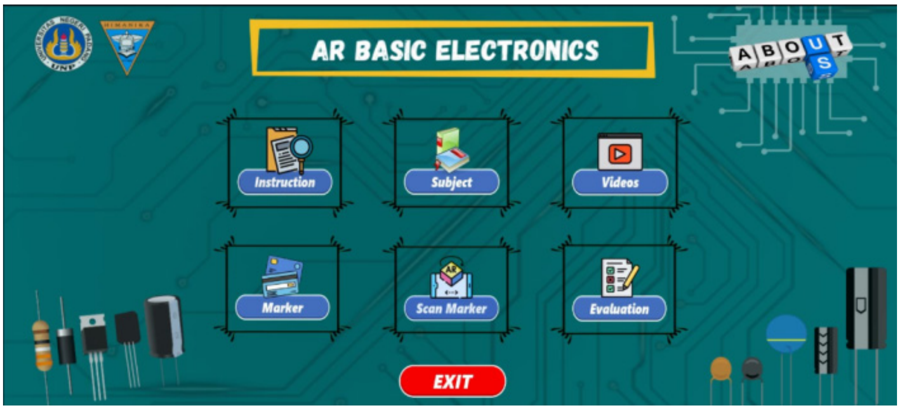

Figure 2. Application menu

Figure 2 shows a range of menu options available to students, including guidelines for application use, subjects containing various materials about basic electronics components, instructional videos, markers used to scan for 3D images, a marker scanning feature, and an evaluation section with questions to assess student comprehension.

Figure 3. Subject menu

Figure 3 shows the subject menu, containing several learning materials that can be understood and even downloaded by students.

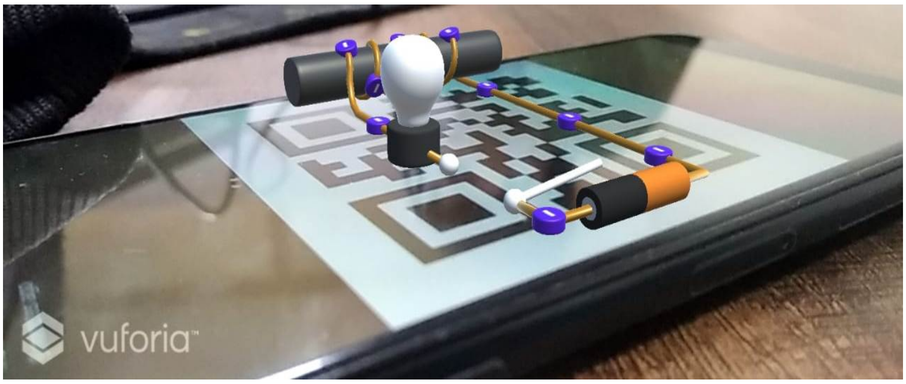

Figure 4. Augmented reality (AR) display

Figure 4 showed the 3D view of a scanned marker with various components, including a battery, switch, lamp, inductor, and a hand showing the direction of electric current. This visual representation aided students in understanding components through symbols and 3D visualizations.

2.2. Measures

In this study, Likert scale was used for measurement, assessing each item on a scale from one to five. The measurement items used were based on previous explorations, with adjustments made to be in line with the context of the investigation.

To measure the computational thinking skill variable, five items adapted from [33] were used. These items included statements related to the proficient use of AR BASIC ELECTRONICS from start to finish, showing the extent of computational thinking skill.

PU was evaluated using a key variable in TAM, which reflected the perceived benefits of technology. The model made PU to be more readily accepted by students using AR Android application. A single item from previous exploration [34] was used to assess whether the application was perceived as useful in supporting the learning process, focusing on the benefits students associated with using the Android application "AR BASIC ELECTRONICS" for learning basic electronics material.

A significant part of TAM was evaluated by focusing on PEU concept, in AR Android application. Two statement items were adopted from [35] to assess this concept. The statements included, "This AR BASIC ELECTRONICS is easy to use and easy to understand." The presence of instructional buttons and guidance facilitated students in understanding the steps of using the application, starting from comprehending the material, practicing 3D images shown from the marker of basic electronics components, and concluding with the evaluation stage, as shown in Figure 3. These statements measured the ease with which students accepted the technology.

ASU variable in AR Android application was assessed by incorporating several items from the study conducted by Xin-Zhu Li [36]. The technology was implemented because it was beneficial and user-friendly.

2.3. Data Analysis

A questionnaire served as the primary data source for data collection. The SmartPLS 3 program was used to implement Partial Least Squares Structural Equation Model as the analysis method. This approach allowed for a better understanding of the relationships between the variables. The analysis incorporated a battery of tests, with average variance extracted (AVE) values exceeding 0.5 to show convergent validity. Values for Cronbach's alpha, composite reliability (CR), and external loadings above 0.7 were preferred. Additionally, the construct discriminant validity, assessing the extent to which the variables captured distinct concepts, was examined based on Fornel and Larcker formula [37] and heterotrait and monotrait [38]. Additionally, an analysis was conducted using Fuzzy C-Means (FCM) Clustering with JASP software.

2.4. Sample

The samples of this study comprised 101 students in the field of electronics engineering education in higher education. Non-probability sampling with random sample selection was used for this purpose.

Table 1. Profile of Respondents

Sample Characterization		Freq	Percent (%)
Gender	Man	98	97,03
	Woman	3	2,97
	Total	101	100
Age	13-14 years old	2	2
	15-16 years old	78	77,2
	>17 years old	21	20,8
	Total	101	100
NIM/Student ID Number	2022	3	2,97
	2023	98	97,03
Class	Class A	28	27,2
	Class B	23	22,8
	Class C	26	25,7
	Class D	24	23,8
	Total	101	100

According to Table 1, among the 101 collected respondent data, 98 (97.03%) were male, and 3 (2.97%) were female. In terms of age, 2 respondents (2%) were aged 13-14 years, 78 (77.2%) were aged 15-16 years, and 21 (20.8%) were above 17 years old. Furthermore, based on the student ID number, 3 (2.97%) enrolled in 2022, and 98 (97.03%) enrolled in 2023. Moving on to classes, there were 28 students (27.7%) from Class A, 23 (22.8%) from Class B, 26 (25.7%) from Class C, and 22 (23.8%) from Class D.

3. Results and Discussion

The main purpose of this section is to clearly communicate the findings, provide an interpretation of the results, and evaluate their impact on the field of research.Tthe following research results have been obtained.

3.1. Structural Equation Model (SEM)

The first test conducted was the reliability test, which examined the values of outer loading, Cronbach's alpha, CR, and AVE.

Table 2. Outer loading, Cronbach's alpha, CR, AVE

Variable	Item	Outer Loading	Cronbach's alpha	CR	AVE
Computational Thinking Skill	CTS1	0.802	0.895	0.923	0.705
	CTS2	0.832			
	CTS3	0.897			
	CTS4	0.844			
	CTS5	0.821			
Perceived Usefulness	PU1	1.000	1.000	1.000	1.000
Perceived Ease of Use	PEU1	0.952	0.909	0.956	0.916
	PEU2	0.962			
Actual System Use	ASU1	0.958	0.931	0.951	0.828
	ASU2	0.897			
	ASU3	0.896			
	ASU4	0.888			

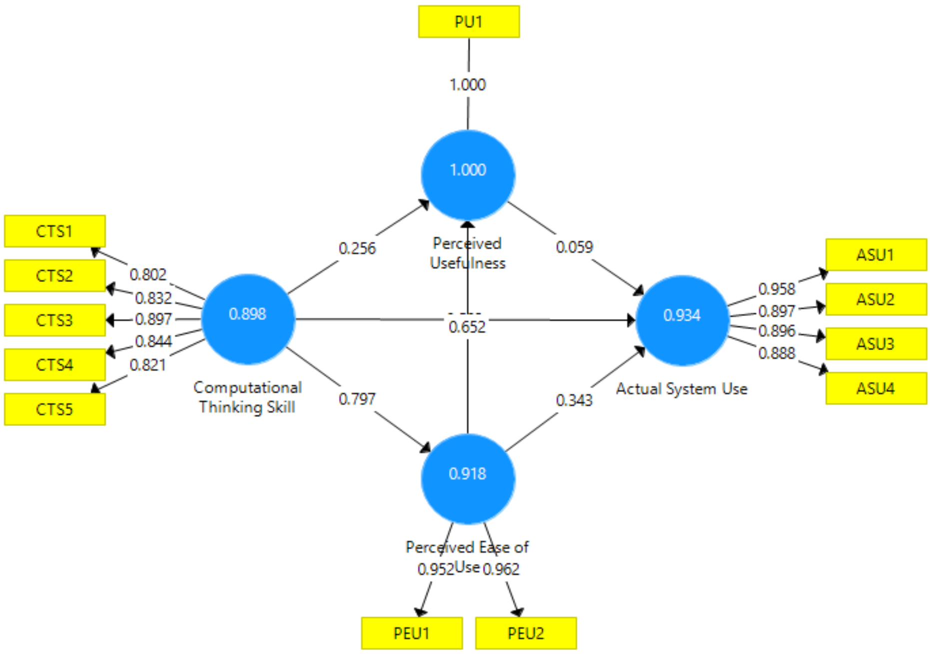

Figure 5. Outer loading

Based on Table 2 and Figure 5, the results of the convergent validity test showed that each item outer loading was above 0.7, implying the reliability of the instrument. Additionally, both Cronbach's alpha and CR values exceeded 0.7, and AVE value was higher than 0.5, meeting expert recommendations.

The next step was the discriminant validity test, which assessed how well the measured constructs represented different concepts [39]. This assessment was carried out using the Fornel and Larcker formula [37] and heterotrait and monotrait (HTMT) [38].

Table 3. Formell-Larcker Crieteria

Variables	ASU	CTS	PEU	PU
ASU	0.910			
CTS	0.823	0.840		
PEU	0.795	0.797	0.957	
PU	0.744	0.776	0.856	1.000

Table 4. HTMT Ratio of Correlations

Variables	ASU	CTS	PEU	PU
ASU				
CTS	0.889			
PEU	0.857	0.879		
PU	0.767	0.817	0.895	

Table 4 show the results of the discriminant validity test, showing HTMT scores ranging from 0.767 to 0.889, all falling below the accepted threshold of 0.9 [40]. Subsequently, the results of hypothesis testing were shown in Table 5.

Table 5. Direct and indirect effects hypothesis

Hypothesis	**β**	**T-Statistic**	**P-Value**	**Results**
H1: Computational Thinking Skill -> Perceived Ease of Use	0.797	12.236	0.000	Accepted
H2: Computational Thinking Skill -> Actual System Use	0.503	2.119	0.035	Accepted
H3: Perceived Ease of Use -> Perceived Usefulness	0.652	3.699	0.000	Accepted
H4: Perceived Usefulness -> Actual System Use	0.059	0.296	0.767	Rejected
H5: Perceived Ease of Use -> Actual System Use	0.343	2.274	0.023	Accepted
H6: Computational Thinking Skill -> Perceived Usefulness -> Perceived Ease of Use	0.520	3.411	0.001	Accepted
H7: Computational Thinking Skill -> Perceived Usefulness -> Actual System Use	0.274	2.133	0.033	Accepted

The table above showed that six hypotheses were accepted since the T-statistic value was above 1.96, and the P-value was less than 0.05 [41]. Hypothesis 1, which explored the impact of computational thinking skill on PEU of AR, showed a significant positive relationship (β = 0.797, p = 0.000). Similarly, Hypothesis 2, focusing on the influence of computational thinking skill on ASU of AR, also showed a significant positive relationship (β = 0.503, p = 0.035). Hypothesis 3 yielded the same result (β = 0.652, p = 0.000). However, Hypothesis 4, suggesting that PU did not have a significant relationship with ASU, was not supported (β = 0.059, p = 0.767).

The results provided empirical support for Hypothesis 5, showing a significant positive relationship between PEU and ASU in AR-based applications (β = 0.343, p = 0.023). Additionally, Hypothesis 6 showed that PU effectively mediated the relationship between computational thinking skill and PEU (β = 0.520, p = 0.001). Finally, Hypothesis 7 also showed that PU effectively mediated the relationship between computational thinking skill and ASU in AR-based applications (β = 0.274, p = 0.033).

4. *Fuzzy C-Means (FCM) Clustering*

The items in this study were analyzed using FCM, a clustering approach that allows data elements to be assigned to more than one group with measurable degrees of membership [42]. In its implementation, each data point was given a degree of membership for each cluster, allowing each data point to have a different membership level. This study introduced an enhanced FCM method based on t-SNE and primarily focused on reducing the dimensionality of t-SNE-clustering samples and classifying sample points by feature distributions as the initial cluster centers for FCM clustering analysis.

5. *Determining the Number of Clusters*

Bayesian information criterion (BIC) was a statistical criterion similar to akaike information criterion (AIC). In academic studies, statistical criteria such as AIC and BIC were frequently used for model selection. These statistical models assisted in evaluating data fit while considering complexity. A lower AIC or BIC signified a superior model fit. Various statistical analyses, including regression and time series, used these criteria. The metric was also used in clustering analysis, particularly with k-means algorithm. Furthermore, it measured the algorithm skill to form compact clusters, achieved through iterative data point assignment to clusters and updating of cluster centroids, which reduced the within-cluster sum of squares (WSS) in k-means clustering. To determine the optimal number of clusters, WSS, AIC, and BIC could be used [43]. AIC or BIC was used to assess the cohesion strategy and the clustering outcome for each statistical model.

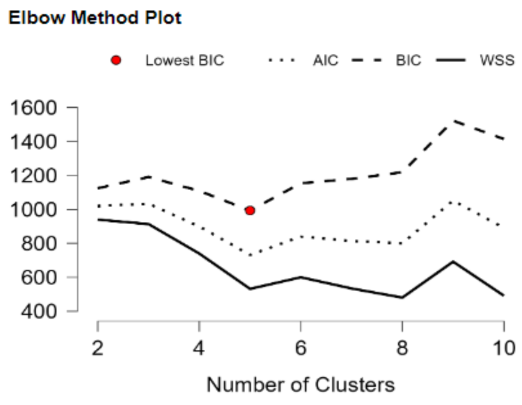

Figure 6. Elbow method plot

According to Figure 6, the initial elbow point was reached at five clusters, showing that a solution with five clusters was the best and most optimal choice. Table 4 showed AIC, BIC, and Silhouette indicators to evaluate the consistency of data interpretation in FCM clustering solution.

Table 6. Fuzzy c-means (FCM) clustering

Cluster	N	R^2	AIC	BIC	Silhouette
5	101	0.695	797.580	1059.090	0.590

Table 6 showed that Silhouette score was 0.590, denoting the typical level of internal consistency achieved through clustering. Furthermore, it assessed the similarity between each instance and cluster compared to other clusters. Scores closer to the lower limit of -1 suggested a poor fit, while values closer to the upper limit of 1 showed more consistent clustering [44]. Emphasizing the maximization of these values was essential for obtaining an optimal cluster solution. Meanwhile, a decrease in BIC and AIC values was necessary for achieving the desired results. All indicators showed satisfactory performance under optimal conditions.

Table 7. Evaluation metrics

Metrics	Value
Person's γ	0.749
Dunn index	0.213
Entropy	0.868
Calinski-Harabasz index	56.324

Table 7 further showed additional evaluation metrics for the cluster solution. Person's γ measured 0.749, showing the correlation between data distances in clusters and distances between clusters. The Dunn index, with a value of 0.213, characterized the separation between different clusters and the proximity of data distances in clusters. The Entropy was 0.868, signifying data diversity in a cluster. Smaller entropy values implied greater data homogeneity. Finally, the Calinski-Harabasz index scored 56.324, signifying the effectiveness of separating data into clusters. Higher Calinski-Harabasz values showed better separation between clusters. Based on these results, the identified clusters were of high quality.

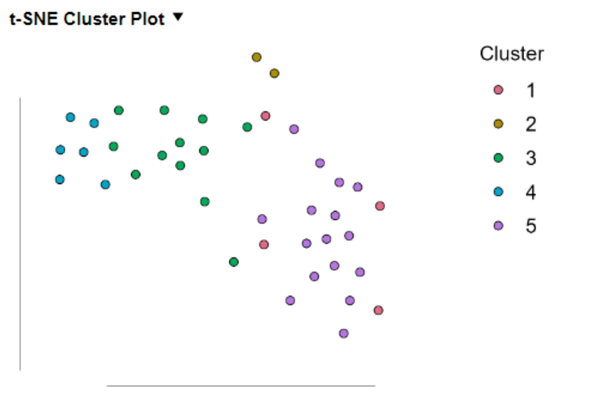

Figure 7. t-NSE cluster plot

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In the image, clusters showed distinct colors positioned adjacent to one another. Similar shades showed that data points shared proximity or similarity in the original space before t-SNE reduced dimensionality. t-SNE was designed to preserve relative distances and local structures between data points. Consequently, when data points shared similar colors, they tended to be in close proximity or showed similar patterns in the original data.

6. Conclusion

In conclusion, this study showed the crucial importance of possessing computational thinking skill for contemporary children. By using smartphone applications with AR technology, students could improve their familiarity with the developing technology, enhance their entire learning experiences, and familiarize with new technology. Additionally, this study showed the significance of acquiring computational thinking skill to effectively adopt and use evolving technology in daily life.

The influence that controlled the relationship between PU and PEU had a significant impact. Students could derive substantial benefits from the insights offered in this exploration, gaining a deeper understanding of media role as a facilitator of learning. The development of AR application provided teachers with a valuable tool to augment students' comprehension and engagement. This application had the potential to facilitate knowledge acquisition and the seamless integration of technological advancements, contributing to intellectual growth. This proposed approach empowered teachers to further enrich the understanding of students and equipped them with skill that extended beyond subject-specific knowledge. As the field of education continued to evolve, these tools opened up opportunities for enhanced learning experiences.

Based on the findings above, further investigation was recommended to explore the impact of AR tools on academic performance and their long-term effects.

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