The Effect of Using Smart Application on Critical Literacy of Engineering Education Students

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Manuscript received October 27, 2023; revised November 29, 2023; accepted January 12, 2024; published June 17, 2024

***Abstract*—The incorporation of technology into educational settings is going through a period of rapid expansion, which is being accompanied by the persistent growth of a variety of forms of media. The purpose of this research is to investigate, among students majoring in engineering at Padang State University, how the utilization of learning apps contributes to the enhancement of fundamental reading and writing abilities. Learning Readiness was included as an independent variable alongside Intrinsic Learning Motivation and Critical Literacy, and Information Literacy was taken into consideration as a moderating variable. The present study involved the collection of a representative sample comprising 899 respondents. The collected data were subsequently subjected to analysis utilizing the Structural Equation Model (SEM). In this study we also conducted Fuzzy C-Means clustering, to see to what extent the value of each cluster can influence the others. The findings of this study indicate that individuals who have a high level of preparedness for learning and a strong sense of motivation are likely to achieve better outcomes. Additionally, possessing a proficient level of information literacy will exert an influence on the development of critical literacy.**

***Keywords*—smart application, critical literacy, digital learning readiness, intrinsic learning motivation, information literacy**

I. Introduction

The expeditious advancement of technology has positioned it as a key enabler for fostering collaboration between educators and learners [1]. The utilization of online discussion forums, video conferencing tools, and networking systems facilitate the collaboration and exchange of ideas among students situated in diverse geographical locations. The proliferation of digital resources, coupled with the active participation of students and educators, has significantly augmented the availability of information for educational purposes. The availability of e-books, educational websites, and digital libraries has expanded the range of educational materials beyond traditional textbooks [2]. In order to cultivate competent graduates, educational institutions must equip their students with the necessary skills to effectively navigate and respond to evolving circumstances, thereby fostering the development of reliable professional competencies [3]. In order to address the labour demand effectively, it is imperative for the industry, society, and technical education to establish a collaborative relationship.

Educators, in particular, need to adapt the subject matter and continuously enhance the existing resources to meet the evolving needs of the workforce [4]. This initiative is undertaken with the conviction that enhancing educational opportunities for the community will facilitate a deeper comprehension and more effective management of daily obstacles. Development in the educational environment with the competence of each student's desire to learn increases their awareness of innovation [5]. Nowadays, many students use their smartphones in their daily activities including their learning activities [6]. With the advancement of technology, applications on students' smartphones can be used as a medium for students to fulfil their learning needs, providing lessons or learning materials that can be accessed at any time, enabling digital learning. The intense use of smartphones by students can provide benefits for education service providers to create application designs that can be downloaded on smartphones [7, 8].

The utilization of the app allows students the flexibility to open and access lessons at their convenience [9]. The effectiveness of digital learning processes may be compromised if students fail to adhere to the prescribed expectations [10]. The utilization of inventive and easily accessible instructional resources has the potential to enhance students' comprehension, facilitate their access to education, foster skill development through practical applications, and ultimately improve their educational achievements. In light of the increasing prevalence of multimedia-based learning, it is imperative to equip learners with the capacity to comprehend the significance of information, students' learning processes holds significance in the identification of strategies to enhance instructional methods [11].

Academics investigate digital learning environments and the primary factors that influence the adoption of technology in educational settings. The level of satisfaction experienced by users and the amount of resources used have a positive correlation. Classes might be made more interesting and engaging by utilizing digital platforms, multimedia presentations, and software designed specifically for teaching purposes. In this time of rapid change, the implementation of active learning technologies facilitates increased student motivation toward learning, a crucial aspect of the advancement of education [12]. Technology has facilitated access to distance learning, his calls for a shift not only in the academic standards that are expected of students but also in the thought processes that they employ.

Students are motivated by education quality and tool availability, advances in learning management systems,

video conferencing, and online collaboration platforms allow students to learn remotely [13]. Educational institutions must provide students with the essential skills and knowledge to adapt to new situations and develop strong abilities that will be extremely valuable in their future careers. Not doing so would inevitably lead to a lack of necessary skills, which would hinder their ability to perform their job duties effectively. The collaboration between the realms of business, society, and technical education is crucial to effectively address the urgent requirement for a skilled workforce. Teachers have a unique obligation to stay updated on the constantly changing requirements of the job market. An effective strategy to accomplish this goal would entail making changes to the teaching methods and using existing educational resources more wisely. This phenomenon can be explained by the continuous evolution of the demands placed on the workforce. The initiation of this initiative was based on the idea that improved educational opportunities would lead to a greater understanding within the community, enabling them to effectively handle the various challenges they face every day. The students in question demonstrate an increased ability to understand new concepts when their natural ability to learn and their internal drive to pursue education are in sync with the current educational environment.

The objective of this study is to examine the efficacy of a software-based intervention in enhancing students' Learning Readiness, Intrinsic Learning Motivation, Critical Literacy, and Information Literacy. The proposed software aims to improve students' proficiency in argumentation, assumption analysis, deductive reasoning, interpretation, and logical reasoning. This study seeks to utilize technology in order to offer a unique and interactive learning experience that encourages students to engage in critical thinking. The main aim of this study is to assess the influence of the software intervention on the critical thinking abilities of students. The study's primary objective is to evaluate the software's efficacy in enhancing students' proficiency in argumentation, assumption analysis, deductive reasoning, interpretation, and logical reasoning. This maintains instructional uniformity and enables accessibility. IT assessment is crucial to maintaining students' educational levels. This study prepares for the creation of A2DIK, a smartphone app. The software aims to develop students' critical thinking skills in argumentation, assumption analysis, deductive reasoning, interpretation, and logical reasoning. This program was created to help kids learn valuable skills for their future, especially in the workplace. This study is needed to determine how accessible digital gadgets affect student learning. Based on previous studies that serve as references in this study, this study proposes a hypothesis shown in Fig. 1:

- H_1: Learning readiness has an impact on intrinsic learning motivation.
- H_2: Learning readiness has an impact on critical literacy.
- H_3: Intrinsic learning motivation has an impact on critical literacy.
- H_4: Information literacy moderating learning readiness and intrinsic learning motivation
- H_5: Information literacy moderating learning readiness and critical literacy
- H_6: Information literacy moderating intrinsic learning motivation and critical literacy.

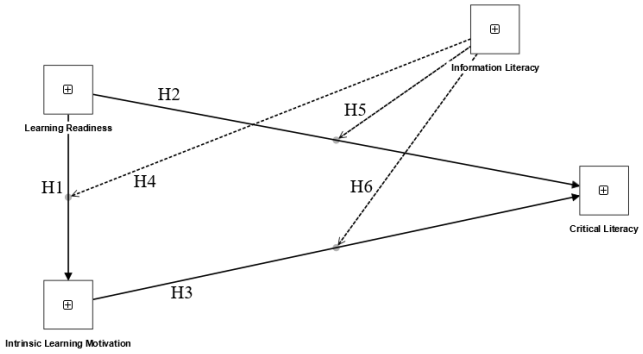

Fig. 1. Hypothesis.

II. Literature Review

A. Learning Readiness

Many of the new ways of learning that are happening now lead to digital learning. It is important to know how ready college students are for this so that they can be given clear instructions. Because colleges and universities quickly started using digital learning methods and principles, there was a big change in how people learned and were taught. The three things that students needed to be ready for digital learning were (1) a desire for a different way of learning than traditional classroom instruction, (2) being able to use technology to learn effectively and with confidence, and (3) being able to learn on their own [14]. According to the research, differences in how ready students are can be caused by things like their grade level and how the teachers feel about creating and teaching online classes [15]. When making learning tracks for online, you should think about the socio-demographics of the learners and how ready they are for digital learning. In e-learning classes, the system should choose introduction materials for each student based on information from the students' self-evaluations when they sign up [16].

The process of digital learning frequently requires the learner to adapt to newly implemented technologies, learning platforms, and instructional methods in order to be successful [17]. People who have a strong propensity and readiness to maintain an open mindset, demonstrate adaptability, and readily adjust to changing circumstances are more likely to be successful in a digital learning environment [18]. Students participating in online education have the opportunity to interact with their teachers and other students through a variety of communication channels [19]. These channels include email, video conferencing and online discussion forums. To actively participate in discussions, ask questions, seek clarification, and work together on group projects or assignments, effective communication and collaboration skills are essential. Thus, this is crucial to the success of student learning by using smartphone applications, in order to improve the ability of students to be able to understand literacy which is crucial for them.

B. Intrinsic Learning Motivation

Individuals exhibit "intrinsic learning motivation" when they seek out learning opportunities out of a genuine interest in and pursuit of their own personal growth and development [20]. Individuals possess a desire and inclination towards engaging in learning activities due to

their perception that they will derive personal advantages from such endeavours [21]. Focusing on developing a person's natural desire to learn is very important in online education because it's a key factor in keeping students interested and promoting successful academic outcomes [22]. Six different types of motivational structures, the difference between doing something because it is interesting or fun and doing something because it leads to an outcome is the most fundamental difference [23]. Engaging in an activity based on personal interest or enjoyment exemplifies intrinsic motivation, whereas engaging in an activity driven by the anticipated outcome exemplifies extrinsic motivation.

Numerous studies spanning over three decades have consistently demonstrated that the underlying motivations, whether intrinsic or extrinsic, significantly influence an individual's experience and performance [24]. There are two main kinds of motivation: internal and external. The major goal of this study is to rethink the standard split between these two types of motivation and show how they work differently [25]. In recent years, educators have recognized the significance of intrinsic motivation as a fundamental factor in facilitating learning and fostering achievement [26]. The process of acquiring knowledge and fostering the creation of innovative ideas and practices. To fulfil the requirements of the task at hand, it is necessary to rephrase the user's text in a more academic manner [25]. While intrinsic motivation is innate, it can be fostered or squelched through parental and pedagogical practices [27]. to foster intrinsic motivation, it is crucial to discern the circumstances and contexts that promote rather than hinder this form of motivation. The enhancement of an individual's essential literacy skills is contingent upon their level of motivation, as a strong drive to continually enhance their abilities fosters further development.

C. Critical Literacy

The adoption of a critical literacy stance is crucial in various contexts, particularly during periods of conflict and polarization. This is not solely due to the fact that it enables us to determine "what to tell the student" [28]. For critical literacy in education, an environment that supports open communication, helps people learn about different cultures and societies, allows for the study of power dynamics, encourages acceptance of complexity, and pushes people to act is essential [29]. It is plausible that individuals across various age groups may benefit from receiving guidance from their educators presently. However, it is equally imperative for these individuals to cultivate independent thinking and effective communication skills, as these abilities are crucial for their present and future endeavours. The process of creating such educational environments is a complex endeavour, underscoring the significance of teacher training in the realm of critical literacy. Educators can be empowered to foster critical literacy through various means, such as leveraging experiential knowledge or engaging in discursive exchanges with theoretical frameworks, facilitating opportunities for observing critical literacy models and practices and receiving support from a critical community that encompasses fellow educators [30].

A study that focused on critical literacy practices came to the conclusion that there are four distinct dimensions of the topic. The critical attitude is the one that is considered to be the most important among these different dimensions [31]. The comprehensive framework facilitates the comprehension of the complexities inherent in critical literacy issues. By challenging the status quo, it is imperative to thoroughly examine multiple perspectives. A model for examining the focus of critical literacy efforts, specifically in relation to political and social, concerns and the intersection of activism, and performance [31]. Critical literacy can be defined as the capacity to perceive the "mundane" from a fresh perspective. Lucero and Avelar [32] argue that through the utilization of language and other sign systems, individuals are able to identify implicit modes of perception and explore novel frameworks for comprehending human experience. Scholars advocating for the incorporation of multiple viewpoints in critical literacy emphasize the importance of empathizing with others so that we can fully understand writings and events from a range of points of view, including our own and other people's [33]. While acknowledging that teaching is inherently intertwined with politics, it is often overlooked how societal and political systems, power relations, and language influence and are influenced by educational instruction [34]. Definitions of critical literacy often include certain aspects, however, to effectively combat oppression or advocate for social justice, individuals must first develop a comprehensive understanding and viewpoint, therefore digital learning readiness and intrinsic learning motivation are described as influencing critical literacy because This provides a critical attitude from a student.

D. Information Literacy

Extensive research has been undertaken and disseminated within the field of information and library science pertaining to the most effective strategies for facilitating students in attaining information literacy. Furthermore, an extensive range of inventive interventions incorporating educational theory, developmental theory, and diverse media formats have been devised and examined to address the educational requirements of students [35]. Many students say they are sure of their ability to find knowledge, think about it, and use it, these students are not information literate. Considerable scholarly investigation has been conducted and shared within the domain of information and library science regarding the optimal approaches for supporting students in acquiring information literacy [36]. Furthermore, an extensive range of inventive interventions incorporating educational theory, developmental theory, and diverse media formats have been devised and examined to address the educational requirements of students [35]. They need to consider various aspects, including the credentials of the author, the reputation of the publication or website, the accuracy of the information, and possible biases, so it is crucial to have an efficient search strategy if they want to find reliable and relevant information in a timely manner [37]. Students doing schoolwork online should be taught how to make useful search queries, apply sophisticated search strategies, and make appropriate use of databases, library resources, and academic search engines [38].

It is very important to know the difference between primary and secondary sources when doing in-depth study. Students in online classes need to be able to tell the

difference between different types of sources, such as original study papers, literature studies, textbooks, and other publications [39]. Being able to use media and find information are not the same thing. People who teach media literacy say that media is like a window through which people can see and talk about the world. On the other hand, information literacy sees information as a way for people to interact with and change the world. In contrast to other measures of literacy, this one relies on a series of multiple-choice questions, each of which has a single correct response [40]. Critical literacy goes beyond information literacy by challenging students to critically examine the information they find in terms of its assumptions, biases, and power dynamics [41]. The primary objectives of information literacy programs encompass the acquisition, evaluation, and proficient utilization of information. The capacity for critical thinking encompasses a broader scope than mere proficiency in fundamental computer competencies. Educators can enhance the cultivation of students' critical literacy by integrating information literacy within the online learning environment [42]. When students are encouraged to question, analyze, and challenge the information they find digitally, they are empowered to develop critical thinking skills, become responsible digital citizens, and actively engage in their own learning [43]. In this study, we investigate how the encouragement acted as a moderating factor on the link between the different factors.

III. Materials and Methods

A. Data Collection

Research locations, component members and populations, constraints in investigating beliefs, and techniques of collection and inquiry for doing research are all part of a thorough research recording approach [44]. The study included a total of 899 participants who were students enrolled in the Faculty of Engineering at Padang State University. These participants had prior experience using the A2DIK smart application, which was specifically developed to support the learning process and enhance students' skills. Fig. 2 presents a visual representation of the A2DIK smart application, illustrating various tests that students can undertake to enhance their abilities in argumentation, assumption, deduction, interpretation, and conclusion.

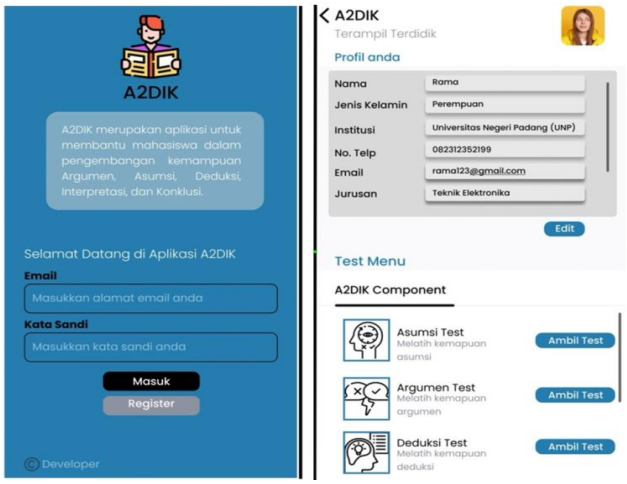

Fig. 2. Smart application A2DIK.

B. Measurement

The majority of the measurement items used in this study refer to research that was done in the past, but there have been some modifications made to account for the context of this study. It was discovered that a Likert Scale was utilized in the process of evaluating the items that were being measured in this research. The Likert Scale rated each item on a scale of one to five, with one representing strong disagreement and five representing strong agreement.

1) Learning readiness

Based on previous research carried out by Hung *et al.* [45], this investigation makes use of four items to measure a variable known as the learning readiness variable. These items are predicted to be a representation of the variable in question. Learners' responses to statements like "Learners can understand the importance of crisis literacy in learning" and "Learners are cognitively prepared to use critical skills in learning" help determine how well learners are prepared for their education. This variable measures the extent to which learners are well prepared for their education.

2) Intrinsic Learning Motivation

According to the findings of research carried out by Hornstra *et al.* [46], the intrinsic Learning Motivation variable was assessed through the utilization of five items that were hypothesized to be representative of the aforementioned variable in this study. This variable measures the extent to which individuals are driven by their own intrinsic interests to learn and advance their critical literacy skills. Strong intrinsic motivation has the potential to encourage individuals to actively engage in critical reading and comprehension of texts. This can be accomplished by responding to statements such as "The learner is confident in critically reading and comprehending texts" and "Can prepare well for exams and critical reading tasks."

3) Critical literacy

According to the findings of research carried out by Hornstra *et al.* [46], the intrinsic learning motivation variable was assessed through the utilization of five items that were hypothesized to be representative of the aforementioned variable in this study. This variable measures the extent to which individuals are driven by their own intrinsic interests to learn and advance their critical literacy skills. Strong intrinsic motivation has the potential to encourage individuals to actively engage in critical reading and comprehension of texts. This can be accomplished by responding to statements such as "The learner is confident in critically reading and comprehending texts" and "Can prepare well for exams and critical reading tasks."

4) Information literacy

According to the findings of Davis and Watson's research [37], the information literacy variable was measured in this study with the help of four items that are thought to be representative of the variable in question. By responding to statements such as "the learner uses various sources to learn" and "the learner can decide where and how to find the information that is needed", these factors show how well the learner understands knowledge and can find the information they need.

C. Data Analysis

Partial Least Squares (PLS), a variant of variance-based Structural Equation Modelling (SEM), is an alternative method within the framework of Structural Partial Least Squares (PLS). It enables the simultaneous examination of relationships between variables, taking into account both direct and indirect effects among these variables [47, 48]. This facilitates the development of route models that provide more explanatory capacity in clarifying the interconnectedness of variables. The Structural Equation Model (SEM) and the SmartPLS version 4 tools were used in this work to analyze the data. It was done to look at the data and see how reliable the structure model was. The first step in the method used to analyze the data in this study was to compare the research theories to measurement models to see how accurate and reliable they were. To check for convergent validity, the study used standard item loading and AVE. The heterotrait-monotrait correlation ratio (HTMT) was also used to check for discriminant validity. Furthermore, a full review was carried out to find out how reliable the study models were. Composite Reliability (CR) and Cronbach's alpha were used as indicators of internal consistency. The second phase of the investigation was an examination of the statistical significance of the structural linkages that underpin the connections between the various components of the study. The task was achieved by producing 5,000 bootstrap samples.

IV. Result and Discussion

A. Descriptive Result

From the total 899 data obtained shown in Table 1, 691 respondents, or equivalent to 76.86% were male, and 208, or equivalent to 23.14% were female. From the age group, twenty-third to twenty-fourth years old, there were 41 participants or 4.56%, and from the twenty-first to twenty-second-year-old group there were 260 people who participated or 28.92% of the total respondents, while from the nineteen to twenty-year-old group 439 people or 48.83% of the total respondents and the seventeen to the eighteen-year-old group who participated in this study were 146 people or 16.24%, and from the group of age more than twenty-fourth 13 people or 1.45%. While using smartphones per day in the group more than ten hours per day 219 people or 24.36%, from the seven hours to nine hours group 314 people or 34.93%. From the four hours to six hours per day group there were 289 people or 32.15%, and for the duration of one hour to three hours per day, there were 77 people or 8.57%.

B. Measurement

In order to assess the extent of bias in our study, we employed the PLS-SEM technique, along with the internal Variance Inflation Factor (VIF) [49]. To reach this conclusion, a statistical methodology was effectively employed. Based on the VIF values, which range from 1.560 to 2.569 and are all below the common method bias threshold of 3.30, it can be concluded that the significance tests are not biased. Upon conducting a visual analysis of Table 2, it is evident that all of the Composite Reliability and Cronbach's alpha values surpass the minimum threshold of 0.70 [50]. Furthermore, the data align with the criteria for convergent validity, as outlined in Table 2. This is because all of the factor loadings for the corresponding latent constructs exceed the benchmark value of 0.60 [50], and the Average Value of Each construct (AVE) is greater than 0.50.

Table 1. Descriptive results

Items		Total	Percentage
Gender	Males	691	76.86%
	Female	208	23.14%
	Total	899	100%
Age (years old)	>24	13	1.45%
	17–18	146	16.24%
	19–20	439	48.83%
	21–22	260	28.92%
	23–24	41	4.56%
	Total	899	100%
Duration on Smartphone in a day (hour)	>10	219	24.36%
	1–3	77	8.57%
	4–6	289	32.15%
	7–9	314	34.93%
	Total	899	100%

Table 2. Validity results

Variables	VIF	Cronbach's alpha	CR	AVE
Critical Literacy (CL)	1.724	0.813	0.816	0.641
CL2	1.748			
CL3	1.658			
CL4	1.874			
Information Literacy (IL)	2.200	0.841	0.847	0.679
IL2	2.160			
IL3	1.880			
IL4	1.560			
Intrinsic Learning Motivation (ILM)	2.258	0.901	0.902	0.717
ILM2	2.425			
ILM3	2.569			
ILM4	2.255			
ILM5	2.331			
Learning Readiness (LR)	2.188	0.862	0.867	0.707
LR2	2.361			
LR3	2.002			
LR4	1.799			

The heterotrait-monotrait ratio (HTMT) (Table 3) was identified as the most effective approach for assessing the discriminant validity between two reflective constructs. To meet the specified criteria [51], the HTMT value needed to be below 0.9. The discriminant validity test yielded scores ranging from 0.641 to 0.717, which remain below the recommended threshold of 0.9 proposed by experts.

Table 3. Heterotrait-Monotrait Ratio of Correlations (HTMT)

Items	CL	IL	ILM	LR	IL × LR	IL × ILM
CL						
IL	0.817					
ILM	0.793	0.865				
LR	0.724	0.757	0.814			
IL × LR	0.389	0.346	0.384	0.426		
IL × ILM	0.453	0.386	0.437	0.365	0.798	

C. Structural and Hypothesis Testing

The outcomes of the data collected from participants and analysed using SmartPLS are presented in Fig. 3 and Table 4. These visual and tabular representations illustrate the relationships between the hypotheses formulated in the current study. According to the data, Hypothesis 1 shows that

learning readiness have significant effect on intrinsic learning motivation and the relationship is positive (β = 0.380, ρ = 0.000). Similarly, Hypothesis 2 also reveals a positive relationship between learning readiness and critical literacy, with a positive significant effect (β = 0.180, ρ = 0.002). Hypothesis 3 demonstrates a significant positive relationship between intrinsic learning motivation and critical literacy (β = 0.251, ρ = 0.000).

Hypothesis 4 the presence of information literacy moderates the relationship between learning readiness and intrinsic learning motivation, resulting in a negative and significant impact (β = −0.034, ρ = 0.035), where a relationship like this needs to be considered, because it has a significant impact but in a negative direction. Hypothesis 5 suggests that the presence of information literacy has a positive effect on the relationship between learning readiness and critical literacy, although this effect is not significant or rejected hypothesis (β = 0.029, ρ = 0.536). On the other hand, Hypothesis 6 proposes that the presence of information literacy has a negative and significant effect on the relationship between intrinsic learning motivation and critical literacy, where a relationship like this needs to be considered, because it has a significant impact but in a negative direction (β = −0.093, ρ = 0.030).

Table 4. Summary of structural models

Hypothesis	β	t	P	Results
H_1	0.380	9.596	0.000	Accepted
H_2	0.180	3.145	0.002	Accepted
H_3	0.251	4.748	0.000	Accepted
H_4	−0.034	2.111	0.035	Accepted
H_5	0.029	0.619	0.536	Rejected
H_6	−0.093	2.164	0.030	Accepted

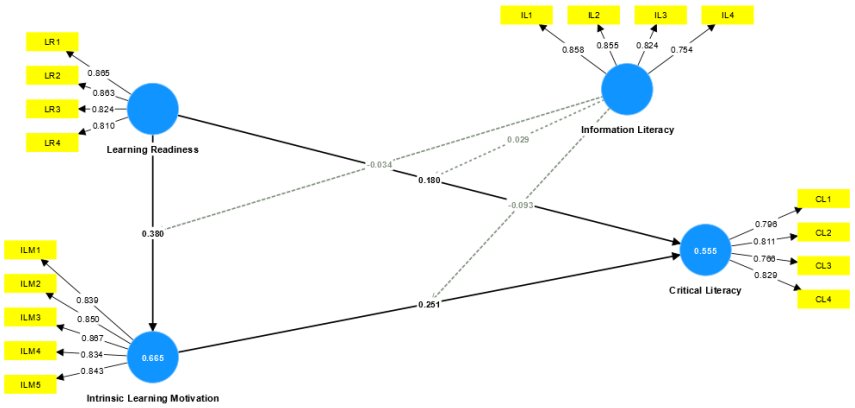

Fig. 3. Analysis result.

D. Fuzzy C-Means Clustering

The indicators were partitioned into homogenous groups using Fuzzy C-Means clustering analysis, as employed by the researchers. The Dunn index was employed to assess cluster validity, while the number of clusters was estimated using the elbow approach [52]. Moreover, in order to evaluate the credibility of the cluster solution, (t-Distributed Stochastic Neighbour Embedding (t-SNE) maps were employed to visually represent high-dimensional data in lower dimensions [53].

E. Determine Number of Clusters

Clustering analysis determines the ideal number of clusters using the elbow approach [54]. The elbow method uses Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and Within-Cluster Sum of Squares (WCSS) to find the graph point where intra-cluster variance decreases significantly as cluster number increases [55]. To choose the optimum statistical model to predict the optimal cluster structure from data, AIC and BIC are used to evaluate statistical models, including clustering models with varying cluster counts [56]. BIC chooses simpler models with fewer parameters to avoid overfitting and increase model generalization [57]. The elbow plot shows AIC, BIC, and WCSS values on the y-axis for different cluster counts on the x-axis. The elbow cluster count is chosen when the plot is elbow-shaped. The elbow point is here. Increasing clusters beyond the elbow point does not appreciably lower AIC, BIC, or WSS. Fig. 4shows a cluster count graph.

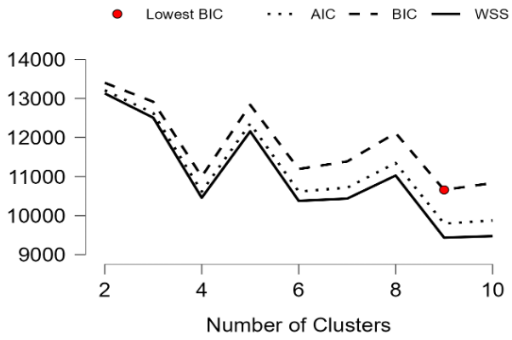

Fig. 4. Elbow method.

Based on Fig. 4, it can be observed that the first elbow point occurs at four, which indicates that the solution with four clusters is the best and optimal choice. AIC, BIC, and Silhouette indicators for the fuzzy C-Means cluster solution are shown in Table 5 to assess data interpretation consistency within clusters.

Table 5. Fuzzy C-Means clustering

Cluster	N	R^2	AIC	BIC	Silhouette
9	899	0.483	10296.980	11161.210	0.120

According to the findings shown in Table 5, Silhouette values exhibit a range spanning from −1 to 1, and it is imperative to maximize these values in order to attain an ideal cluster solution. Conversely, both BIC and AIC values

should be decreased in order to obtain the desired outcome. All indicators demonstrate satisfactory performance under favourable conditions. In contrast, Table 6 provides further assessment metrics for the cluster solution, including Pearson's γ, the Calinski-Harabasz index, the Dunn index, and entropy.

According to the findings shown in Table 6, the Pearson γ-measure is utilized to calculate the Pearson correlation for each pairwise distance between the vectors representing the clusters. A value of 0 indicates that the vectors belong to the same cluster, while a value of 1 show that they belong to distinct clusters. The Calinski-Harabasz index is derived by the comparison of the ratio of inter-cluster variability to intra-cluster variability [52]. A clustering that may be considered effective based on the Calinski-Harabasz index is one that has a higher ratio of between-cluster variability to within-cluster variability [58]. In other words, higher values of the Calinski-Harabasz index indicate that the clusters are more separated from each other and more internally compact. The Dunn index is based on two important aspects in clustering analysis: cluster dissimilarity and maximum diameter, which aim to measure the quality of data partitioning [59]. Therefore, it can be observed that all evaluation metrics show an increase in cluster density.

Table 6. Evaluation metrics

Metrics	Value
Pearson's γ	0.394
Dunn index	0.070
Entropy	1.619
Calinski-Harabasz index	89.822

F. Cluster Validation

A non-linear dimensionality reduction method called t-SNE (t-Distributed Stochastic Neighbour Embedding) [60, 61] can be used to show high-dimensional data in two- or three-dimensional space. The goal of t-SNE is to keep the relative structure between data points in the lower dimension [62] so that data points that are similar in the high-dimensional space stay close to each other in the low-dimensional space. To make a probability distribution in t-SNE [63], you use the distance between data points in the high-dimensional space and the distance between data points in the low-dimensional space (where the data will be shown). t-SNE can show both global structures, like groups of different sizes, and a lot of the local structure of high-dimensional data [64, 65]. It does this by using unsupervised machine learning methods. The t-SNE plot for the cluster solution is displayed in Fig. 5.

Based on Fig. 5, we can observe that members of distinct coloured clusters are typically located in close proximity to one another. Cluster members with comparable or closely related features are clustered together, indicating the validity of the employed clustering technique. That is to say, similar pieces of information are drawn together in a tight cluster on the graph. A good clustering solution is one in which cluster members on the plot are separated by larger distances from members of other clusters and have smaller distances amongst themselves within the same cluster. Fig. 5 shows that the data has been properly grouped into groups with shared features, proving the validity and trustworthiness of the proposed clustering approach.

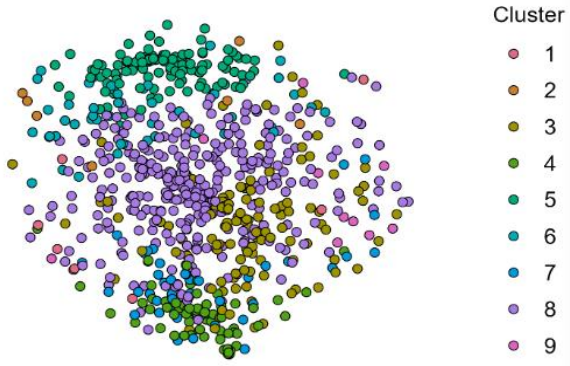

Fig. 5. t-SNE cluster plots.

By applying Fuzzy C-Means clustering analysis in this study, nine clusters representing engineering students' study skills were identified. These results show that the skills have a strong degree of homogeneity, which indicates that they are interrelated and influence each other during the learning process. This implies that a better understanding of these relationships can assist educators in designing more targeted and effective learning strategies. Using the elbow technique to calculate the ideal number of clusters verifies Fuzzy C-Means clustering analysis's ability to uncover important skill trends.

In addition, digital technologies, such as the use of interactive learning, play an important role in helping students gain a deeper understanding of technical concepts in engineering learning. Learning Readiness enables students to effectively utilize these tools and maximize the benefits of available learning resources. In addition, in the context of readiness to learn, Learning Motivation is also relevant in understanding how ready students are to engage in technology-based learning. Students with high levels of learning motivation are likely to be better equipped to handle the demands of learning involving technology, while students with lower learning motivation may need additional support in overcoming such barriers.

Critical literacy is the capacity of someone who not only concentrates on the text or reading presented [66], but also maintains a healthy balance with the ability to think critically about it. The development of critical literacy requires, above all, a heightened awareness of one's surroundings and a keen understanding of current events. It is important to investigate the history of the information provided because the truth can be found by looking at the motivation behind the writing of the information. To acquire critical literacy, readers must comprehend that texts are not "true" but rather the author's perspective and the socio-cultural environment in which they were created [67].

How engineering students in higher education are prepared to learn affects their critical literacy skills. Critical literacy helps engineering students evaluate technical information, understand the social and ethical implications of their work, and communicate with stakeholders. Critical literacy is easier for engineering students with a strong technical foundation. Students who understand basic engineering concepts and methods can critically analyse technical information, assess its reliability, and make informed decisions. Students acquire critical literacy by developing communication and problem-solving abilities to analyze and explain complex topics. Critical literacy requires

desire and curiosity. Motivated engineering students are more likely to use effective learning techniques, actively seek out resources, and critically reflect on their learning experiences. Intrinsic motivation and a curious attitude allow students to probe deeper, question assumptions, and critically analyse engineering's social and ethical aspects [25].

Problem-solving and analytical thinking are stressed in engineering education. Critical thinking and deductive reasoning help identify, investigate, and solve difficult problems. Methodical and analytical engineering students will learn to evaluate technical information, determine its validity and relevance, and make evidence-based decisions. The act of collaborating facilitates the cultivation of critical literacy skills among students. Group discussions, peer feedback, and collaborative projects foster an environment that prompts students to contemplate various viewpoints, question their preconceived notions, and actively participate in analytical discourse. In an educational setting characterized by collaboration, students have the opportunity to enhance their critical literacy abilities by engaging in constructive interactions with their peers and instructors. The establishment of a welcoming and engaging learning environment by college instructors can facilitate the enhancement of critical literacy among students [33]. Real-world case studies, interdisciplinary conversations, and student participation can help students critically evaluate the social, ethical, and environmental impacts of engineering decisions and case studies based on real-world scenarios. Research, internships, and community service help engineering students develop critical literacy.

Engineering students at the university level experience a notable enhancement in their intrinsic motivation to acquire knowledge. Students who are intrinsically motivated exhibit a genuine enjoyment for learning, independent of any external incentives or pressures. Intrinsic motivation has a notable influence on the development of critical literacy skills [21]. Intrinsic motivation serves as a catalyst for fostering curiosity and promoting the pursuit of new knowledge and experiences. Engineering students who are intrinsically motivated demonstrate a strong inclination towards acquiring novel knowledge, embracing diverse perspectives, and considering alternative viewpoints. The cultivation of curiosity in students fosters an inclination to inquire about assumptions, interrogate established knowledge, and cultivate the ability to critically analyze and interpret information. The process of learning is enhanced through the presence of intrinsic motivation. Intrinsically motivated engineering students will study harder. They enjoy complex engineering topics, interdisciplinary relationships, and evaluation of technical information. Deep engagement helps students think critically, analyze information from multiple sources, and evaluate evidence. Intrinsic motivation fosters autonomy and ownership of learning. Intrinsically motivated engineers feel more in control. They set goals, choose strategies, and own their learning. Students can engage in critical literacy practices that are meaningful to them, improving understanding and analysis of technical content.

Individuals in this context exhibit a strong appreciation for the acquisition of knowledge, personal growth, and the exploration of novel viewpoints. The cultivation of critical literacy skills is facilitated by the consistent application of critical analysis, reflection, and evaluation throughout students' academic and professional trajectories [16]. Educators in the realm of higher education possess the capacity to inspire engineering students and cultivate their critical literacy skills through the creation of tailored learning opportunities that align with their individual interests and objectives. Real-world engineering challenges, hands-on projects, student-led investigations, and interdisciplinary perspectives can accomplish this. Engineering students' critical literacy can be enhanced by giving them choice and autonomy in tasks, creating a supportive learning environment, and celebrating their intrinsic motivation.

When engineering students learn computer literacy skills, they are able to find and evaluate knowledge on their own. Independent learning gives students the chance to explore on their own, which lets them dig deeper into personal interests, think critically, and understand things more deeply. Effective information retrieval and application skills give students the power to take charge of their own education and encourage them to be aggressive about learning on their own [68–70]. The present study looked into how learning disposition and critical reading are related. However, this study's results show that information literacy did not have a calming effect. People who have improved their information literacy skills are more likely to have the skills they need to take part in critical literacy practices. It's important to note, though, that these people's level of willingness to learn might not necessarily have an effect on their critical reading skills [35]. This may be because students' learning readiness has been the thing that has a direct effect on critical literacy, so it was found that moderating information literacy had little effect on the performance of students' readiness and students' critical literacy.

Information literacy moderating intrinsic learning motivation and critical literacy has a strong influence, critical literacy requires students to evaluate information for fairness, accuracy, and inclusiveness and consider the ethical implications of their work. Information literacy is a very important skill for engineering students to have in order to find and use relevant information successfully. Students acquire knowledge about research inquiries, appropriate search terms, and sophisticated search methodologies. These strategies facilitate the exploration of diverse perspectives, the examination of alternative viewpoints, and the critical analysis of information by students. The inclusion of information literacy instruction within higher education can facilitate the cultivation of critical thinking skills and information literacy among technical students. Effective instructional approaches to information literacy, including the instruction of search strategies, the promotion of critical evaluation skills for assessing sources, and the implementation of practical research projects [39]. Information literacy and critical literacy in engineering education can be enhanced by discussing the ethical use of information, teaching proper citation, and promoting digital literacy.

Engineering students who possess proficient information literacy skills are more adept at locating pertinent information from diverse sources, retrieving said

information, and critically assessing its validity and reliability. Consequently, individuals are able to establish a robust knowledge base, thereby enhancing their preparedness to actively participate in the critical analysis and evaluation of technical material. Students who possess information literacy skills are more inclined to have the necessary access to resources that facilitate the proficient development of critical literacy abilities [42]. The reason for this is that information literacy equips students with the essential skills to navigate the intricate landscape of information. Research skills play a crucial role in fostering critical literacy as they encourage the utilization of evidence-based methodologies when addressing intricate engineering issues.

V. Conclusion and Suggestion

This study investigated the relationship between readiness for learning and the motivation to learn, as well as the factors that influence the development of innate critical literacy. They can learn new things and make important contributions more easily now that there are new technologies. These changes have helped them in many ways to come up with new ideas. We use statistics and other types of research to get a better look at the study's results. If students are ready for digital learning, they will be more motivated and able to understand and think about what they are learning better. It is directly related to how ready someone is to learn if they want to learn. Students who are self-disciplined and good at keeping things in order are more intrinsically motivated. When a student is intrinsically motivated, they are responsible for their actions, think logically, solve problems quickly, and work hard to do well in school. Students should be put into groups based on how well they can learn. This will help you make sure that their projects and activities go well. This helps people learn on purpose. Criticism and being ready to learn go hand in hand because students who can do things on their own are better at solving problems and thinking critically. Students who are self-motivated like to read, work hard at tough tasks, are sure of themselves and take charge of their own learning. Students who want to learn critical literacy will be more interested in reading and other social activities, which is good for society as a whole.

The study found that when information literacy programs are designed to be engaging, students are more inclined to proactively plan and make use of learning opportunities both inside and outside the classroom. Evidence indicates that information literacy does not have a moderating effect on learning readiness and intrinsic learning motivation. Compelling evidence indicates that incorporating motivating design and promoting learning can enhance students' motivation and engagement in acquiring information literacy. Studies establish a correlation between information literacy and critical literacy. The relationship between information literacy, learning readiness, and critical literacy is unclear. Hence, the available evidence fails to establish a causal relationship between information literacy and the enhancement of learning readiness and critical literacy and does not quantify the extent of this impact. Further investigation is required to definitively determine the nature of this interaction. The study demonstrates that incorporating motivational design into information literacy sessions can enhance students' inherent and external motivation to structure and offer learning opportunities. Comprehending the distinction between information literacy and critical thinking is of utmost importance.

The study's sample was limited to one university, limiting its generalizability. Researchers can better understand student subgroup strengths and weaknesses by defining replicable types. They can tailor therapy to each subgroup with this knowledge. Despite awareness efforts, these students may perform poorly and remain disengaged. As their profiles show, they lack motivation. These findings match research that lack of desire and resistance to learning preparation rarely leads to poor academic achievement and disengagement. Thus, the intervention should emphasise motivation and learning readiness. Today's culture is shaped by advanced technology. True today. Many people use different instructional technology in education. The technologies aim to simplify information sharing. There is growing interest in understanding how well people use technology in education and teaching. This trend may inspire teaching methods.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Hendra Hidayat wrote the paper, assisted in the data analysis, and did all the necessary revisions to comply with the standards of the journal. On the other hand, Nur Hidayah, Nandang Rusmana, Afdal facilitated the gathering of data together with the former, assisted in the data analysis. Next, Rezki Hariko, Reza Tririzky facilitated the reviewed/edited the final version of the paper. All authors had approved the final version.

Funding

This worked supported by the Institute for Research and Community Service, Universitas Negeri Padang for funding this study, which has funded this research with grant number: 1534/UN35.15/LT/2023.

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