

## Improving Integral Concept Understanding Ability through ICT: Systematic Literature Review

Lina Nurhayati<sup>1\*</sup>, Nurmala Setianing Putri<sup>2</sup>, Bill Chairy Rizki Bustaren<sup>3</sup>

<sup>1</sup>Universitas Sangga Buana

<sup>2,3</sup>Universitas Pendidikan Indonesia

\*) lina270284@gmail.com

### Abstract

Understanding the concept of integral is critical for engineering students, particularly civil engineering students. Many civil engineering students struggle to understand the concept of antiderivatives and the procedure for calculating integral. The objective of this study was to examine if technology, especially information and communication technology (ICT), can significantly improve civil engineering students' knowledge of the integral. The research sample comprises ten studies that employ diverse research approaches to investigate the impact of integrating ICT, including GeoGebra, Maple, MATLAB, and Other technologies, on enhancing knowledge of integral concepts. The method employed was a Systematic Literature Review (SLR) that followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. ERIC, SCOPUS, and Google Scholar-indexed journals published between 2012 and 2023 were sampled. The findings revealed that studying with Maple and Integrating technology has a significant impact on helping students comprehend integrals. It is demonstrated by the effect size values of 1,23 and 1,26, respectively.

**Keywords:** ICT, Integral, PRISMA, Systematic literature review.

### Introduction

Integrals are an essential concept for successfully mastering the fields of science and technology (Bingimlas, 2009; Zakaria & Salleh, 2015a; Lawrence & Tar, 2018; Pedro et al., 2018; Bower, 2019; Aldammagh et al., 2021), including civil engineering. Civil engineering courses that deal with force and bending moments are in critical need of integral concepts (González-Martin & Gomes, 2017; OBrien et al., 2018; Sharifi & Toopchi-Nezhad, 2018; Marini et al., 2022). Civil engineering uses integrals in the case of mechanics of materials and electromagnetics (Das & Saha, 2018; Gonzalez-Martin & Hernandez-Gomes, 2019; Srivastava, 2021; Chaudhuri et al., 2022). In addition, integrals must be mastered by civil engineering students in studying the finite element method (Chai, 2020; Faulkner et al., 2020; Akin, 2022;) as well as in structural analysis courses (Kassimali, 2018; Rangel & Martha, 2019; García-Alberti et al., 2021; Karnovsky & Lebed, 2021). Therefore, it is essential for students studying civil engineering to excel in learning integrals.

Many students fall behind in the Civil Engineering course (Faulkner et al., 2020). This is owing to the significant number of students who struggle to understand the integral concept. According to Nurhayati, Suryadi, et al. (2023), civil engineering students face conceptual and psychological ontogenic learning challenges. In line with this, Nurhayati, Priatna, et al. (2023) discovered epistemic learning barriers in civil engineering students when grasping the integral concept. Students frequently struggle to study integrals due to a lack of understanding of integral concepts.

Many research efforts have been made to improve students' understanding of integrals, including by using Information and Communication Technology (ICT) assistance such as GeoGebra (Attorps et al., 2013; Tatar & Zengin, 2016; Machromah et al., 2019; Kado et al., 2022), Maple (Awang-Salleh & Zakaria, 2012; Attorps et al., 2013; Zakaria & Salleh, 2015b; T. S. Salleh & Zakaria, 2016), MATLAB (Majid et al., 2012) and integrating technology (Awang-Salleh & Zakaria, 2012; Milenković et al., 2022). The novelty of this research is that the researchers synthesized these various studies to analyze the results of research efforts made to improve civil engineering students' understanding of integral concepts using ICT.

Many studies have been conducted on the understanding of integral concepts using ICT both in higher education in general and in civil engineering students. There has not, however, been a comprehensive Systematic Literature Review (SLR) of all relevant research findings. Thus, SLR needs to be conducted to obtain more comprehensive conclusions so that it can represent all existing related research, minimize research bias and the level of researcher subjectivity. As the results, an important SLR stage is data collection in the form of study results on the use of ICT that aids in a better understanding of the integral concept. Based on the research data gathered the researcher posed the following research questions:

1. What is the overview of the effect of ICT on improving the understanding of integral concepts based on the type of ICT?
2. What is the effect size of each type of ICT on improving the understanding of integral concepts?

## **Method**

Systematic Literature Review (SLR) was employed as the research method. The SLR research method is a systematic approach to researching a topic, examining various

studies to see if the findings can answer specific research questions (Xiao & Watson, 2019). This research approach is transparent and can be trusted, allowing it to be used again (Juandi, 2021). SLR is a research approach that tries to comprehensively discover and synthesize research that pertains to the researcher's specific questions by employing a systematic, transparent, and repeatable procedure at each step of the process (Ferk Savec & Mlinarec, 2021).

The research was carried out in the following stages: Journal articles were collected from electronic databases registered and indexed by SCOPUS, ERIC, and Google Scholar. The use of these three databases was done to ensure all articles were collected completely, while still ensuring that no duplicate articles were used. Afterward, articles related to the research questions and those that met the criteria were studied further based on the title and abstract of the articles, and the findings of the article data analysis were interpreted. Furthermore, the final stage involved generating conclusions. The following are the criteria for selecting articles and the flow of article selection using the PRISMA diagram:

a. Inclusion Criteria

Table 1 shows the research objectives' inclusion criteria for acquiring article data.

**Table 1.** Inclusion Criteria

No	Inclusion Criteria
1	Articles published in Journals or Proceedings
2	Articles are written in English
3	Articles published between 2012 and 2023
4	Articles are published in three databases: Scopus, ERIC or Google Scholar
5	Research articles were conducted on ICT and understanding of integral concepts.

b. Exclusion Criteria

Exclusion criteria are characteristics used to identify potential research articles that should not be included in the study because they do not relate to the research objectives. These criteria can be seen in Table 2 below

**Table 2.** Exclusion Criteria

No	Exclusion Criteria
1	Articles published in books, theses/dissertations, chapters of a book, etc., that are not journals or proceedings.
2	Articles that are not written in English.
3	Articles not published between 2012 and 2023.
4	Articles have not been published in Scopus, ERIC, or Google Scholar databases.
5	Research conducted is not about ICT and understanding of integral concepts.

c. Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA)

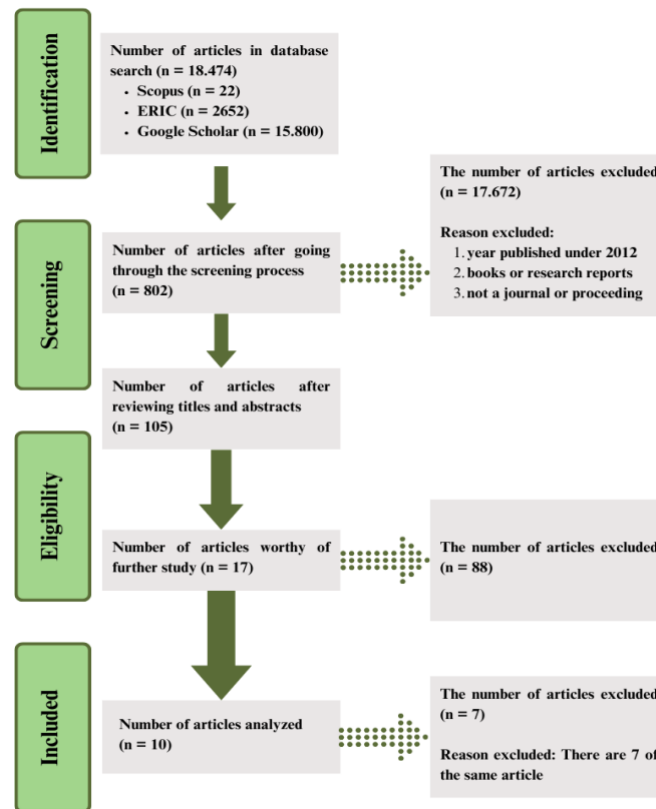


Figure 1. PRISMA Flow

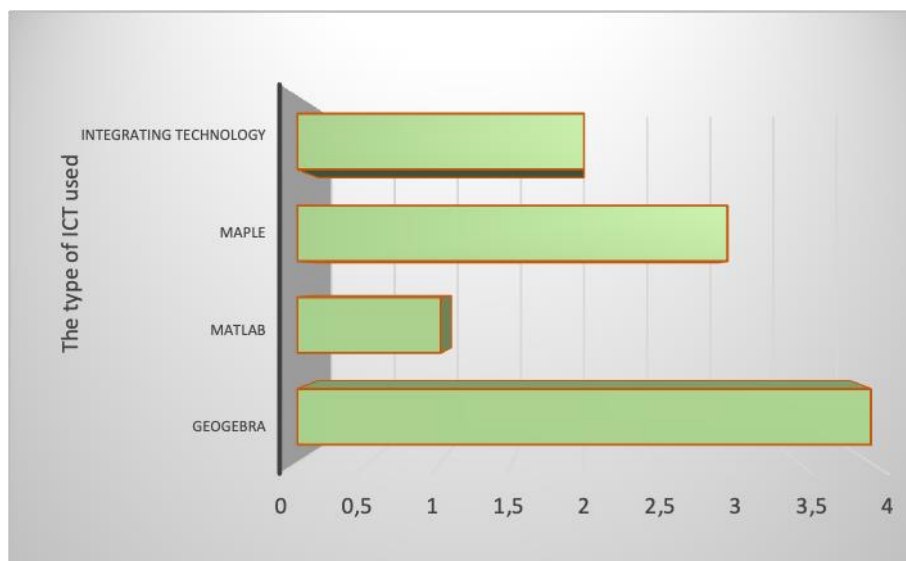
In selecting the research articles, the approach used to analyze the articles was the PRISMA approach. PRISMA is a standardized peer-review method that uses a list of guidelines to facilitate the quality assurance and revision process (Conde et al., 2020; Mohamed et al., 2022). The stages of PRISMA are identification, screening, eligibility, and inclusion (Mohamed et al., 2022). Figure 1 below explains the PRISMA stages carried out in the research process.

The first stage of PRISMA is identification. In this stage, articles were searched through three databases: SCOPUS, ERIC, and Google Scholar. At this stage, articles were searched using the keywords ("integral" OR "ANTIDERIVA-TIVE") AND ("conceptual understanding" OR "theoretical understanding") AND ("ICT" OR "Technology"). The data found were 18.474 articles, with details of 22 articles indexed by SCOPUS, 2652 articles from ERIC, and 15.800 articles found on Google Scholar. Furthermore, at the screening step, by creating an automatic filter for the year of publication of articles in the range 2012-2023 and journal articles or proceedings, there were 17.672 improper data, resulting in only 802 articles being filtered.

Researchers checked the article's eligibility during the eligibility stage by looking at the title and abstract of the article data. At this stage, articles were eliminated if they did not meet the established inclusion criteria, namely not explicitly examining the use of Information and Communication Technology (ICT) in improving integral conceptual understanding. Furthermore, articles that focused solely on the procedural aspects of integral calculations without examining conceptual understanding were also excluded at this stage. This filtering resulted in 105 article data. Furthermore, at the full-text review stage, articles were eliminated if they did not present adequate empirical data, did not clearly explain the research design and measurement instruments for integral conceptual understanding, had a research context that was too general and not directly related to ICT-assisted integral learning, or did not allow for comparative analysis based on pre-test and post-test data. Thus, only 17 articles met the criteria. The final stage involved examining all of the data again, and 7 articles were the same, leaving only 10 articles to be further studied by the research objectives.

## Results and Discussion

The data analysis results address the two study questions posed. The first section describes the influence of ICT on improving understanding of integral concepts based on the type of ICT used. Only 10 articles fulfilled the requirements based on data searches from 2012 to 2023. The ten articles were divided into four types of ICT found to increase understanding of integral concepts. Figure 2 depicts the different forms of ICT and the number of articles analyzed.



**Figure 2.** Number of articles

a. Overview of the Effect of GeoGebra on Understanding Integral Concepts

According to the findings of 11 years of data collecting, Geogebra is the most widely utilized ICT in enhancing understanding of integral concepts. GeoGebra is a free online software tool that helps different classes and teachers learn geometry (Alqahtani & Powell, 2016), algebra, and calculus (Arbain & Shukor, 2015; Weinhandl et al., 2020). There are four papers reviewed regarding the use of Geogebra for improving understanding of integral concepts. Table 3 below provides details of the article data regarding the effect of Geogebra on learning integral.

**Table 3.** GeoGebra Review

Article Code	Article Title	Research Method	Research Sample	Country	Year
GG1	Varied Ways to Teach the Definite Integral Concept	Phenomenographic research tradition	85 students	Sweden	2013
GG3	Effectiveness of GeoGebra in Developing the Conceptual Understanding of Definite Integral at Gongzim Ugyen Dorji Central School, in Haa Bhutan	Quasi-experimental static-group comparison design	94 grade 12 students	Bhutan	2020
GG2	Conceptual Understanding of Definite Integral: An Experimental Study Using Geo-Gebra At University Level	Quasi-experimental design	52 Students	Nepal	2021
GG4	How Can Blended Learning and GeoGebra Promote Students' Achievement in Calculus during the COVID-19 Pandemic?	Pseudo-experimental research	114 students	Indonesia	2023

The first study was conducted in Sweden in 2013. The study employed a phenomenographic research methodology. The findings of this study suggest that learning provides an effective variation pattern in understanding integral concepts up to a significant level (Attorps et al., 2013). In line with this, GeoGebra offers students a variety of learning opportunities and experiences (Bayaga et al., 2019; Celen, 2020; Tamam & Dasari, 2021).

The second study was conducted in Bhutan in 2020. The quasi-experimental static-group comparison design method was employed in this study. The answer to the research question, “What is the impact of GeoGebra software on the achievement of conceptual

understanding of specific integrals?” is that GeoGebra-assisted instruction supports meaningful and conceptual student learning. In line with this, learning with GeoGebra is a multidimensional method, allowing for both visual and algebraic representations of concepts, as well as connecting visual representations to their corresponding definitions, which leads to significant advances in the teaching and learning process. It was because one of the learning methodologies utilizing Geogebra technology can assist students in applying and analyzing concepts (Binti Misrom et al., 2020).

The third study on Geogebra was conducted in Nepal in 2021. The research was conducted using the Quasi-experimental design methodology. The research was conducted by giving a definite integral test for data collection (Adhikari, 2021). In line with the results of his study, computer-assisted teaching methods using GeoGebra were found to contribute positively to the successful teaching of spesific integral topics (Attorps et al., 2013). Likewise, learning using GeoGebra can create a fun and engaging learning atmosphere ((Dockendorff & Solar, 2018; Septian et al., 2020) with dynamic learning elements, providing visualization in learning mathematics through direct interactive (Pinkernell et al., 2023).

The fourth study was conducted in 2023 in Indonesia, involving 224 students, with 114 randomly selected to participate in additional tests. A pseudo-experimental research method was utilized in this study. According to the study's findings, learning integral concepts in GeoGebra-based calculus courses can significantly enhance student learning outcomes (Syarifuddin et al., 2023). According to the findings of past studies, GeoGebra is one application that can aid in the visual understanding of mathematical concepts, particularly integrated topics (Negara et al., 2022).

Based on the four Geogebra studies mentioned above, all research findings show that learning using GeoGebra produces considerable positive effects. Table 4 displays the average Pre-Test and Post-Test results for the four articles.

**Table 4.** Presentation of GeoGebra-based Integral Concept Understanding Ability Score

No	Article Code	Average Value (%)		Increase (%)
		Pre-Test	Post-Test	
1	GG1	66,01	73,12	7,11
2	GG3	7,58	23,83	16,25
3	GG2	33,89	41,00	7,11
4	GG4	60,46	66,92	6,46
	<b>Average</b>	41,99	51,22	9,23

From the four data, an increase with an average of 9,23% was obtained. The results indicate that learning with GeoGebra has a significant positive impact on the understanding of integral concepts.

b. Overview of the Effect of Maple on Integral Concept Understanding

Maple is an application that assists in the learning process. Maple documents are capable of combining numerical and symbolic calculations, exploration, mathematical notation, documentation, pictures, and animations that may be shared and reused (Zotos, 2007). The findings of an 11-year study of the article data yielded three articles about Maple-based integral learning. Table 5 describes all of the data that was analyzed.

Table 5. Maple Review

Article Code	Article Title	Research Method	Research Sample	Country	Year
MP1	Enhancing Students' Understanding in Integral Calculus through the Integration of Maple in Learning	Quasi-experimental non-equivalent control group design	51 students	Malaysia	2012
MP2	Implementing Interactive Information Technologies When Learning Integral Calculus in Teaching Further Mathematics	The educational experiment	125 students	Russia	2018
MP3	Use of Maple Software to Reduce Senior High School Students' Errors in Integral Calculus	A quasi-experimental non-equivalent group design research	80 high school students	Ghana	2021

The first study was conducted in Malaysia in 2012. According to Salleh's research, students struggle with integration, which is the opposite of derivative (Salleh & Zakaria, 2013). Lecturers have employed a range of methods to help students grasp the concept of integral. Every lecturer is responsible for providing the best possible instruction to support students in their learning process (Juma et al., 2022). Learning with the use of technology, such as Maple, which is specifically designed for the learning process, can have a positive impact on students' understanding of integral concepts.

The second study was undertaken in Russia in 2018 at Sholom-Aleichem Priamursky State University, Moscow Civil Engineering University, and Omsk State Technical University. The study found that Maple-based technology has a good influence on learning about integral. The interactive educational method that utilizes Maple can encourage student involvement and independent learning, helping students comprehend important topics more thoroughly (Eyrikh et al., 2020).

The third study was conducted in 2021 in Ghana. The study's results indicated that learning integral concepts using Maple software can help explain them more effectively

and comprehensively (Sallah, 2021). Based on the three studies, the use of Maple for integral learning has a positive impact on understanding integral concepts. In addition to interactive and fun learning, it gives significant changes. It can be seen from Table 6 below.

**Table 6.** Presentation of Maple-based Integral Concept Understanding Ability Score

No	Article Code	Average Value (%)		Increase (%)
		Pre-Test	Post-Test	
1	MP1	7,08	19,87	12,79
2	MP2	35,00	52,00	17,00
3	MP3	4,18	25,72	21,52
	<b>Average</b>	15,42	32,53	17,11

The average increase from the three findings obtained was 17,11%. It demonstrates that studying using Maple has a significant impact on the comprehension of integral concepts.

c. Overview of the Effect of MATLAB on Integral Concept Understanding

MATLAB is an example of ICT software. MATLAB is utilized as a dynamic visual tool to examine how students' visual skills are employed in teaching and learning activities (Amevor et al., 2021). There is one article that contains data suitable for evaluation in this study using MATLAB. Table 7 shows the data from the article.

**Table 7.** MATLAB Review

Article Code	Article Title	Research Method	Research Sample	Country	Year
ML1	A Study of The Effects of Using Matlab as A Pedagogical Tool for Engineering Mathematics Students	Mix method	81 students	Saudi Arabia	2012

A study on integral learning using the MATLAB application was conducted in Saudi Arabia in 2012. The research method employed was a mixed-methods approach. The use of MATLAB software has improved students' conceptual understanding despite their weak math skills (Majid et al., 2012). Table 8 below states the Pre-Test and Post-test data from the study.

**Table 8.** Presentation of MATLAB-based Integral Concept Understanding Ability Score

No	Article Code	Average Value (%)		Increase (%)
		Pre-Test	Post-Test	
1	ML1	53,12	62,91	9,79
	<b>Average</b>	53,12	62,91	9,79

Based on the data obtained, the increase was 9,79%. The results show that integral learning using MATLAB has a significant effect.

d. Overview of the Effect of Integrating Technology on Understanding Integral Concepts

Students' views toward computers were found to be positive, with low levels of computer aversion and average levels of familiarity with computers (Zakaria & Salleh, 2015a). Based on these findings, it is possible to improve calculus instruction and implementation using computers. Two articles can be studied in terms of the impact of integrating technology, specifically computers, on the understanding of integral concepts. Table 9 has an explanation of the data. The first study was conducted in Malaysia in 2012, using a quasi-experimental design (Awang & Zakaria, 2012). In the study, teaching and learning of integrals were conducted through a mixed approach that combined existing lecture teaching models with math software as a learning aid. In line with that, the second study was researched in Serbia in 2020. Based on the results of SLR involving 10 articles, the results have shown the positive impact of integrating technology strategies on student understanding by incorporating computers into the learning of integral concepts (Milenković et al., 2022). Significant changes in both datasets can be seen in Table 10 below.

**Table 9.** Integrating Technology Review

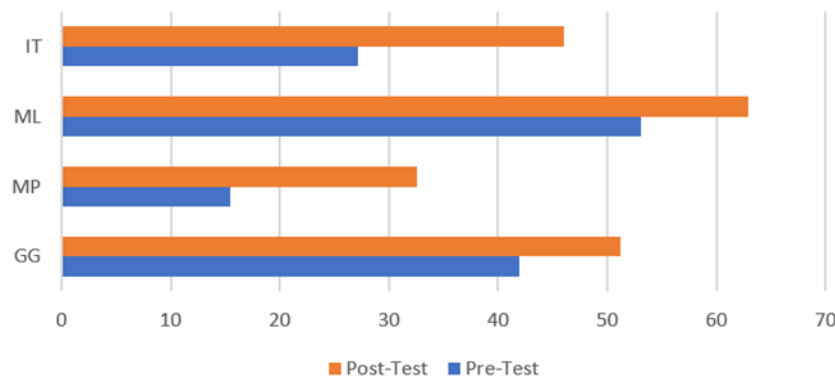
Article Code	Article Title	Research Method	Research Sample	Country	Year
IT1	The Effects of Integrating Technology on Students' Conceptual and Procedural Understandings in Integral Calculus	A quasi-experimental	50 students	Malaysia	2012
IT2	On the influence of software application for visualization in teaching double integrals	A quasi-experimental	103 students	Serbia	2020

**Table 10.** Presentation of Integral Concept Understanding Ability Score Based on Integrating Technology

No	Article Code	Average Value (%)		Increase (%)
		Pre-Test	Post-Test	
1	IT1	8,66	35,73	27,07
2	IT2	45,65	56,27	10,62
	<b>Average</b>	27,16	46,00	18,84

e. Effect Size

Based on the analysis and calculation of data obtained from the four types of ICT, the Pre-Test and Post-Test data are presented in Figure 3 as follows.



**Figure 3.** The Difference in the Average Measurement of ICT-Based Learning

Based on the data obtained, the effect size value was then calculated. This effect size value determines the magnitude of the influence of a variable on other variables (Becker, 2000). The size of the difference does not depend on the effect of sample size. Effect size is influenced by the Pre-Test and Post-test learning values of each type of ICT provided. The effect size value in the t-test used Cohen's formula as follows:

$$d = \frac{M_1 - M_2}{\sigma_{pooled}} \quad (1)$$

with:

$d$  = Cohen's  $d$  effect size       $M_1$  = mean treatment condition  
 $M_2$  = mean control condition       $\sigma_{pooled}$  = Standard deviation

$$\sigma_{pooled} = \sqrt{\frac{\sigma_1^2 + \sigma_2^2}{2}} \quad (2)$$

with the criteria for interpreting the value of Cohen's  $d$  in Table 11 below

**Table 11.** Interpretation table of effect size

Effect Size	Interpretation
$0 < d < 0.2$	Small
$0.2 < d \leq 0.5$	Medium
$0.5 < d \leq 0.8$	Large
$d > 0.8$	Very Large

Cohen's  $d$  above was calculated using the average pre-test and post-test scores collected from multiple studies without accounting for the original standard deviation, individual sample sizes, or variations in study design. This was done to ensure the completeness of the data available in the studies being synthesized. This approach may introduce bias, which is a limitation of this study. Despite its limitations, the study still provides a comprehensive synthesis. The main contribution of this SLR lies in systematically

mapping the characteristics of ICT interventions in integral learning, especially for civil engineering students.

Table 12 below states the effect size values of each type of ICT-based learning.

**Table 12.** Effect size values based on type of ICT

Type of ICT	Average value (%)		Difference (%)	d	Criteria
	Pre-Test	Post-Test			
GG	41,99	51,22	9,23	0,42	Medium
MP	15,42	32,53	17,11	1,23	Very large
ML	53,12	62,91	9,79	0,17	Small
IT	27,16	46,00	18,84	1,26	Very large

According to Table 12, studying with Maple and integrating technology has a very high effect size value. Learning with GeoGebra gives an influence on understanding the concept of integral with a medium effect size value. This is consistent with the findings of Sallah et al., (2020) who found that Maple is recommended as software that assists students and teachers in the learning of integral. For further research, factors such as education level, duration of intervention, and other factors can be analyzed to obtain more in-depth synthesis results.

### Conclusion and Suggestion

The study concludes that the ICT-based learning of integrals, utilizing Maple software and Integrating technology, has a very high influence, with effect size values of 1,23 and 1,26, respectively. However, the use of other tools, such as GeoGebra and MATLAB, has a considerable effect, albeit with moderate and low effect size values. The limitation of this study is the small number of articles found and the limited data required. Suggestions for further research include determining the magnitude of the effect of employing each type of ICT for learning or other abilities.

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