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THE EFFECT OF DIGITAL LITERACY ON STUDENTS' LEARNING OUTCOMES IN A GEOGRAPHIC INFORMATION SYSTEMS COURSE IN THE ENVIRONMENTAL ENGINEERING STUDY PROGRAM AT UNIVERSITAS HAMZANWADI

PENGARUH LITERASI DIGITAL TERHADAP HASIL BELAJAR MAHASISWA PADA MATA KULIAH SISTEM INFORMASI GEOGRAFIS DI PROGRAM STUDI TEKNIK LINGKUNGAN UNIVERSITAS HAMZANWADI

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Abstract

The rapid development of information and communication technologies has significantly transformed higher education. Teaching and learning processes are increasingly supported by digital platforms, Learning Management Systems (LMS), and abundant online learning resources. In this context, university students are required to possess adequate digital literacy, particularly in software- and spatial-analysis-based courses such as Geographic Information Systems (GIS), which is a key course in the Environmental Engineering curriculum. This study aimed to analyze the effect of digital literacy on students' learning outcomes in a GIS course offered in the Environmental Engineering Study Program at Universitas Hamzanwadi. A quantitative approach with a correlational design was employed. The population consisted of students enrolled in the GIS course in the odd semester of the 2024/2025 academic year, and all 44 students were taken as the sample using a saturated sampling technique. Digital literacy was measured using a Likert-scale questionnaire (1–5) covering technical skills, information search and evaluation, information management, online communication and collaboration, and ethical use of digital media, while learning outcomes were obtained from the final course grades. The data analysis showed that the mean score of students' digital literacy was 3.6 (moderately high), with a standard deviation of 0.45, whereas the mean GIS course grade was 78.5 with a standard deviation of 6.8. Pearson correlation analysis indicated a positive and significant relationship between digital literacy and learning outcomes ($r = 0.62$; $p < 0.01$). Simple linear regression further revealed that digital literacy accounted for approximately 38% of the variance in learning outcomes ($R^2 = 0.38$), with the regression equation $\hat{Y} = 52.3 + 7.3X$. These findings highlight the importance of strengthening students' digital literacy in GIS instruction through training, project-based assignments, and the optimal utilization of Learning Management Systems.

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Keywords : digital literacy, learning outcomes, Geographic Information Systems, ICT-based learning, environmental engineering.

Abstrak

Perkembangan teknologi informasi dan komunikasi telah mengubah proses pembelajaran di perguruan tinggi yang semakin didukung oleh platform digital, Learning Management System (LMS), dan sumber belajar daring. Kondisi ini menuntut mahasiswa memiliki literasi digital yang memadai, terutama pada mata kuliah berbasis perangkat lunak dan analisis spasial seperti Sistem Informasi Geografis (SIG) yang merupakan mata kuliah kunci dalam kurikulum Teknik Lingkungan. Penelitian ini bertujuan menganalisis pengaruh literasi digital terhadap hasil belajar mahasiswa pada mata kuliah SIG di Program Studi Teknik Lingkungan Universitas Hamzanwadi. Penelitian menggunakan pendekatan kuantitatif dengan desain korelasional. Populasi penelitian adalah seluruh mahasiswa yang memprogram mata kuliah SIG pada semester ganjil 2024/2025 dan seluruhnya sebanyak 44 orang dijadikan sampel dengan teknik sampling jenuh. Literasi digital diukur menggunakan angket skala Likert 1–5 yang mencakup dimensi kemampuan teknis, pencarian dan evaluasi informasi, pengelolaan informasi, komunikasi dan kolaborasi daring, serta etika penggunaan media digital, sedangkan hasil belajar diperoleh dari nilai akhir mata kuliah. Hasil analisis data menunjukkan bahwa skor rata-rata literasi digital mahasiswa sebesar 3,6 (kategori cukup tinggi) dengan simpangan baku 0,45, sedangkan rata-rata nilai mata kuliah SIG sebesar 78,5 dengan simpangan baku 6,8. Analisis korelasi Pearson menunjukkan adanya hubungan positif yang signifikan antara literasi digital dan hasil belajar ($r = 0{,}62$; $p < 0{,}01$). Analisis regresi linear sederhana lebih lanjut menunjukkan bahwa literasi digital menjelaskan sekitar 38% variasi hasil belajar ($R^2 = 0{,}38$) dengan persamaan regresi $\hat{Y} = 52{,}3 + 7{,}3X$. Temuan ini menegaskan pentingnya penguatan literasi digital dalam pembelajaran SIG melalui pelatihan, penugasan berbasis proyek, dan pemanfaatan LMS secara optimal.

Kata Kunci : literasi digital, hasil belajar, Sistem Informasi Geografis, pembelajaran berbasis TIK, teknik lingkungan.

1. INTRODUCTION

Over the past decade, the development of information and communication technologies (ICT) has driven a substantial transformation in higher education. Teaching and learning processes are no longer dependent solely on conventional face-to-face meetings but are increasingly integrated with digital platforms, Learning Management Systems (LMS), and abundant online learning resources. Universities are therefore required to ensure that students have sufficient capacity to participate actively in these digital learning environments. A growing body of research indicates that the success of learning in the digital era is strongly influenced by students' ability to use technology and information effectively (Georgopoulou et al., 2025; Kayyali, 2024; Wirasti & Irawan, 2024).

In this context, digital literacy has emerged as a key competency that must be systematically developed in higher education. Digital literacy is not limited to the technical ability to operate hardware and software; it also encompasses skills in accessing, evaluating, organizing, producing, and communicating digital information in a critical and ethical manner (Gutiérrez-Ángel et al., 2022; Yuan et al., 2025). Studies in Indonesia show that university students' digital literacy profiles are diverse: some already have strong abilities, whereas others

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still struggle to filter information, manage learning resources, and utilize digital platforms for academic purposes (Mariyani & Triyani, 2023; Nahdi & Jatisunda, 2020).

Empirical evidence consistently suggests that digital literacy is positively related to academic achievement and student engagement in learning activities. Latip et al. (2022) found that digital literacy significantly influenced learning outcomes in chemistry instruction. Yuan et al. (2025) reported that digital literacy contributed to learning outcomes through the mediating roles of self-efficacy and the digital learning climate. Studies in language learning and educational technology also indicate that students with higher levels of digital literacy are better able to capitalize on online resources, complete project-based tasks, and participate actively in virtual discussions (Pertiwi & Rodliyah, 2022; Wirasti & Irawan, 2024). Similar findings have been reported in various national studies examining the relationships among digital literacy, self-regulated learning, motivation, and learning outcomes across different study programs (Dinata, 2021; Efendi & Hanif, 2022; Manubey et al., 2022; Rini et al., 2022; Junita et al., 2025; Hidayad et al., 2025; Sianturi et al., 2025; Suziani et al., 2025; Wahyuni et al., 2022). However, most of these studies have not specifically focused on courses that heavily rely on specialized software, such as Geographic Information Systems (GIS).

GIS courses have distinctive characteristics because they integrate spatial concepts with the use of mapping and geospatial analysis software. Mastery of GIS requires students to manage spatial data, perform digitization, produce map visualizations, and conduct spatial analyses using specialized software. A number of studies have shown that the use of GIS in geography and engineering education can enhance students' conceptual understanding and spatial thinking skills (Bondarenko, 2025; Meechandee & Meekaew, 2025; Yang et al., 2024). However, the success of GIS learning largely depends on students' digital literacy, including both technical competencies and the ability to manage information based on geospatial data (Muzaki et al., 2022; Purwanto, 2021).

In the field of environmental engineering, GIS is widely used to map air and water pollution, analyze flood vulnerability, determine locations for waste treatment facilities, and design green infrastructure based on spatial data. Accordingly, GIS proficiency constitutes an essential competency for environmental engineering graduates in planning and managing the environment in a sustainable manner. Inadequate digital literacy may hinder students' ability to engage with GIS software, interpret spatial information, and complete analytical tasks effectively.

Within higher education institutions, including the Environmental Engineering Study Program at Universitas Hamzanwadi, considerable variation can be observed in students' digital literacy levels. Students with strong ICT backgrounds tend to adapt more easily to the demands of GIS learning, whereas those who are less familiar with software and digital learning resources may encounter challenges in following the course optimally. To date, empirical studies that specifically analyze the relationship between digital literacy and students' learning outcomes in GIS courses in the context of regional universities, particularly in East Lombok, remain limited. Previous research in Indonesia has primarily focused on pre-

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service teachers, virtual classroom-based learning in general, or digital literacy in non-technical courses (Latip et al., 2022; Mariyani & Triyani, 2023; Nahdi & Jatisunda, 2020).

To address this gap, the present study was conducted to empirically examine the extent to which digital literacy influences students' learning outcomes in a GIS course at Universitas Hamzanwadi. Specifically, the study aimed (1) to describe the levels of digital literacy and GIS learning outcomes among students, and (2) to analyze the relationship and effect of digital literacy on learning outcomes in the course. Based on the theoretical framework and previous empirical findings, the hypothesis proposed in this study was that digital literacy has a positive and significant effect on students' learning outcomes in the GIS course.

2. RESEARCH METHOD

a. Research Design

This study employed a quantitative approach with a correlational design (Amelia et al., 2023). The main purpose was to determine the relationship and effect of digital literacy (independent variable, X) on students' learning outcomes in a GIS course (dependent variable, Y). A quantitative approach was chosen because it allows for an objective and measurable description of the degree of association between variables through systematic statistical analysis. In a correlational design, the researcher does not manipulate the independent variable but instead observes empirically how variations in students' digital literacy scores are associated with variations in their learning outcomes in the GIS course.

The study did not aim to test the effectiveness of a specific treatment but rather to identify the pattern of association and the magnitude of the contribution of digital literacy to learning outcomes. Therefore, measurement was carried out at a single point in time (cross-sectional) with the same group of students, so that the digital literacy scores and learning outcomes analyzed reflected their actual conditions at the end of the course. The correlational design also enabled the use of simple linear regression analysis to estimate the extent to which average learning outcomes might change given an increase in students' digital literacy levels.

b. Population and Sample

The population comprised all students in the Environmental Engineering Study Program who enrolled in the GIS course in the odd semester of the 2024/2025 academic year at Universitas Hamzanwadi. A total of 44 students took the course, and all of them were included as the sample using a saturated sampling technique. This approach was deemed appropriate given the relatively small population size and the intention to describe the entire group of students enrolled in the course.

c. Variables and Instruments

1) Digital literacy (X)

Digital literacy was measured using a Likert-scale questionnaire (1–5) that consisted of items grouped into the following dimensions:

- ✓ Technical skills in operating hardware and software relevant to learning;

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- ✓ Information search and evaluation, including the ability to locate, select, and evaluate the credibility of digital information sources;
- ✓ Information management and organization, such as storing, categorizing, and organizing digital documents;
- ✓ Online communication and collaboration in learning environments;
- ✓ Ethical use of digital resources, including academic integrity and responsible use of media.

Table 1 presents the blueprint of the digital literacy instrument based on dimensions and indicators.

Table 1. Blueprint of the digital literacy instrument

Dimension	Main indicator	Sample item	Number of items	Response scale
Technical skills	Operating devices and basic applications for coursework	"I am able to install and operate learning applications on my laptop or smartphone."	5	Likert scale 1–5 (strongly disagree–strongly agree)
Information search and evaluation	Searching, selecting, and evaluating the credibility of web-based information	"I can distinguish between credible and non-credible online information sources."	6	Likert scale 1–5 (strongly disagree–strongly agree)
Information management and organization	Storing, grouping, and organizing digital files and documents	"I create dedicated folders to store course materials in an organized manner on my device."	4	Likert scale 1–5 (strongly disagree–strongly agree)
Online communication and collaboration	Interacting and collaborating in digital learning environments	"I actively use online platforms (LMS, WhatsApp groups, or email) to discuss and coordinate course tasks."	5	Likert scale 1–5 (strongly disagree–strongly agree)
Ethical use of digital resources	Maintaining academic integrity and adhering to ethical norms in using information	"I always acknowledge sources when citing materials from the internet in my assignments."	4	Likert scale 1–5 (strongly disagree–strongly agree)

Students' digital literacy scores were obtained by summing the item scores and then computing the mean score for each respondent.

2) GIS learning outcomes (Y)

Learning outcomes were measured using the final course grades in the GIS class, expressed on a scale from 0 to 100. The final grade was a composite of scores from assignments, quizzes, midterm examinations, and final examinations, as determined by the course instructor in accordance with the syllabus.

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d. Instrument Validity and Reliability

Prior to the main data collection, the digital literacy questionnaire was subjected to validity and reliability testing. A pilot test was conducted with students who had similar characteristics to the main sample but were not included as respondents in this study. Item validity was examined using Pearson's product–moment correlation between each item score and the total scale score. An item was considered valid if its correlation coefficient was positive and greater than the critical r value at the 0.05 significance level. The results indicated that the majority of items had moderate to high correlation coefficients that were statistically significant, and thus were retained in the instrument. Items with low and non-significant coefficients were reviewed, revised in wording, or removed to ensure accurate measurement of the digital literacy construct.

Internal consistency reliability was assessed using Cronbach's alpha coefficient. The alpha value obtained exceeded 0.80, indicating good to excellent internal consistency according to common criteria in educational research (Sugiyono, 2017). Therefore, the digital literacy instrument used in this study was considered reliable for consistently measuring students' digital literacy levels.

e. Data Collection Procedures

Digital literacy data were collected by administering the questionnaire in the form of a Google Form distributed to all respondents at the end of the course. Before completing the questionnaire, the instructor–researcher explained the purpose of the study, the procedure for responding to each item, and the assurance of confidentiality so that students would feel comfortable and respond honestly. The questionnaire link was shared via the LMS and course communication groups, allowing students to access it using their personal devices (laptops or smartphones).

Each digital literacy item was rated on a 1–5 Likert scale ranging from "strongly disagree" to "strongly agree," producing numerical scores that were subsequently averaged for each respondent.

Data on learning outcomes were obtained from the official academic information system after all assessment components (assignments, quizzes, midterm and final exams) had been completed and verified by the course instructor. The final grades were exported from the academic system into a spreadsheet and cross-checked against manual records to ensure accuracy and consistency. All grades were coded using respondent identification codes without including students' names, thereby enabling anonymous statistical analysis and adhering to ethical research principles.

f. Data Analysis

Data analysis proceeded in several stages. First, descriptive statistics were used to summarize students' digital literacy and GIS learning outcomes, including the mean, standard deviation, minimum, and maximum scores for each variable. This analysis provided an overview of the distribution and central tendency of the data prior to inferential analysis.

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Second, assumption tests were conducted to ensure that the statistical requirements for correlation and regression analyses were met. Normality of the digital literacy and learning outcome distributions was tested using the Kolmogorov–Smirnov or Shapiro–Wilk test at the 0.05 significance level. Data were considered normally distributed if the p-value exceeded 0.05. Linearity of the relationship between digital literacy and learning outcomes was examined through ANOVA in the regression model, where a significant linear component ($p < 0.05$) and non-significant deviation from linearity ($p > 0.05$) indicated a linear relationship.

Third, Pearson's product–moment correlation was used to address the research question concerning the relationship between digital literacy and learning outcomes. This technique was appropriate because both variables were measured on interval/ratio scales and the normality assumption was satisfied. The correlation coefficient (r) was interpreted in terms of both strength and direction of the relationship, with significance evaluated at $\alpha = 0.05$ and 0.01.

Fourth, simple linear regression analysis was performed to determine the extent to which digital literacy predicted learning outcomes in the GIS course. Digital literacy served as the predictor, and GIS learning outcomes as the criterion variable. The analysis yielded the regression equation, the coefficient of determination (R^2), and tests of significance for the overall model (F-test) and the regression coefficient (t-test). All statistical analyses were carried out using a statistical software package (e.g., SPSS) to minimize computational errors and enhance the accuracy of the results.

3. RESULT AND DISCUSSION

a. Assumption Tests

Prior to conducting correlation and regression analyses, assumption tests were performed to ensure that the data met the required statistical conditions. Normality of the digital literacy and GIS learning outcome scores was examined using the Kolmogorov–Smirnov or Shapiro–Wilk test at the 0.05 significance level. The results indicated that the p-values for both variables were greater than 0.05 ($p > 0.05$), suggesting that the distributions of digital literacy and learning outcomes did not significantly deviate from normality. Thus, the normality assumption was considered satisfied and parametric analyses were deemed appropriate.

Linearity of the relationship between digital literacy and learning outcomes was evaluated through ANOVA in the regression model. The significance value for the linear component was less than 0.05, whereas the significance value for deviation from linearity exceeded 0.05. These findings indicated that the relationship between digital literacy and GIS learning outcomes was linear and that there was no substantial deviation from linearity. On this basis, the use of Pearson's correlation and simple linear regression was justified.

b. Descriptive Statistics

Descriptive analysis showed that the mean score of students' digital literacy was 3.6 on a 1–5 scale, with a standard deviation of 0.45. This suggests that, on average, students' digital literacy was at a moderately high level, although some students still scored below the mean. The mean GIS course grade was 78.5 with a standard deviation of 6.8. The minimum grade

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recorded was 65, and the maximum was 92. Overall, students' learning outcomes in the GIS course can be categorized as good, while still leaving room for improvement.

Table 2. Descriptive statistics for digital literacy and GIS learning outcomes

Variable	N	Mean	SD	Minimum	Maximum
Digital literacy (X)	44	3.60	0.45	2.50	4.50
GIS learning outcomes (Y)	44	78.50	6.80	65.00	92.00

c. Relationship between Digital Literacy and Learning Outcomes

Pearson's correlation analysis yielded a correlation coefficient of $r = 0.62$ with a significance value of $p < 0.01$, indicating a positive and statistically significant relationship between digital literacy and GIS learning outcomes. In other words, students with higher digital literacy scores tended to obtain higher final grades in the GIS course.

Table 3. Pearson correlation between digital literacy and GIS learning outcomes

Variables	r	Sig. (p)	N
Digital literacy (X) – GIS learning outcomes (Y)	0.62	0.000	44

Conceptually, the pattern of this relationship can be represented by a scatterplot in which data points form an upward trend from the lower left to the upper right, reflecting the positive association between the two variables. Students with higher digital literacy are generally more adept at accessing and managing digital information, which supports their performance in GIS tasks that require searching for spatial data, operating software, and using online learning resources.

In terms of magnitude, an r value of 0.62 falls within the moderate to strong range, indicating that digital literacy has a substantive rather than trivial association with learning outcomes. Students who are proficient in operating devices and applications, selecting credible information sources, organizing digital learning materials, and engaging in effective online communication are better prepared to follow the demands of GIS learning, which relies heavily on interaction with data and software.

These findings are consistent with previous research. Latip et al. (2022) reported that digital literacy significantly influenced learning outcomes in science education, while Yuan et al. (2025) found that digital literacy contributed to academic achievement through increased technological self-efficacy and a positive digital learning atmosphere. In the Indonesian context, studies by Nahdi and Jatisunda (2020), Mariyani and Triyani (2023), and Wirasti and Irawan (2024) have shown that students with higher digital literacy are more adaptive to ICT-based learning and tend to demonstrate better academic performance. The present findings thus reinforce empirical evidence that digital literacy is an important determinant of learning success in the digital era, particularly in application-oriented courses such as GIS.

At the same time, the correlation does not reach the very high category, suggesting that other factors beyond digital literacy also influence learning outcomes. These may include intrinsic motivation, learning strategies, the quality of instructor–student interaction, and the availability of devices and stable internet connections. Consequently, efforts to improve digital literacy should be integrated with initiatives targeting these other factors to achieve optimal improvements in learning outcomes.

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d. Effect of Digital Literacy on Learning Outcomes

Simple linear regression analysis with digital literacy as the predictor and GIS learning outcomes as the criterion variable produced the following regression equation:

$\hat{Y} = 52.3 + 7.3X$

The coefficient of determination was $R^2 = 0.38$. A summary of the regression results is presented in Table 4.

Table 4. Summary of simple linear regression analysis

Component	Value
Intercept (a)	52.30
Digital literacy coefficient (b)	7.30
R	0.62
R^2	0.38
F	25.74
Sig. F	0.000

These results indicate that approximately 38% of the variance in GIS learning outcomes can be explained by variations in students' digital literacy, while the remaining 62% is attributable to other factors outside the model, such as learning motivation, instructional quality, resource availability, and the learning environment.

A contribution of 38% can be categorized as moderate, suggesting that digital literacy is an important, though not exclusive, determinant of learning success. From the perspective of learning theory, this finding is plausible because digital literacy facilitates students' access to diverse learning resources, the management of course materials, and active participation in project-based and discussion-oriented learning activities. Consistent with the findings of Georgopoulou et al. (2025) and Gutiérrez-Ángel et al. (2022), students with higher digital literacy tend to be better at leveraging digital learning ecosystems to construct conceptual understanding independently.

Yuan et al. (2025) further emphasized that digital literacy influences learning outcomes not only directly but also indirectly through enhanced technological self-efficacy and positive perceptions of the digital learning environment. In the context of GIS, this is reflected in students' confidence in using software, exploring spatial data, and solving technical problems encountered during practice. However, the portion of unexplained variance in the regression model underscores the importance of considering other factors—such as course design, quality of feedback, and students' individual characteristics (e.g., motivation, discipline, prior knowledge)—when seeking to improve learning outcomes in GIS and similar software-based courses.

e. Implications for Teaching

The findings of this study have several implications for the management of GIS instruction at Universitas Hamzanwadi and similar institutions.

First, the results underscore the need to strengthen students' digital literacy systematically. Instructors and program administrators can design short training sessions,

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workshops, or structured assignments that require students to utilize a variety of digital resources, thereby enhancing their technical and informational skills.

Second, the use of LMS and well-organized digital learning resources can support students in developing digital literacy while simultaneously deepening their understanding of GIS concepts. LMS platforms can be leveraged to distribute materials, host discussion forums, collect assignments, and provide feedback, all of which encourage active engagement with digital tools.

Third, students with relatively low levels of digital literacy may benefit from targeted support, such as peer tutoring or additional practice sessions in computer laboratories. Such measures can help reduce disparities in digital skills, ensuring that all students have a fair opportunity to succeed in the GIS course.

In the specific context of environmental engineering education, strengthening digital literacy and GIS proficiency will improve students' capacity to read, process, and analyze environmental data, such as water and air quality indicators and land use patterns. This not only supports the achievement of course learning outcomes but also better prepares graduates to meet professional demands that increasingly rely on spatial data modeling and evidence-based decision-making.

f. Limitations and Suggestions for Future Research

This study has several limitations that should be taken into account when interpreting the results. First, the sample was limited to a single GIS class in one study program at a single university. Therefore, caution is warranted when generalizing the findings to other programs or institutions with different characteristics. Future research could involve multiple cohorts, study programs, or universities to enhance the generalizability of the results.

Second, the cross-sectional design captured the relationship and effect of digital literacy on learning outcomes at only one point in time, which restricts the ability to draw strong causal conclusions about the dynamics of change in digital literacy and academic performance. Longitudinal or experimental designs could provide deeper insights into how improvements in digital literacy over time influence learning outcomes.

Third, digital literacy was measured using a self-report questionnaire, which may be susceptible to response biases, such as over- or underestimation of one's abilities. Future studies might consider combining self-report measures with performance-based assessments to obtain a more comprehensive and objective picture of students' digital literacy.

Additional research could also incorporate other variables, such as learning motivation, technological self-efficacy, and instructional design quality, to develop more comprehensive models explaining learning outcomes in GIS and other software-intensive courses. Such studies would contribute to a richer understanding of how cognitive, affective, and contextual factors interact in shaping student success in the digital learning environment.

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4. CONCLUSION

This study examined the effect of digital literacy on students' learning outcomes in a Geographic Information Systems course in the Environmental Engineering Study Program at Universitas Hamzanwadi. Based on data from 44 students, the findings indicated that students' digital literacy was at a moderately high level (M = 3.6), and their average GIS course grade was 78.5. Pearson's correlation analysis showed a positive and significant relationship between digital literacy and learning outcomes ($r = 0.62$; $p < 0.01$). Simple linear regression analysis further revealed that digital literacy accounted for 38% of the variance in GIS learning outcomes ($R^2 = 0.38$).

Substantively, these findings reinforce the view that digital literacy is a key competency that must be systematically developed in higher education. Students' ability to operate devices and applications, select credible information, manage digital learning resources, and communicate effectively in online environments contributes to their success in GIS courses. At the same time, the fact that 62% of the variance in learning outcomes remains unexplained by digital literacy alone suggests that other factors—such as learning motivation, course design, instructor–student interaction, and learning resources—are also important. In environmental engineering education, these factors collectively shape graduates' readiness to conduct comprehensive, data-driven analyses and to solve complex environmental problems.

The practical implications of this study point to the need for structured efforts to strengthen students' digital literacy, including integrating digital literacy training into the curriculum, optimizing the use of LMS and online learning resources, and providing targeted support for students with lower levels of digital literacy. The findings also open avenues for future research to explore mediating and moderating variables, such as technological self-efficacy, learning motivation, and instructional design quality, in the relationship between digital literacy and learning outcomes. In this way, the present study offers an initial empirical contribution to understanding the role of digital literacy in GIS learning in a regional higher education context and provides a foundation for designing strategies to enhance teaching and learning quality in the digital era.

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