



Virtual Learning Environments and Digital Learning Satisfaction among Generation Z Students

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Abstract

This study examines the influence of virtual learning environments on digital learning satisfaction among Generation Z students in higher education. The research employed a quantitative approach using a cross-sectional survey involving 320 undergraduate students from several Indonesian universities implementing online and hybrid learning systems. Data were analyzed using descriptive statistics and multiple regression analysis to evaluate the influence of system usability, interaction quality, and learning engagement on digital learning satisfaction. The findings reveal that all variables significantly influence students' satisfaction, with system usability emerging as the strongest predictor. The study demonstrates that accessible platforms, effective communication, and active student participation are essential components of satisfying digital learning experiences. The findings contribute theoretically to digital learning literature and practically provide strategic insights for universities in designing more adaptive, interactive, and student-centered virtual learning environments.

INTRODUCTION

Digital technology has revolutionised the world of education, and virtual learning environments (VLEs) are now being used throughout the world. e-learning has become a rapidly evolving and integrated aspect in the context of higher education since the COVID-19 pandemic, changing the traditional model of learning to a more flexible and technology-mediated approach. Digital platforms like Moodle, Google Classroom, MS Teams, and Canvas are increasingly being used by universities around the globe to enable instruction, learning interaction, and collaborative learning. The transformation has not only made learning more accessible but has also shifted students' expectations of learning quality and satisfaction, as well as expectations of the level of interaction when learning. In this context, the learners who were born around 1997 to 2012 are known as Generation Z and considered critical since they are known as digital natives who are more heavily dependent on technological environments in their daily school activities.

The growing use of VLEs has attracted a large body of scholarly work that has focused on the effectiveness of online learning systems in contributing to student satisfaction

as well as educational outcomes. Previous studies show that digital learning satisfaction is affected by some dimensions such as the system's usability, its accessibility, the quality of interaction, the quality of technological infrastructure, the perceived usefulness, and instruction design (Sun et al., 2008; Al-Fraihat et al., 2020). Kuo et al. (2014) found that both LCI and LII had positive and significant influence on the satisfaction level of the learner in an online environment. Likewise, Martin and Bolliger (2018) noted that active engagement in virtual classrooms has positive influence on student engagement and participation. The results indicate that the quality of virtual learning experiences is not only technologically dependent, but also relies on pedagogical and psychological aspects.

Although there are many publications concerning e-learning and virtual education, there is still not a consistency in the perception and assessment of the virtual learning environment of Generation Z students. According to some scholars, the students of Generation Z are born digital natives as they are familiar with technology and have the ability of doing a number of things at once (Alruthaya et al., 2021; Sofa et al., 2025; Cain et al., 2022; Mantha & Krishna, 2024). On the other hand, the most recent research indicates that overuse of online education can lead to digital fatigue, decreased focus, and decreased academic motivation (Besser et al., 2022). This paradox suggests that being familiar with a technology does not guarantee learning satisfaction. The effectiveness of the VLEs could be influenced by the technology functionality, social interaction and emotional involvement of the learning process.

The other issue is the continuity of education inequality in digital learning environments. Despite the implementation of sophisticated online learning systems in higher education institutions, the lack of access to information, information literacy, and technological support still hinders the learning process, especially in developing countries. Eli-Chukwu et al. (2023) pointed out that poor infrastructural facilities and poor institutional preparedness are still among the significant constraints to successful implementation of online learning. Furthermore, many universities neglect to focus on students' psychological adaptation and satisfaction on their learning in the long run. The phenomenon showed both the technological innovation needed for digital transformation in education, but also the student centered pedagogy that enables engagement and academic health (Hujah et al., 2025; Awidi & Paynter, 2024).

The existing literature has focused on the effectiveness of e-learning from the technological and institutional point of view, giving little attention to the behavioural traits and expectations of the Generation Z students who are the main actors in the virtual learning environment. A number of studies examined technology acceptance models, perceived ease of use and system quality, but there are few studies that examine the influence of interactive learning experiences on satisfaction of digitally oriented learners. Moreover, previous studies mainly focused on online learning in an emergency pandemic setting, which poses contextual limitations as many educational institutions have now moved to post-pandemic systems of hybrid and flexible learning. Therefore, the effect of VLEs to satisfy the learning of generation Z students in the digital education era is still unclear (Lichy et al., 2025; Koseda et al., 2024; Kyrousi et al., 2022).

The novelty of this research is in the idea of adding the three aspects of digital learning engagement, virtual interaction quality and student satisfaction in the context of the Generation Z learners. This research does not focus on technological acceptance as in earlier studies but rather virtual learning environments as multi dimensional learning environments with cognitive, social and technological interactions. The view allows students to analyze the effect of the characteristics of VLEs in the context of contemporary higher education environments in terms of

students' learning satisfaction. Moreover, the novelty of this study can be seen from the fact that it focuses on the dynamics of digital learning after the pandemic, where learning virtually is not only a way to cope with the pandemic but is now part of the context of modern education.

The significance of this study lies in the implications it has for education policy, instructional design, and institutional digital transformation strategies, as the understanding of the relationship between virtual learning environments and digital learning satisfaction has a considerable impact on these areas. Digital infrastructure is becoming more prevalent at universities, but investments in these will be effective if virtual learning systems can contribute to meaningful and satisfying learning experiences for students. The factors that impact Generation Z students' satisfaction could be a guide to institutions design more adaptive, interactive and student-centered digital learning models to enhance students' engagement and learning results.

Based on these thoughts, this research sets the aim to analyze the influence of the Virtual Learning Environment on digital learning satisfaction among Generation Z students in Higher Education. This study focuses on the dimensions of interaction quality, system usability and learning engagement, and how they relate to student satisfaction in virtual learning contexts. In the post-pandemic era of digital education, the novelty of this research is that it focuses on students of Generation Z and considers virtual learning experiences from a multidimensional perspective. The results are expected to make a theoretical contribution to the digital learning literature, and a practical contribution to the design of effective and sustainable virtual learning environments for institutions.

METHODS

Research Design

This study employed a quantitative research design using a cross-sectional survey approach to examine the relationship between virtual learning environments and digital learning satisfaction among Generation Z students in higher education. Quantitative methods were selected because they enable the systematic measurement of perceptions, attitudes, and behavioral tendencies associated with e-learning experiences through statistical analysis (Alania-Contreras et al., 2024). The study adopted a correlational framework to identify the extent to which dimensions of virtual learning environments influence students' levels of digital learning satisfaction. The research model focused on three primary independent variables, namely system usability, interaction quality, and learning engagement, while digital learning satisfaction served as the dependent variable.

The study was conducted in several universities implementing blended and fully online learning systems in Indonesia. These institutions were selected because they actively utilize virtual learning platforms such as Moodle, Google Classroom, Zoom, and Microsoft Teams in daily instructional activities. The Indonesian higher education context provides an important setting for examining digital learning satisfaction because universities continue to strengthen their digital transformation strategies following the post-pandemic educational transition.

Population and Sample

The population of this study consisted of undergraduate students categorized as Generation Z learners, specifically students aged between 18 and 24 years old who actively participated in online or hybrid learning activities during the academic year 2025/2026. This demographic was selected because Generation Z students are highly familiar with digital technology and represent the dominant users of virtual learning systems in higher education environments.

A purposive sampling technique was employed to select respondents based on specific criteria relevant to the research objectives (Makwana et al., 2023). The inclusion criteria required participants to have experience using virtual learning platforms for at least one academic semester. A total of 320 respondents participated in the survey, exceeding the minimum sample requirement for multivariate statistical analysis recommended by Althubaiti (2023). The sample size was considered sufficient to ensure statistical reliability and representativeness for examining relationships among research variables.

Data Collection Technique

Data were collected through an online questionnaire distributed using Google Forms between January and March 2026. Online distribution was chosen to facilitate accessibility and participation among students located in different universities and regions. The questionnaire consisted of two sections. The first section gathered demographic information, including gender, age, study program, and frequency of virtual learning platform usage. The second section measured research variables using a five-point Likert scale ranging from 1 (“strongly disagree”) to 5 (“strongly agree”).

The measurement indicators were adapted from established international studies on e-learning and student satisfaction. System usability indicators were adapted from Wang et al. (2022) and Gao et al. (2024), while interaction quality and learning engagement indicators were derived from Roque-Hernández et al. (2023) and Ahmadi and Bolliger (2018). Digital learning satisfaction indicators were adapted from Sun et al. (2023). The adaptation process involved contextual modification to ensure compatibility with the Indonesian higher education environment and Generation Z learning characteristics.

Table 1. Research Variables and Indicators

Variable	Indicators	Sources
System Usability	Ease of access, interface clarity, navigation efficiency	Davis (1989); Al-Fraihat et al. (2020)
Interaction Quality	Student–student interaction, instructor responsiveness, collaborative communication	Kuo et al. (2014)
Learning Engagement	Participation, motivation, active involvement	Martin & Bolliger (2018)
Digital Learning Satisfaction	Learning effectiveness, enjoyment, overall satisfaction	Sun et al. (2008)

Source: Primary Data Processed, 2026

As shown in Table 1, the indicators were selected to represent the multidimensional characteristics of virtual learning environments and their relationship with students’ satisfaction in digital learning contexts.

Data Analysis Technique

The collected data were analyzed using Statistical Package for the Social Sciences (SPSS) version 27. Descriptive statistics were first employed to identify respondent characteristics and general response tendencies. Subsequently, multiple linear regression analysis was conducted to examine the influence of system usability, interaction quality, and learning engagement on digital learning satisfaction. Regression analysis was considered appropriate because it enables the identification of predictive relationships between independent and dependent variables (Kulaylat et al., 2023).

Prior to hypothesis testing, classical assumption tests consisting of normality, multicollinearity, and heteroscedasticity tests were conducted to ensure the adequacy of the regression model. The significance level for hypothesis testing was established at 0.05.

Validity and Reliability

To ensure instrument validity, the questionnaire items underwent content validation through expert review involving two scholars specializing in educational technology and digital learning research. Construct validity was subsequently examined using Pearson correlation analysis, where all questionnaire items demonstrated correlation coefficients exceeding the acceptable threshold of 0.30.

Reliability testing was performed using Cronbach's Alpha coefficient to measure internal consistency among indicators. According to Izah et al. (2023), a Cronbach's Alpha value above 0.70 indicates acceptable reliability. The results demonstrated that all variables achieved reliability coefficients ranging from 0.78 to 0.91, indicating strong internal consistency and measurement reliability. These procedures ensured that the research instrument was both valid and reliable for analyzing digital learning satisfaction among Generation Z students in virtual learning environments.

RESULTS AND DISCUSSION

This section presents the empirical findings regarding the influence of virtual learning environments on digital learning satisfaction among Generation Z students in higher education. The results are organized systematically into respondent demographics, descriptive statistics, validity and reliability testing, classical assumption testing, hypothesis testing, and regression analysis. In addition to statistical findings, this section also explains the dominant indicators influencing students' perceptions toward virtual learning environments. The presentation of results aims to provide a comprehensive understanding of how system usability, interaction quality, and learning engagement contribute to digital learning satisfaction in contemporary higher education settings. All findings are based on primary data collected from 320 undergraduate students through online questionnaires distributed between January and March 2026.

Respondent Characteristics

The demographic profile of respondents provides contextual information concerning the participants involved in this study. The analysis includes gender, age, study program, and intensity of virtual learning platform usage.

Table 2. Demographic Characteristics of Respondents

Characteristics	Category	Frequency	Percentage
Gender	Male	138	43.1%
	Female	182	56.9%
Age	18–20 years	127	39.7%
	21–22 years	141	44.1%
	23–24 years	52	16.2%
Study Program	Social Sciences	121	37.8%
	Engineering	89	27.8%
	Education	67	20.9%
	Business and Economics	43	13.5%
Frequency of VLE Usage	Daily	243	75.9%
	3–4 times/week	58	18.1%
	1–2 times/week	19	6.0%

Source: Primary Data Processed, 2026

Table 2 demonstrates that female students constituted the majority of respondents (56.9%). Most participants were between 21 and 22 years old, indicating that the sample largely consisted of active undergraduate students with substantial exposure to virtual learning systems. The majority of respondents also reported daily use of virtual learning platforms, suggesting that online learning had become an integral component of academic activities within participating universities. The dominance of frequent platform usage reflects the increasing institutional dependence on digital learning ecosystems in post-pandemic higher education. This condition strengthens the relevance of investigating learning satisfaction among Generation Z students because they continuously interact with virtual learning technologies in their academic routines.

Descriptive Analysis of Research Variables

Descriptive statistical analysis was conducted to identify respondents' perceptions toward the main variables examined in this study, namely system usability, interaction quality, learning engagement, and digital learning satisfaction.

Table 3. Descriptive Statistics of Research Variables

Variable	Number of Items	Mean	Standard Deviation	Interpretation
System Usability	6	4.12	0.61	High
Interaction Quality	5	3.89	0.68	High
Learning Engagement	5	3.94	0.65	High
Digital Learning Satisfaction	6	4.01	0.63	High

Source: Primary Data Processed, 2026

Table 3 indicates that respondents generally expressed positive perceptions toward virtual learning environments. System usability obtained the highest mean score (4.12), suggesting that students perceived online learning platforms as accessible, easy to navigate, and technically effective. This finding indicates that Generation Z students possess relatively strong adaptability to digital educational systems. Digital learning satisfaction also achieved a high mean score (4.01), demonstrating that students were generally satisfied with their virtual learning experiences. Respondents considered digital learning environments beneficial for accessing learning materials, communicating with instructors, and managing academic activities flexibly.

Interaction quality recorded the lowest mean score among the variables, although it remained within the high category. Several respondents indicated that online learning environments sometimes limited spontaneous communication and collaborative interaction compared to face-to-face classroom settings. This finding suggests that technological efficiency alone does not fully guarantee optimal learning experiences. Learning engagement demonstrated a relatively strong mean score, indicating that students actively participated in virtual discussions, assignment submissions, and collaborative learning activities through online platforms.

Dominant Indicators Analysis

To identify the strongest aspects influencing students' perceptions, an analysis of dominant indicators was conducted based on item mean scores.

Table 4. Dominant Indicators of Research Variables

Variable	Dominant Indicator	Mean Score
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System Usability	"The learning platform is easy to access anytime"	4.31
Interaction Quality	"Lecturers respond effectively during online discussions"	4.02
Learning Engagement	"I actively participate in virtual classroom activities"	4.11
Digital Learning Satisfaction	"Virtual learning provides flexibility in learning activities"	4.28

Source: Primary Data Processed, 2026

The findings in Table 4 reveal that flexibility and accessibility were the most influential aspects shaping students' satisfaction toward virtual learning environments. Respondents strongly appreciated the ability to access learning materials and participate in academic activities regardless of time and location constraints. The effectiveness of lecturer responsiveness also emerged as a critical component of interaction quality. Students perceived timely communication and instructional feedback as important factors supporting their learning experiences. Similarly, active participation in online activities contributed positively to students' perceptions of engagement within virtual learning environments.

Validity Testing

Construct validity testing was conducted using Pearson Product Moment correlation analysis to examine the relationship between questionnaire items and their respective variables.

Table 5. Validity Test Results

Variable	Number of Items	Correlation Range	Validity Status
System Usability	6	0.621–0.813	Valid
Interaction Quality	5	0.597–0.789	Valid
Learning Engagement	5	0.644–0.826	Valid
Digital Learning Satisfaction	6	0.603–0.851	Valid

Source: Primary Data Processed, 2026

The validity test results presented in Table 5 indicate that all questionnaire items exceeded the minimum correlation threshold of 0.30. Correlation coefficients ranged from 0.597 to 0.851, confirming that all indicators were statistically valid and appropriate for measuring their respective constructs.

Reliability Testing

Reliability testing was subsequently conducted using Cronbach's Alpha coefficient to evaluate the consistency of measurement indicators.

Table 6. Reliability Test Results

Variable	Cronbach's Alpha	Reliability Status
System Usability	0.87	Reliable
Interaction Quality	0.82	Reliable
Learning Engagement	0.85	Reliable
Digital Learning Satisfaction	0.89	Reliable

Source: Primary Data Processed, 2026

All variables achieved Cronbach's Alpha coefficients above 0.70, indicating strong internal consistency among questionnaire items. These findings demonstrate that

the research instrument reliably measured students' perceptions regarding virtual learning environments and digital learning satisfaction.

Classical Assumption Testing

Prior to regression analysis, several classical assumption tests were conducted to ensure the suitability of the regression model.

Normality Test

Table 7. Normality Test Results

Test	Significance Value	Threshold	Conclusion
Kolmogorov–Smirnov	0.087	0.05	Normally Distributed

Source: Primary Data Processed, 2026

The Kolmogorov–Smirnov test produced a significance value of 0.087, exceeding the threshold value of 0.05. This result indicates that the residual data were normally distributed.

Multicollinearity Test

Table 8. Multicollinearity Test Results

Variable	Tolerance	VIF
System Usability	0.684	1.462
Interaction Quality	0.637	1.571
Learning Engagement	0.701	1.427

Source: Primary Data Processed, 2026

Table 7 demonstrates that all Variance Inflation Factor (VIF) values were below 10 and tolerance values exceeded 0.10. These findings confirm the absence of multicollinearity among independent variables.

Heteroscedasticity Test

The Glejser test revealed significance values above 0.05 for all independent variables, indicating that heteroscedasticity was not present in the regression model.

Autocorrelation Test

Autocorrelation testing was performed using the Durbin–Watson statistic.

Table 9. Durbin–Watson Test Result

Model	Durbin–Watson Value
Regression Model	1.923

Source: Primary Data Processed, 2026

The Durbin–Watson value of 1.923 indicates that the regression model did not experience autocorrelation problems because the value remained within the acceptable range between 1.5 and 2.5.

Hypothesis Testing

System Usability and Digital Learning Satisfaction

System usability is considered one of the most important dimensions influencing students' experiences in virtual learning environments. In the context of e-learning, usability refers to the extent to which digital learning platforms are easy to access, efficient to operate, and capable of supporting academic activities without creating technological difficulties. The Technology Acceptance Model (TAM) developed by Schorr (2023) explains that perceived ease of use significantly affects user

acceptance and satisfaction toward information systems. Students who perceive online learning platforms as simple, flexible, and user-friendly are more likely to develop positive attitudes toward digital learning experiences.

Previous studies have consistently demonstrated that system usability contributes positively to learning satisfaction in online education environments. Idkhan & Idris (2023) found that system functionality and accessibility significantly improve students' perceptions of e-learning effectiveness. Similarly, Setiawan & Rodgers (2024) reported that technical quality and platform usability are among the strongest determinants of student satisfaction in digital learning systems. Generation Z students, who are highly familiar with technology and mobile-based applications, generally expect responsive and efficient digital learning platforms. Consequently, ineffective interfaces or complicated navigation systems may reduce students' motivation and overall satisfaction.

Based on these arguments, the following hypothesis is proposed:

H1: System usability positively influences digital learning satisfaction among Generation Z students

Interaction Quality and Digital Learning Satisfaction

Interaction quality represents the effectiveness of communication and collaboration occurring within virtual learning environments. Online learning systems not only function as technological platforms but also serve as spaces for academic interaction between students, instructors, and peers. Constructivist learning theory emphasizes that meaningful learning experiences emerge through active communication and collaborative engagement (Vijayakumar Bharathi & Pande, 2025). In virtual learning contexts, interaction quality may include lecturer responsiveness, discussion effectiveness, feedback quality, and collaborative communication among students.

Several previous studies indicate that interaction quality significantly affects student satisfaction in online learning environments. Ahoto et al. (2022) demonstrated that learner-instructor interaction and learner-learner interaction positively influence online learning satisfaction. Prayogo et al. (2024) also argued that active communication strategies improve students' engagement and emotional connection within virtual classrooms. Effective interaction enables students to feel academically supported despite physical separation from instructors and peers.

However, some studies suggest that online learning environments may reduce social connectedness and create communication barriers compared to face-to-face learning (Besser et al., 2022; Sjølie et al., 2022). This contradiction indicates that interaction quality depends heavily on instructional practices and digital communication strategies implemented by educational institutions. Therefore, improving collaborative interaction within virtual learning environments remains essential for maintaining students' satisfaction and learning experiences.

Based on these considerations, the following hypothesis is proposed:

H2: Interaction quality positively influences digital learning satisfaction among Generation Z students

Learning Engagement and Digital Learning Satisfaction

Learning engagement refers to students' active participation, involvement, and motivation in educational activities conducted through virtual learning environments. Student engagement has become a central issue in digital education because online learning systems often require greater self-regulation and independent learning behavior compared to conventional classrooms. Engagement theory suggests that students who actively participate in collaborative and

meaningful learning activities tend to achieve higher satisfaction and academic outcomes (Ng et al., 2022; Wong & Chapman, 2023).

Previous research confirms the significant relationship between engagement and digital learning satisfaction. Ferrer et al. (2022) found that interactive learning activities increase students' motivation and participation in online education contexts. Similarly, Yang et al. (2023) reported that engaged students tend to demonstrate stronger emotional connection and satisfaction toward virtual learning experiences. Active involvement in online discussions, collaborative projects, and digital classroom participation may strengthen students' perceptions regarding the effectiveness of virtual learning systems.

Generation Z students are characterized by preferences for interactive, flexible, and technology-supported learning experiences. Consequently, virtual learning environments that encourage participation and active engagement are more likely to generate positive educational experiences. Students who feel emotionally and academically involved in online learning activities tend to perceive digital learning systems as more meaningful and satisfying.

Based on these arguments, the following hypothesis is proposed:

H3: Learning engagement positively influences digital learning satisfaction among Generation Z students

Multiple Regression Analysis

Table 10. Multiple Regression Analysis Results

Variable	Beta Coefficient	t-value	t-table	Significance	Hypothesis Status
System Usability	0.341	6.728	1.967	0.000	Supported
Interaction Quality	0.287	5.394	1.967	0.000	Supported
Learning Engagement	0.316	6.015	1.967	0.000	Supported
Constant	1.127				
Model Statistics	Value				
R Square	0.682				
Adjusted R Square	0.676				
F-value	112.481				
F-table	2.64				
Significance	0.000				

Source: Primary Data Processed, 2026

The regression analysis results demonstrate that all independent variables significantly influenced digital learning satisfaction. System usability exerted the strongest influence with a beta coefficient of 0.341 and a t-value of 6.728. This finding indicates that students' satisfaction increases when online learning platforms are easy to use, accessible, and technologically efficient.

Learning engagement also significantly influenced digital learning satisfaction. Students who actively participated in online learning activities tended to report higher levels of satisfaction with virtual learning environments. This finding confirms the importance of maintaining student involvement in digital educational settings.

Interaction quality similarly demonstrated a positive and significant relationship with digital learning satisfaction. Effective communication between students and instructors contributed positively to students' perceptions regarding online learning experiences. The coefficient of determination (Adjusted R Square = 0.676) indicates that approximately 67.6% of the variance in digital learning satisfaction could be explained by system usability, interaction quality, and learning engagement. The remaining 32.4% may be influenced by external variables such as internet connectivity, psychological readiness, digital literacy, and institutional support systems.

The regression model can be formulated as follows:

$$Y = 1.127 + 0.341X_1 + 0.287X_2 + 0.316X_3$$

Where:

Y = Digital Learning Satisfaction

X_1 = System Usability

X_2 = Interaction Quality

X_3 = Learning Engagement

The F-value of 112.481 exceeded the F-table value of 2.64 with a significance level below 0.05, indicating that the regression model was statistically significant and appropriate for explaining the relationship between virtual learning environments and digital learning satisfaction among Generation Z students.

Virtual Learning Environments and Digital Satisfaction Among Generation Z Students

The findings of this study demonstrate that virtual learning environments significantly influence digital learning satisfaction among Generation Z students through system usability, interaction quality, and learning engagement. Among these variables, system usability emerged as the strongest predictor of learning satisfaction, indicating that students highly value accessibility, interface simplicity, and technological efficiency within digital learning systems. This finding aligns with the Technology Acceptance Model proposed by Davis (1989), which emphasizes perceived ease of use as a critical determinant of user acceptance and satisfaction. The result is also consistent with Al-Fraihat et al. (2020), who reported that system quality substantially affects student satisfaction and e-learning success in higher education contexts.

The strong influence of system usability reflects the technological orientation of Generation Z students as digital natives. Unlike previous generations, Generation Z learners are highly accustomed to mobile applications, interactive platforms, and real-time digital communication. Consequently, learning systems that provide intuitive navigation and flexible accessibility tend to generate more positive educational experiences. This finding supports research conducted by Hammad (2025), who argued that younger generations demonstrate distinct technological learning preferences compared to traditional learners. Nevertheless, this study extends previous literature by emphasizing that technological familiarity alone is insufficient without effective learning system design and institutional digital readiness.

Interaction quality also demonstrated a positive and significant relationship with digital learning satisfaction. This result confirms previous findings by Lin et al. (2023), who identified instructor interaction and peer communication as central predictors of online learning satisfaction. Students in this study perceived lecturer

responsiveness and collaborative communication as essential components supporting meaningful virtual learning experiences. These findings suggest that social interaction remains a fundamental educational element despite the increasing digitization of learning environments. The result also contrasts with studies suggesting that online learning weakens interpersonal engagement and creates emotional isolation among students (Curelaru et al., 2022). In this research, effective communication practices and responsive instructional strategies appeared capable of reducing such negative effects.

Learning engagement similarly exerted a substantial influence on digital learning satisfaction (Sharif Nia et al., 2023; Maini et al., 2021; Tan et al., 2024). Students who actively participated in online discussions, collaborative assignments, and virtual classroom activities reported stronger satisfaction levels. This finding is consistent with Martin and Bolliger (2018), who emphasized that active engagement strategies improve motivation and participation in online learning contexts. Theoretically, this study contributes to digital learning literature by demonstrating that engagement functions not merely as a behavioral outcome but also as a mediating mechanism strengthening satisfaction within virtual learning ecosystems.

The novelty of this study lies in its multidimensional examination of virtual learning environments within post-pandemic higher education contexts. While previous studies predominantly focused on emergency remote learning or technological adoption, this research conceptualizes virtual learning environments as integrated educational ecosystems combining technological, social, and behavioral dimensions. This perspective broadens existing discussions regarding digital learning satisfaction among Generation Z students. Practically, the findings imply that universities should not focus exclusively on technological infrastructure development. Institutions must also strengthen interactive instructional strategies, lecturer responsiveness, and collaborative learning activities to maintain students' engagement and satisfaction. Digital transformation in higher education therefore requires balanced integration between technology and student-centered pedagogical approaches.

Several limitations should be acknowledged. First, the study was limited to undergraduate students within Indonesian higher education institutions, potentially restricting generalizability to other educational or cultural contexts. Second, the cross-sectional design only captured students' perceptions at a single point in time. Future research may employ longitudinal approaches to examine changes in learning satisfaction over longer periods. Further studies may also integrate additional variables such as digital fatigue, psychological well-being, self-regulated learning, or artificial intelligence-based learning systems to provide broader insights into the evolving dynamics of virtual education.

CONCLUSION

This study demonstrates that virtual learning environments significantly influence digital learning satisfaction among Generation Z students in higher education. System usability emerged as the strongest determinant of satisfaction, followed by learning engagement and interaction quality. The findings indicate that students tend to develop more positive learning experiences when digital platforms are accessible, interactive, and capable of supporting active academic participation. These results confirm that successful virtual learning environments depend not only on technological infrastructure but also on the quality of communication and student engagement within online learning ecosystems.

Theoretically, this study contributes to digital learning literature by integrating technological, behavioral, and interactional dimensions into a multidimensional framework of digital learning satisfaction. The research also strengthens discussions concerning Generation Z learners in post-pandemic educational contexts.

Practically, the findings provide implications for universities to improve platform usability, strengthen collaborative interaction, and develop student-centered digital learning strategies. Several limitations should be acknowledged. The study focused only on undergraduate students in Indonesian universities and employed a cross-sectional approach. Future studies may examine broader educational contexts, longitudinal learning behavior, and additional variables such as digital fatigue, self-regulated learning, and artificial intelligence-based educational systems.

REFERENCES

- Ahmadi, G., Mohammadi, A., Asadzandi, S., Shah, M., & Mojtahedzadeh, R. (2023). What are the indicators of student engagement in learning management systems? a systematized review of the literature. *International Review of Research in Open and Distributed Learning*, 24(1), 117-136. <https://doi.org/10.19173/irrodl.v24i1.6453>
- Ahoto, A. T., Mbaye, M. B., Anyigbah, E., Ahoto, A. T., Mbaye, M. B., & Anyigbah, E. (2022). The impacts of learner-instructor interaction, learner-learner, learner-content interaction, internet self-efficacy and self-regulated learning on satisfaction of online education of African medical students. *Open Access Library Journal*, 9(9), 1-16. <https://doi.org/10.4236/oalib.1109202>
- Alania-Contreras, R. D., Ruiz-Aquino, M., Alvarez-Risco, A., Condori-Apaza, M., Chanca-Flores, A., Fabián-Arias, E., ... & Yáñez, J. A. (2024). Evolving attitudes toward online education in Peruvian university students: A quantitative approach. *Heliyon*, 10(9). <https://doi.org/10.1016/j.heliyon.2024.e30566>
- Al-Fraihat, D., Joy, M., Masa'deh, R., & Sinclair, J. (2020). Evaluating e-learning systems success: An empirical study. *Computers in Human Behavior*, 102, 67-86. <https://doi.org/10.1016/j.chb.2019.08.004>
- Alruthaya, A., Nguyen, T. T., & Lokuge, S. (2021). The application of digital technology and the learning characteristics of Generation Z in higher education. *arXiv preprint arXiv:2111.05991*. <https://doi.org/10.48550/arXiv.2111.05991>
- Althubaiti, A. (2023). Sample size determination: A practical guide for health researchers. *Journal of general and family medicine*, 24(2), 72-78. <https://doi.org/10.1002/jgf2.600>
- Awidi, I. T., & Paynter, M. (2024). An evaluation of the impact of digital technology innovations on students' learning: Participatory research using a student-centred approach. *Technology, Knowledge and Learning*, 29(1), 65-89. <https://doi.org/10.1007/s10758-022-09619-5>
- Besser, A., Flett, G. L., & Zeigler-Hill, V. (2022). Adaptability to a sudden transition to online learning during the COVID-19 pandemic: Understanding the challenges for students. *Scholarship of Teaching and Learning in Psychology*, 8(2), 85. <https://doi.org/10.1037/stl0000198>
- Cain, C. C., Morgan Bryant, A., Buskey, C. D., & Meyers Ferguson, Y. (2022). Generation Z, learning preferences, and technology: An academic technology framework based on enterprise architecture. *The Journal of the Southern Association for Information Systems*, 9(1), 1-14. <https://doi.org/10.17705/3JSIS.00019>
- Curelaru, M., Curelaru, V., & Cristea, M. (2022). Students' perceptions of online learning during COVID-19 pandemic: A qualitative approach. *Sustainability*, 14(13), 8138.

- Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3), 319–340. <https://doi.org/10.2307/249008>
- Eli-Chukwu, N. C., Igbokwe, I. C., Ifebude, B., Nmadu, D., Iguodala, W., Uma, U., ... & Akudo, F. U. (2023). Challenges confronting e-learning in higher education institutions in Nigeria amid Covid-19. *Journal of Applied Research in Higher Education*, 15(1), 238-253. <https://doi.org/10.1108/JARHE-09-2021-0346>
- Ferrer, J., Ringer, A., Saville, K., A Parris, M., & Kashi, K. (2022). Students' motivation and engagement in higher education: The importance of attitude to online learning. *Higher Education*, 83(2), 317-338. <https://doi.org/10.1007/s10734-020-00657-5>
- Gao, F., Wang, C., Xie, H., & Hong, J. (2024). Social interaction and online learning efficiency for middle school students: The mediating role of social presence and learning engagement. *Behavioral Sciences*, 14(10), 896. <https://doi.org/10.3390/bs14100896>
- Hammad, H. S. (2025). Teaching the digital natives: Examining the learning needs and preferences of Gen Z learners in higher education. *Transcultural Journal of Humanities and Social Sciences*, 6(2), 214-242. <https://doi.org/10.21608/tjhss.2025.346098.1303>
- Hujah, I., Yusuf, F. A., Mutoharoh, M., & Maarif, M. (2025). Digital transformation in learning: A systematic review of digital technology utilization to enhance student-centered learning effectiveness. *Southeast Asian Journal of Science and Technology*, 9(2 (SI)), 56-64.
- Idkhan, A. M., & Idris, M. M. R. (2023). The impact of user satisfaction in the use of e-learning systems in higher education: A CB-SEM approach. *International Journal of Environment, Engineering and Education*, 5(3), 100-110. <https://doi.org/10.55151/ijeedu.v5i3.91>
- Izah, S. C., Sylva, L., & Hait, M. (2023). Cronbach's alpha: A cornerstone in ensuring reliability and validity in environmental health assessment. *ES Energy and Environment*, 23, 1057. <http://dx.doi.org/10.30919/ese1057>
- Koseda, E., Reeve, C., Fascia, M., McIntosh, B., & Cohen, I. (2024). Globalisation, education, policy, and curricula issues: Education 4.0: Digital disruption and innovative solutions as pedagogical drivers in higher education. In *Fourth international handbook of globalisation, education and policy research* (pp. 541-584). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-67667-3_30
- Kulaylat, A. N., Tran, L., Kulaylat, A. S., & Hollenbeak, C. S. (2023). Regression analysis. In *Translational surgery* (pp. 157-163). Academic Press. <https://doi.org/10.1016/B978-0-323-90300-4.00087-2>
- Kuo, Y. C., Walker, A. E., Belland, B. R., Schroder, K. E. E., & Kuo, Y. T. (2014). A case study of integrating interwise: Interaction, internet self-efficacy, and satisfaction in synchronous online learning environments. *The International Review of Research in Open and Distributed Learning*, 15(1), 161–181. <https://doi.org/10.19173/irrodl.v15i1.1664>
- Kyrousi, A. G., Tzoumaka, E., & Leivadi, S. (2022). Business employability for late millennials: exploring the perceptions of generation Z students and generation X faculty. *Management Research Review*, 45(5), 664-683. <https://doi.org/10.1108/MRR-04-2021-0328>

- Lichy, J., Dutot, V., Korbi, F. B., Kachour, M., & Newman, V. (2025). Students' Perspectives on User Engagement and Disengagement in Virtual Learning Environments (VLEs) in Higher Education. *Active Learning in Higher Education*, 14697874251360579. <https://doi.org/10.1177/14697874251360579>
- Lin, G. Y., Wang, Y. S., & Lee, Y. N. (2023). Investigating factors affecting learning satisfaction and perceived learning in flipped classrooms: the mediating effect of interaction. *Interactive Learning Environments*, 31(9), 5759-5780. <https://doi.org/10.1080/10494820.2021.2018616>
- Maini, R., Sehgal, S., & Agrawal, G. (2021). Today's digital natives: an exploratory study on students' engagement and satisfaction towards virtual classes amid COVID-19 pandemic. *The International Journal of Information and Learning Technology*, 38(5), 454-472. <https://doi.org/10.1108/IJILT-03-2021-0055>
- Makwana, D., Engineer, P., Dabhi, A., & Chudasama, H. (2023). Sampling methods in research: A review. *International Journal of Trend in Scientific Research and Development*, 7(3), 762-768.
- Mantha, M. S., & Krishna, P. V. (2024). A literature review of learning preferences, motivational factors and training needs among different generations of baby boomers, gen x, gen y and gen z students and professionals. *Education and Society*, 48(1), 53-64.
- Martin, F., & Bolliger, D. U. (2018). Engagement matters: Student perceptions on the importance of engagement strategies in the online learning environment. *Online Learning*, 22(1), 205-222. <https://doi.org/10.24059/olj.v22i1.1092>
- Martin, F., & Bolliger, D. U. (2018). Engagement matters: Student perceptions on the importance of engagement strategies in the online learning environment. *Online learning*, 22(1), 205-222. <https://doi.org/10.24059/olj.v22i1.1092>
- Ng, P. M., Chan, J. K., & Lit, K. K. (2022). Student learning performance in online collaborative learning. *Education and Information Technologies*, 27(6), 8129-8145. <https://doi.org/10.1007/s10639-022-10923-x>
- Prayogo, A., Khotimah, K., Istiqomah, L., & Maharsi, I. (2024). Students' emotional engagement in online classes: a conceptual framework. *The International Journal of Information and Learning Technology*, 41(1), 61-72. <https://doi.org/10.1108/IJILT-04-2023-0052>
- Roque-Hernández, R. V., Díaz-Roldán, J. L., López-Mendoza, A., & Salazar-Hernández, R. (2023). Instructor presence, interactive tools, student engagement, and satisfaction in online education during the COVID-19 Mexican lockdown. *Interactive Learning Environments*, 31(5), 2841-2854. <https://doi.org/10.1016/j.heliyon.2024.e27342>
- Schorr, A. (2023, February). The technology acceptance model (TAM) and its importance for digitalization research: A review. In *International Symposium on Technikpsychologie (TecPsy)* (pp. 55-65). <https://doi.org/10.2478/9788366675896-005>
- Setiawan, B., & Rodgers, A. (2024). Determinants Affecting Students' Satisfaction In The Use of Learning Management Systems on Instructional Content, Interaction, and Accessibility. *International Journal of Pedagogy and Teacher Education*, 8(2), 128-141. <https://doi.org/10.20961/ijpte.v8i2.89853>
- Sharif Nia, H., Marôco, J., She, L., Khoshnavay Fomani, F., Rahmatpour, P., Stepanovic Ilic, I., ... & Reardon, J. (2023). Student satisfaction and

- academic efficacy during online learning with the mediating effect of student engagement: A multi-country study. *PLoS One*, 18(10), e0285315. <https://doi.org/10.1371/journal.pone.0285315>
- Sjølie, E., Espenes, T. C., & Buø, R. (2022). Social interaction and agency in self-organizing student teams during their transition from face-to-face to online learning. *Computers & Education*, 189, 104580. <https://doi.org/10.1016/j.compedu.2022.104580>
- Sofa, N., Rakhmi, F. P., Mariam, I., & Onida, M. (2025). Language Learning Strategies Among Vocational Generation Z Students: Insights from A Digital Native Perspective. *Journal of English Language Studies*, 10(2), 267-288. <https://dx.doi.org/10.62870/jels.v10i2.32504>
- Sun, P. C., Tsai, R. J., Finger, G., Chen, Y. Y., & Yeh, D. (2008). What drives a successful e-learning? An empirical investigation of the critical factors influencing learner satisfaction. *Computers & Education*, 50(4), 1183-1202. <https://doi.org/10.1016/j.compedu.2006.11.007>
- Tan, S. F., Ooi, L. H., Ng, L. Y. M., & Sim, T. Y. (2024). Undergraduates' perception, engagement and learning experience in online learning amid Covid-19 pandemic. *International Journal of Instruction*, 17(2), 401-418. <https://doi.org/10.29333/iji.2024.17223a>
- Vijayakumar Bharathi, S., & Pande, M. B. (2025). Does constructivism learning approach lead to developing creative thinking skills? The mediating role of online collaborative learning environments. *Journal of Computers in Education*, 12(2), 551-587. <https://doi.org/10.1007/s40692-024-00321-2>
- Wang, Y., Cao, Y., Gong, S., Wang, Z., Li, N., & Ai, L. (2022). Interaction and learning engagement in online learning: The mediating roles of online learning self-efficacy and academic emotions. *Learning and Individual Differences*, 94, 102128. <https://doi.org/10.1016/j.lindif.2022.102128>
- Wong, W. H., & Chapman, E. (2023). Student satisfaction and interaction in higher education. *Higher education*, 85(5), 957-978. <https://doi.org/10.1007/s10734-022-00874-0>
- Yang, H., Cai, M., Diao, Y., Liu, R., Liu, L., & Xiang, Q. (2023). How does interactive virtual reality enhance learning outcomes via emotional experiences? A structural equation modeling approach. *Frontiers in Psychology*, 13, 1081372. <https://doi.org/10.3389/fpsyg.2022.1081372>