Enhancing Higher Order Thinking Skill (HOTS) through Student Engagement and Learning Support

Ganefri[1], Abna Hidayati[2,*], Hendra Hidayat[3], Zadrian Ardi[4], Ulfia Rahmi[2], Nofrion[5], and Andra Saputra[6]

[1]Electrical Engineering Education, Universitas Negeri Padang, Indonesia
[2]Curriculum and Educational Technology, Universitas Negeri Padang, Indonesia
[3]Electronic Engineering Education, Universitas Negeri Padang, Indonesia
[4]Guidance and Counseling, Universitas Negeri Padang, Indonesia
[5]Geography Education, Universitas Negeri Padang, Indonesia
[6]Craft Education, Institut Seni Indonesia Padangpanjang, Padang Panjang, Indonesia
Email: ganefri@unp.ac.id (G.); abnahidayati@fip.unp.ac.id (A.H.); hendra.hidayat@ft.unp.ac.id (H.H.); zadrian@fip.unp.ac.id (Z.A.); ulfia@fip.unp.ac.id (U.R.); nofrion@fis.unp.ac.id (N.); andrasaputra552@gmail.com (A.S.)
*Corresponding author

Manuscript received January 17, 2025; revised February 10, 2025; accepted March 17, 2025; published September 11, 2025

Abstract—**This study analyzes the factors that influence the development of Higher Order Thinking Skills (HOTS) among Generation Z students in higher education. The focus of the study includes student engagement, learning readiness, self-management skills, digital literacy, academic flow, and learning facility support. Data were collected through a survey method on 850 undergraduate students from various regions in Indonesia. Analysis using structural equation modeling showed that student engagement contributed 35% to the increase in HOTS, while learning readiness contributed 29.8%. Digital literacy was also found to have a significant influence on learning performance with a path coefficient of 0.089. Academic flow has a strong relationship with learning performance (t-statistic = 39.971, $p < 0.05$), while learning facility support makes an important contribution to HOTS development with a t-statistic of 37.982 ($p < 0.05$). Overall, these factors explain 99.3% of the variance in learning performance and 98.9% of the variance in HOTS. This study emphasizes the importance of supporting facilities, innovative curriculum, and digital competence in supporting students' cognitive development. However, this study has limitations related to geographical and cultural coverage, and has not considered socio-economic factors. These results underscore the need for learning strategies that are tailored to the educational needs of Generation Z in the digital era.**

Keywords—**higher order thinking skills, generation Z, student engagement, digital literacy, academic flow, learning facilities support**

I. Introduction

Generation Z, born and raised in an environment full of digital technology, presents significant challenges and opportunities for higher education. As digital natives, this group is naturally more familiar with technology than previous generations. Generation Z refers to individuals born between 1997 and 2012. This generation grew up in an environment that was heavily influenced by the rapid development of digital technology and the internet, which shaped their mindset and learning style [1, 2]. In addition to age and location, their learning experience is also an important factor that differentiates Generation Z from previous generations. Generation Z is generally more accustomed to technology-based learning, has wide access to information via the internet, and tends to prioritize flexible and interactive learning experiences [3]. These characteristics contribute to the way they develop Higher-Order Thinking Skills (HOTS) in the context of higher education. Stephanie [4] shows that more than 70% of individuals in this generation have better technology skills, making them capable users of technology. However, this ability must be balanced with mastery of 21st century skills, especially Higher Order Thinking Skills (HOTS), which include critical, analytical, creative, and innovative thinking skills to solve complex problems [5, 6].

This challenge is increasingly relevant given the rapid changes in the global workplace [7]. According to the World Economic Forum 2020 report, critical thinking and problem-solving skills are two of the ten most needed skills by 2025 [8]. The report emphasizes that higher education needs to develop a curriculum that is not only technology-based, but also oriented towards developing higher-order cognitive skills. Support for project-based learning, collaborative learning, and Problem-Based Learning (PBL) approaches can be effective strategies to prepare Generation Z for a dynamic and complex workplace [9–12].

Higher Order Thinking Skills (HOTS) learning among Generation Z is influenced by various multidimensional factors involving cognitive, affective, and technological aspects. One of the main contributing factors is the level of student engagement. A study from the National Student Engagement Survey 2022 found that active student involvement in academic and non-academic activities contributed 35% to the increase in HOTS [13, 14]. This shows that a supportive, collaborative, and participatory learning environment is essential for developing critical, creative, and analytical thinking skills [15–17].

In addition to engagement, other factors such as readiness learning, self-organization, and digital literacy also play a significant role. Baskoro *et al.* [11], Dewi *et al.* [12], Astriyani *et al.* [18] revealed that 68% of Generation Z students with high levels of digital literacy tend to adapt more quickly to educational technology and are able to optimally utilize technology-based learning methods. This is reinforced by Hoang and Thy [9], Hastini *et al.* [19], who stated that digital literacy is not only the ability to use technological tools, but also includes an understanding of how technology can support complex problem solving [20].

In addition, readiness to learn plays an important role in HOTS learning. Students with a high level of readiness to learn tend to be better able to organize their learning strategies, manage time effectively, and take responsibility for their own learning. As explained by Zhang and Ma [21], Prayogi *et al*. [22], Parong *et al*. [23], self-regulated learners have advantages in managing their learning process, including in setting goals, monitoring progress, and evaluating learning outcomes.

The implementation of HOTS-oriented educational technology requires an integrated approach, involving project-based learning, flipped classrooms, and collaborative learning. Akinina *et al*. [24] shows that these strategies can create immersive learning experiences, which not only prepare students for academic challenges but also professional challenges in the digital age.

In addition to student engagement and readiness learning, academic flow or deep involvement in academic activities also shows a significant relationship with academic achievement and the development of Higher Order Thinking Skills (HOTS). Academic flow, as explained by Thahir *et al*. [25] and Dima *et al*. [26], is a condition when an individual is fully immersed in an activity, with high concentration and a sense of intrinsic satisfaction. Csikszentmihalyi's research shows that students who frequently experience academic flow record an increase in academic achievement of up to 25%, because this involvement encourages deeper understanding and more creative problem solving [27].

However, intrinsic factors such as academic flow must be supported by a conducive learning environment. One important element in this environment is Learning Facilities Support (LFS), which includes infrastructure, advanced technology, and easy access to academic resources. A report from the International Higher Education Survey 2022 revealed that 75% of students felt that adequate learning facilities greatly influenced their success in developing HOTS [25, 26]. Facilities such as comfortable study rooms, fast internet access, modern technological devices, and digital libraries not only increase learning efficiency but also facilitate exploration and innovation.

Therefore, intervention through improving learning facilities is a priority that cannot be ignored. Higher education institutions need to ensure that their learning environments are able to support technology-based and project-based learning, which have been proven effective in developing critical, analytical, and creative thinking skills. As stated by Cain *et al*. [28–30], Velički [29], Daeid [30], Generation Z tends to be more responsive to interactive and collaborative learning environments, which can be achieved through the integration of technology with flexible learning space designs. By understanding and integrating these factors, higher education institutions can design more effective and relevant learning strategies, preparing Generation Z to face global challenges with complex and adaptive higher-order thinking skills. One of the key skills needed in the 21st century is Higher Order Thinking Skills (HOTS), which includes critical, analytical, creative, and innovative thinking. However, the development of HOTS does not only depend on individual skills, but is also influenced by external factors such as student engagement, digital literacy, and learning facilities support. Previous studies have shown that student engagement plays an important role in improving HOTS because it encourages active participation in the learning process. This study aims to analyze the influence of student engagement, digital literacy, and learning facilities support on HOTS.

II. Literature Review

A. Student Engagement and HOTS Development

Student engagement is a multidimensional concept encompassing behavioral, emotional, and cognitive aspects that collectively drive student engagement in academic activities [31]. Recent studies have highlighted its critical role in the development of HOTS. For example, the National Student Engagement Survey 2022 found that increased engagement contributed 35% to students' ability to analyze, evaluate, and create-key components of HOTS [32–34]. Engaged students are more likely to immerse themselves in challenging academic tasks, which promotes deep learning and enhances their cognitive abilities [31, 35, 36].

B. Academic Flow

Academic flow, defined as a state of optimal engagement and fulfillment in learning tasks, is related to increased academic achievement and HOTS development [13, 37]. Mirvis and Csikszentmihalyi [38] stated that students who frequently experience academic flow show an increase in academic achievement of up to 25%. This phenomenon occurs when students face tasks that are balanced between challenges and skills, resulting in high focus and intrinsic motivation [39, 40].

C. Learning Support as a Catalyst

While student engagement is important, the existence of a strong learning support system is equally important. Learning Facilities Support (LFS), which includes access to advanced technology, academic resources, and a conducive learning environment, plays a critical role in improving educational outcomes [41]. The International Higher Education Survey 2022 revealed that 75% of students attribute their success in achieving HOTS to adequate learning facilities [31, 42, 43]. Effective learning support not only provides the tools needed for complex problem solving but also reduces barriers to engagement, enabling students to tap into their full cognitive potential.

D. Digital Literacy and Learning Readiness

Digital literacy and learning readiness further strengthen the relationship between engagement, support, and HOTS. The Journal of Digital Literacy in Education reported that 68% of Generation Z students with high digital literacy were more adaptable to technology-based learning models, thereby maximizing their engagement and cognitive development. Learning readiness, which includes self-regulation and intrinsic motivation, ensures that students can effectively utilize available resources and opportunities [44–46].

E. Challenges and Opportunities

While these findings provide valuable insights, challenges remain in implementing strategies to improve HOTS among college students. Variations in institutional resources, disparities in digital literacy, and varying levels of student engagement require tailored approaches to maximize impact. However, these challenges also present opportunities for innovation, particularly through blended learning models, adaptive technologies, and personalized learning pathways [47].

F. Generation Z

Generation Z, consisting of individuals born between 1997 and 2012, is known as the digital native generation who grew up in an environment full of digital technology [1]. Exposure to technology from an early age has shaped their mindset and learning style differently compared to previous generations. This generation is more accustomed to technology-based learning environments and tends to be more comfortable using digital devices to access information and communicate in learning [48, 49]. In the context of education, Generation Z shows unique learning preferences. They prefer interactive and experiential learning methods, such as flipped classrooms, project-based learning, and gamification [50, 51].

In addition, they have a shorter attention span due to rapid exposure to digital information, so learning based on short and visual content is more effective than traditional lecture methods [50]. This generation is also known to have better multitasking skills, but often has difficulty maintaining focus for long periods of time, making microlearning an increasingly relevant strategy in higher education [2, 52]. In the Indonesian context, Generation Z shows a similar tendency to the global trend, but with some differences influenced by social and economic factors.

The IDN Research Institute Report [3] revealed that more than 90% of students in Indonesia use digital platforms as part of their learning process. However, there is a gap in access to digital infrastructure between students living in urban areas and in remote areas, which can affect the effectiveness of technology-based learning. In addition, Generation Z students in Indonesia rely more on mobile devices than computers to access learning materials, indicating the need for adaptation in the design of teaching materials to be more compatible with mobile platforms.

III. Materials and Methods

A. Research Design

This study focuses on factors that influence Generation Z learning in higher education, including student engagement, readiness to learn, self-organization, digital literacy, academic flow, and support from learning facilities. This study uses a survey method to develop a model by adopting previous research models and studies on students in Indonesia [27, 45, 46]. This study is an applied research that explores theories and concepts to propose a model in determining Higher Order Thinking Skills (HOTS) among students. The findings of this study are expected to strengthen previous theories on learning and the development of Higher Order Thinking Skills (HOTS), as well as provide deeper insights into how these factors interact with each other in the context of higher education. Thus, the results of this study can contribute to the development of more effective curricula and learning strategies for Generation Z in higher education [30, 41, 53, 54]. This study uses a quantitative method with a survey approach to analyze the factors that influence HOTS in students. Surveys are used because they are able to capture large amounts of data and provide an overview of the relationship between variables.

B. Population and Sample

The population in this study were students in Indonesia who were pursuing undergraduate education. In general, the target population of the study were students taking general courses at universities. The total sample was 1027 students spread throughout Indonesia. We distributed the questionnaire link to prospective participants spread across various university regions in Indonesia. Consent was obtained from the respondents, allowing them to participate in the survey and allowing the use of their personal information in the online questionnaire. The data was stored neatly in a research database to maintain the confidentiality of the respondents. Of all the responses collected, 177 responses were incomplete, resulting in a total of 850 valid and usable responses. The strength of the sample was tested using G-Power analysis, with a power coefficient of 0.94 [55, 56]. The sample selection was carried out using purposive random sampling. There are several criteria set in the selection of the sample. As explained in Table 1, the sample is spread across all types of faculties and uses family status to measure relational support. The sample in this study has an age range from 19 to 23 years. Before data collection, respondents were informed about data consent and filled out a consent form to meet research ethics standards, so that the research is more focused on the research focus with good results [42, 57].

Table 1. Sample demographics

Sample demographics		*n*	%
Gender	Men	101	33.01%
	Women	205	66.99%
Faculty	Language and art	30	9.80%
	Economy	21	6.86%
	Sports science	40	13.07%
	Education	72	23.53%
	Social sciences	47	15.36%
	Natural sciences	44	14.38%
	Hospitality and tourism	22	7.19%
	Engineering	30	9.80%
Family status	Complete family	240	78.43%
	Incomplete family	66	21.57%

Note: *n* = Number of respondents

C. Measurement

The measurement of each construct in this study was developed from previous studies and modified according to the context of this study. The Higher Order Thinking Skills (HOTS) variable consists of six indicators derived from previous studies. In addition, the student engagement variable according to Fredricks *et al.* [31]. Includes three indicators, namely Behavioral Engagement, Emotional Engagement, Cognitive Engagement. Furthermore, the readiness to learn variable was developed with three indicators sourced from Panwala *et al.* [58]. The support from learning facilities variable consists of three main constructs: educational, relational, and structural, all of which include eight indicators developed by Saputra *et al.* [59, 60]. The digital literacy, academic flow, and self-organization variables each consist of six, five, and four indicators adapted from Falloon [61] and Ana-Marija *et al.* [62]. To measure all these variables, a five-point Likert scale was used (1 =

strongly disagree and 5 = strongly agree).

D. Hypothesis Development

Generation Z learning in college is influenced by various interrelated factors. Student Engagement is expected to have a positive influence on Higher Order Thinking Skills (HOTS). Hypothesis 1 states that students who are more actively involved in the learning process will show an increase in higher-order thinking skills. Readiness to Learn also plays an important role in learning. Hypothesis 2 proposes that students who are more ready to learn will have better HOTS. This readiness includes adequate mental and emotional readiness to engage in the learning process. Self-Organization as the third variable is expected to have a positive impact on HOTS. Hypothesis 3 states that students who are able to manage their time and resources well will be better able to achieve a higher level of HOTS.

In addition, Digital Literacy is an important factor in today's technological era. Hypothesis 4 proposes that students who have good digital literacy will show higher HOTS, thanks to their ability to use information technology effectively in learning. Academic Flow is expected to be a significant influence in the development of HOTS. Hypothesis 5 states that students who experience academic flow where they are fully focused on learning activities will show improvements in higher-order thinking skills.

Finally, Learning Facilities Support (LFS) functions as an intervention that strengthens the relationship between these factors and HOTS. Hypothesis 6 states that support from learning facilities will increase the effectiveness of student engagement, readiness to learn, self-organization, digital literacy, and academic flow in influencing HOTS.

The hypothesis is formulated as follows:

H1: Student engagement has a positive effect on HOTS.

H2: Digital literacy has a positive effect on HOTS.

H3: Learning facilities support has a positive effect on HOTS.

H4: Digital literacy moderates the relationship between student engagement and HOTS.

H5: Learning facilities support moderates the relationship between student engagement and HOTS.

E. Data Collection and Data Analysis

A questionnaire approach was used to collect data by sending a link to the respondents. First, the respondents were informed about the purpose of the study, and they expressed their willingness to participate. The following statistics are derived from various reviews and previous studies related to the validated model. The results of the study were evaluated using SmartPLS 3.0 software [55–57], which has the potential to develop measurement models from a predictive perspective. The following considerations are related to the high sample size to meet the minimum sample requirement without imposing a normal distribution on the sample. The next issue is the capacity of the Structural Equation Model (SEM) to use the partial least squares approach to offer a causal explanation of a model with multiple effects.

This study uses path analysis to assess the direct and indirect impacts of exogenous factors on endogenous variables and their mediators. Furthermore, the analysis is designed to test the hypotheses. During the analysis process, the direct effect of variables is tested first, followed by the indirect effect to find the mediating variables.

Data were analyzed using Structural Equation Modeling (SEM) with SmartPLS 3.0. This model is used to test the relationship between variables and the moderating effects of digital literacy and learning facility support on HOTS.

IV. Result and Discussion

A. Result

1) Measurement model analysis

The first step in evaluating a model is to apply the model measurement assessment [57]. Several tests were conducted by following the rules of thumb in analyzing measurement models. The outer model test was conducted to obtain the validity and reliability values presented in Table 2.

Table 2. Loading factor

	DL	FA	HOTS	LFS	LP	RL	SOL	SE
DL1	0.89							
DL2	0.94							
DL3	0.95							
FA1		0.90						
FA2		0.95						
FA3		0.98						
FA4		0.95						
HOTS1			0.95					
HOTS2			0.95					
HOTS3			0.94					
HOTS4			0.99					
LFS1				0.98				
LFS2				0.97				
LFS3				0.95				
LFS4				0.94				
LFS5				0.94				
LP1					0.96			
LP2					0.96			
RL1						0.95		
RL2						0.95		
SE1								0.94
SE2								0.96
SE3								0.96
SE4								0.92
SOL1							0.93	
SOL2							0.95	
SOL3							0.96	
SOL4							0.97	
SOL5							0.93	

Note: Digital Literacy = DL; Flow Academic = FA; Higher Order Thinking Skill = HOTS; Learning Facility Support = LFS; Learning Performance = LP; Readiness Learning = RL; Self Organization in Learning = SOL; Student Engagement = SE

As presented in Table 2, all indicators explaining the construct have a loading value >0.7. This finding also meets the requirements of the construct convergent validity test with the confirmatory nature of each indicator. In addition, the variables that moderate the relationship between the existence of Learning Performance and Higher Order Thinking Skill have a loading value >0.7. Furthermore, the construct reliability is measured by Cronbach's alpha and Composite Reliability (CR) analysis to prove the accuracy and consistency of the instrument in measuring the construct. Both tests have different referability values, but in terms of acceptance, all measured variables have high reliability values, so all construct variables are reliable. The following model assessment values are convergent validity values obtained by evaluating the Average Variance Extracted (AVE) metric, which must be above 0.5. Table 1 shows that all AVE values are >0.5, which means that in terms of construct, each measured variable is valid.

Measurement of differences between constructs was carried out using two analyses, namely the Heterotrait-Monotrait Ratio (HTMT) and the Fornell-Larcker criteria, to ensure that each construct measured is unique and does not represent other constructs in the model being measured.

The HTMT test in Table 3 and the Fornell-Larcker criteria in Table 4 imply that all variables meet the requirements of discriminant validity. The HTMT test indicates a low correlation between indicators across constructs that measure different constructs, so that each construct is significantly different with a value of <0.90. In addition, testing was carried out using the Fornell-Larcker criteria with the requirement that the correlation of all.

In this model, there are eight main constructs, namely Readiness Learning (RL), Self Organization in Learning (SOL), Digital Literacy (DL), Student Engagement (SE), Learning Facility Support (LFS), Learning Performance (LP), Flow Academic (FA), and Higher Order Thinking Skills (HOTS). Each construct is measured through several indicators indicated by a high loading factor value (average above 0.90), indicating that these indicators have good validity. The direction of the arrows in the model shows the relationship between constructs, with the magnitude of the coefficient listed on each path. RL has a positive influence on SE (0.298), DL has a positive influence on LP (0.089), and LP has a significant influence on HOTS (0.262) and FA (1.654). Meanwhile, the relationship between SOL and LP only shows a very small influence (0.013), and SE actually shows a negative influence on LP (−1.063). In addition, there is also a path from LFS to HOTS with a small coefficient value (0.073), indicating a weak but still relevant influence. The coefficient of determination (R^2) values for the LP and HOTS constructs are 0.993 and 0.989, respectively, indicating that this model is able to explain the variability of the dependent construct strongly. Fig. 1 as a whole provides a visual depiction of the strength of the relationship between variables in the conceptual model of the study.

Table 3. Discriminant validity (Fornell-Larcker Criterion)

	DL	FA	HOTS	LFS	LP	RL	SOL	SE
DL	0.93							
FA	0.91	0.94						
HOTS	0.92	0.99	0.96					
LFS	0.90	0.98	0.99	0.95				
LP	0.92	0.98	0.97	0.96	0.96			
RL	0.95	0.97	0.98	0.97	0.97	0.95		
SOL	0.91	0.99	0.99	0.98	0.97	0.96	0.95	
SE	0.90	0.99	0.99	0.98	0.96	0.97		0.95

Table 4. Reliability

Construction variables	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	The mean variance is extracted (AVE)
DL	0.924	0.937	0.952	0.868
FA	0.963	0.966	0.973	0.901
HOTS	0.971	0.972	0.979	0.921
LFS	0.978	0.978	0.982	0.918
LP	0.919	0.919	0.961	0.925
RL	0.899	0.900	0.952	0.908
SOL	0.975	0.975	0.980	0.908
SE	0.964	0.964	0.974	0.902

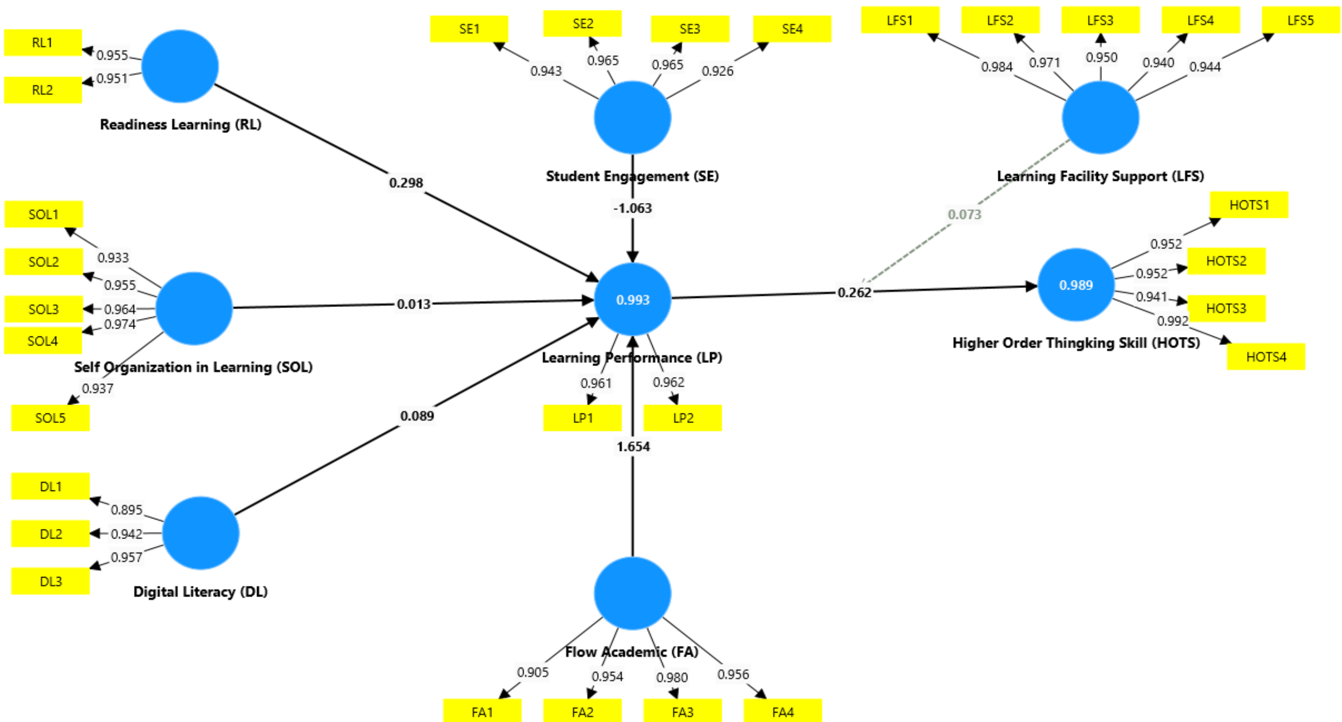

Fig. 1. Hypothesis testing and model significance.

2) Structural model analysis

The analysis of each latent variable was carried out using R-square to determine the predictive strength of the structural model. As presented in Table 5, the R-square value of Learning Performance (LP) has a strong condition, with a coefficient of 0.993. This means that 99.3% of Learning Performance (LP) can be explained by the existence of the variables Digital Literacy (DL), Flow Academic (FA), Learning Facility Support (LFS), Readiness Learning (RL), Self Organization in Learning (SOL), Student Engagement (SE). The strength of the R-square shows that the model has a very strong power in explaining the influence of the seven variables on Higher Order Thinking Skill (HOTS), with the remaining 98.9% influenced by other variables.

Table 5. R-Square

	R-square	Adjusted R-square
Higher Order Thingking Skill (HOTS)	0.989	0.989
Learning Performance (LP)	0.993	0.993

3) Hypothesis testing and path analysis

The hypothesis is tested using the bootstrapping method. The t-statistic and *p*-value can be used to analyze the hypothesis test. The hypothesis is accepted if the range of t-statistic values is >1.96 and the *p*-value is <0.05, which implies that the exogenous variable affects the endogenous variable and vice versa.

Based on respondent data, the majority of survey participants were female, as many as 719 people or 67.8%, while men numbered 342 people or 32.2%. Respondents were spread across various years of entry, with the largest proportion being students entering in 2023 as many as 313 people (29.5%), followed by 2022 with 261 people (24.6%), and 2024 as many as 256 people (24.1%). Students who entered in 2021 numbered 197 people (18.6%), while those who entered before 2021 were only 34 people (2.3%). In terms of internet access devices, the majority of respondents used their own devices, as many as 1005 people (94.7%), while 40 people (3.8%) used campus-owned devices, and 16 people (1.5%) rented devices. Most respondents accessed the internet via cellphones, namely 966 people (91%), and only 93 people (8.8%) used laptops. The duration of respondents' internet access was also quite long, where 783 people (73.8%) spent 3–8 h per day accessing the internet, while 278 people (20.2%) spent less than 3 hours. In terms of domicile, more than half of the respondents lived in the city center, namely 573 people (54.2%), while 486 people (45.8%) lived in the suburbs. The results of the model fit analysis can be seen in Table 6.

Table 6. Fit model

Fit model	Saturated Model (saturated)	Model Forecast
SRMR	0.054	0.055
d_ULS	1.287	1.313
d_G	n/a	n/a
Chi-square	∞	n/a
NFI	n/a	n/a

In detail, hypothesis testing also reveals direct and indirect influences, as presented in, as presented in Table 7, the results of the Path coefficient analysis, Table 8, the results of the Indirect effect analysis, Table 9, the results of the Specific indirect effect analysis and Table 10, the results of the analysis. Based on the measurements, the variables learning facilities support and student engagement have a fairly strong direct influence on Higher Order Thinking Skills (HOTS), this can be seen from the t-statistic results of 37.982 with a *p*-value of 0.000 on the learning facilities support variable and t-statistics of 14.097 with a *p*-value of 0.000 on the student engagement variable. The variable that also has a strong influence on Hots abilities in students is academic flow, with a t-statistic value of 14.865 and a *p*-value of 0.000. These variables are significant contributors in shaping higher-order thinking skills in Gen Z. Another variable that affects exogenous variables is the fairly close relationship between readiness learning and hinger order thinking skills. In addition, there is a relationship between digital literacy and hinger order thinking skills.

Table 7. Path coefficient

Relationship between Variables	Original sample (O)	Standar deviasi (STDEV)	T statistik (|O/STDEV|)	Nilai P (P values)
DL→LP	0.089	0.007	12.656	0.000
FA→LP	1.654	0.041	39.971	0.000
LFS→HOTS	0.823	0.022	37.982	0.000
LP→HOTS	0.262	0.019	13.568	0.000
RL→LP	0.298	0.014	20.853	0.000
SOL→LP	0.013	0.033	0.403	0.687
SE→LP	−1.063	0.029	36.224	0.000
LP→HOTS	0.073	0.009	8.218	0.000

Note: The variable—which has a P Value marked green shows a significant relationship between the indicator—indicators that influence Higher Order Thing Skill.

Table 8. Indirect effect

Relationship between Variables	Original sample (O)	Standar deviasi (STDEV)	T statistik (|O/STDEV|)	Nilai P (P values)
DL→HOTS	0.023	0.002	10.398	0.000
FA→HOTS	0.433	0.029	14.865	0.000
RL→HOTS	0.078	0.007	10.650	0.000
SOL→HOTS	0.003	0.009	0.392	0.695
SE→HOTS	−0.278	0.020	14.097	0.000

Table 9. Specific indirect effect

Relationship between Variables	Original sample (O)	Standar deviasi (STDEV)	T statistik (|O/STDEV|)	(P values)
RL→LP→HOTS	0.078	0.007	10.650	0.000
SOL→LP→HOTS	0.003	0.009	0.392	0.695
SE→LP→HOTS	−0.278	0.020	14.097	0.000
DL→LP→HOTS	0.023	0.002	10.398	0.000
FA→LP→HOTS	0.433	0.029	14.865	0.000

Table 10. Total effect

Relationship between Variables	Original sample (O)	Standar deviasi (STDEV)	T statistik (|O/STDEV|)	Nilai P (P values)
DL→HOTS	0.023	0.002	10.398	0.000
DL→LP	0.089	0.007	12.656	0.000
FA→HOTS	0.433	0.029	14.865	0.000
FA→LP	1.654	0.041	39.971	0.000
LFS→HOTS	0.823	0.022	37.982	0.000
LP→HOT	0.262	0.019	13.568	0.000
RL→HOTS	0.078	0.007	10.650	0.000
RL→LP	0.298	0.014	20.853	0.000
SOL→HOTS	0.003	0.009	0.392	0.695
SOL→LP	0.013	0.033	0.403	0.687
SE→HOTS	−0.278	0.020	14.097	0.000
SE→LP	−1.063	0.029	36.224	0.000
LFS×LP→HOTS	0.073	0.009	8.218	0.000

4) Network analysis

Network analysis in this study aims to understand the dynamic relationship between various variables that influence Higher Order Thinking Skills (HOTS) in Generation Z students. Using a structural analysis model, this study maps the interaction between the variables Digital Literacy, Academic Flow, Student Engagement, Readiness to Learn, Self-Organization, and Learning Facilities Support (LFS) on Learning Performance (LP) and its impact on HOTS. This approach not only measures the direct relationship between variables, but also identifies indirect influences through mediators such as Learning Performance. The resulting network image shows that Digital Literacy and Academic Flow act as key nodes that have high connectivity to other variables. Student Engagement, Readiness to Learn, and self-organization act as bridging nodes that strengthen the integration between various dimensions of learning.

Fig. 2 shows the results of the centrality analysis on the research variable network through four main indicators: Closeness, Betweenness, Strength, and Expected Influence. The Learning Facility Support (LFS) indicator appears to dominate the Strength and Expected Influence values, indicating a strong and broad influence in the network. Meanwhile, the SE2 indicator has the highest Betweenness value, indicating its role as an important link between indicators. The highest Closeness value is shown by SE4 and HOTS2, which means its closeness is high to other elements in the network. These findings identify the most influential key indicators in the learning system studied.

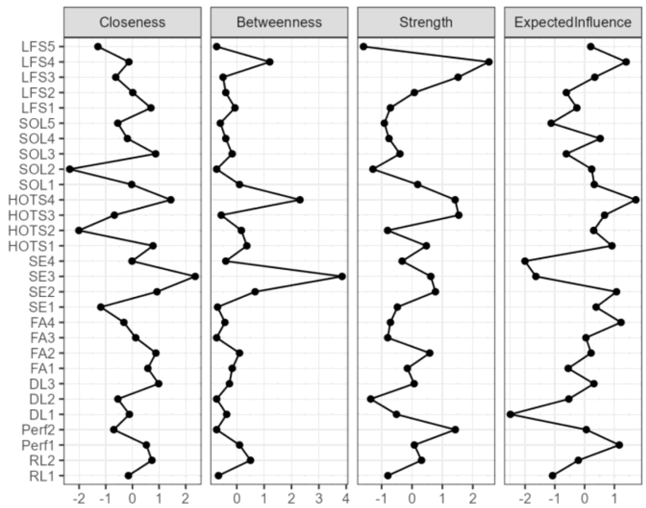

Fig. 2. Centrality plot.

The results of the analysis show that Digital Literacy has a significant influence on Learning Performance with a t-statistic value of 12.656 (p <0.05). This variable provides an indirect contribution to HOTS by increasing the efficiency and effectiveness of technology-based learning processes. In addition, Academic Flow acts as a reinforcement of Learning Performance with a very significant relationship, indicated by a t-statistic of 39.971 (p <0.05). Academic Flow helps students achieve optimal learning conditions that have a positive impact on the development of high-level thinking skills.

Fig. 3 shows the visualization of the network between research variables using network analysis. Each node represents an indicator of the variable, while the connecting lines (edges) indicate the strength and direction of the relationship between the indicators. Blue indicates a positive correlation, while red indicates a negative correlation; the thicker the line, the stronger the relationship between the indicators. It appears that the LFS3, LFS4, and Perf2 indicators form a cluster with a very strong relationship, indicated by the thick blue line. The SE2 and HOTS1 indicators also appear to play an important role as links in the network, indicating a central role in the learning system studied.

Meanwhile, student involvement or Student Engagement actively has a direct effect on Learning Performance with a t-statistic of 36.224. However, there is a complex dynamic where this variable shows a direct negative effect on HOTS with a value of −0.278. This indicates the need for intervention to ensure that student involvement can have a positive impact on HOTS development. Other contributing factors are readiness to learn and self-organization. Readiness to Learn has a significant relationship both directly and through Learning Performance, with a t-statistic of 10.650. Conversely, Self-Organization shows a less significant impact on HOTS even though it has a positive effect on Learning Performance. Learning Facilities Support (LFS) plays an important role as a moderating variable that strengthens the relationship between learning factors and HOTS, with a t-statistic of 37.982. This support includes technological facilities, educational resources, and a conducive learning environment, which allows students to maximize their potential in the learning process.

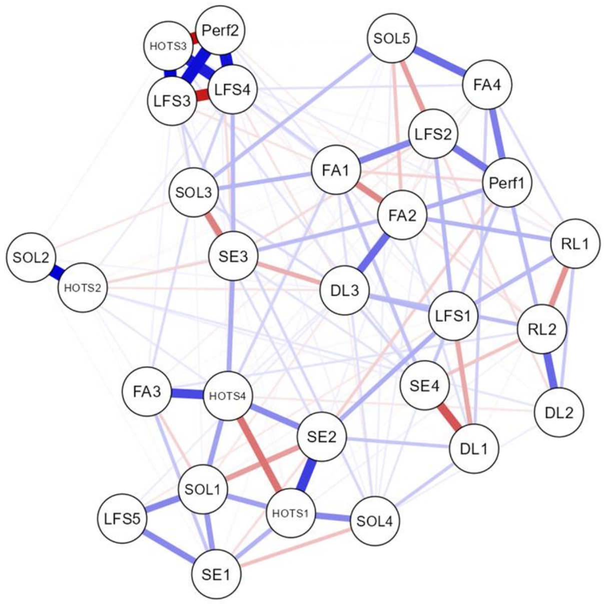

Fig. 3. Network analysis.

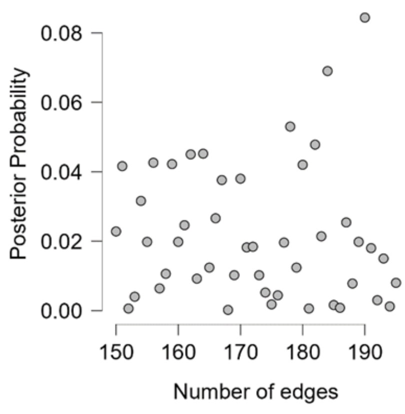

Fig. 4. Complexity o.

The results of this network analysis provide an in-depth picture of the complex interactions between variables. Digital Literacy and Academic Flow are proven to be dominant factors that strengthen Learning Performance and HOTS. However, the negative effect of Student Engagement suggests that learning strategies should be directed to ensure more productive student engagement. Learning Facilities Support (LFS)-based interventions are needed to increase synergy between learning variables. Educational institutions are advised to focus on providing innovative learning facilities that support collaboration, thereby increasing the effectiveness of Generation Z learning.

Fig. 4 showing the relationship between Posterior Probability and Number of Edges represents the results of model estimation to explore the relationship between important variables in the student learning process, such as student engagement, learning readiness, digital literacy, self-organization, and higher-order thinking skills (HOTS). The plot results show that there is no single network structure that is dominantly most likely, but rather there are several models with relatively high posterior probability values. This reflects the complexity and interconnectedness of the variables that form the student learning system.

B. Discussion

After testing the developed model, we found that Higher Order Thinking Skills (HOTS) in Generation Z students are highly influenced by several key factors such as Student Engagement, Readiness to Learn, Self-Organization, Digital Literacy, and Academic Flow. These findings reinforce the importance of students' active involvement in the learning process as a driver of higher-order thinking skills. Students who are actively involved in learning tend to have better HOTS, as this involvement increases their participation and motivation in analyzing and solving complex problems [7, 28, 63].

In addition, Readiness to Learn has also been shown to be a significant predictor in influencing HOTS. Students who are more mentally and emotionally prepared to learn show higher abilities in developing critical and analytical thinking skills. This factor is important in supporting the process of in-depth mastery of the material [64, 65]. Self-Organization makes a major contribution to the achievement of HOTS, because organizing time and resources effectively helps students to be more focused and structured in their learning [32, 66].

In the context of rapidly developing technology, Digital Literacy plays an important role in improving HOTS. Students who are proficient in using technology to search for information and complete learning tasks tend to have better critical and innovative thinking skills [10, 67, 68]. Academic Flow is also a significant factor. Students who experience a state of academic flow, where they are fully focused on learning tasks, tend to achieve better results in higher-order thinking. These findings indicate that Learning Facilities Support (LFS) plays an important role in strengthening the influence of these factors on HOTS [11, 69]. Adequate learning facility support allows students to utilize existing resources optimally, thereby increasing the effectiveness of engagement, learning readiness, and digital literacy in developing HOTS [70–72]. Therefore, universities need to ensure that supportive learning facilities are available to create an ideal learning environment for HOTS development among Generation Z students.

Judging from the data above, researchers found that self-organization not only contributes to the improvement of Higher Order Thinking Skills (HOTS), but also has an impact on the Learning Performance of Generation Z students. The ability of students to manage time and resources effectively plays an important role in determining how well they can adapt to complex and diverse academic demands. When students are able to plan their learning activities, they are more likely to be actively involved in learning, which in turn improves their academic performance. The ability of students to manage time and resources well contributes significantly to their academic performance. This is in line with previous studies showing that Generation Z, who are able to organize themselves, tend to be more successful in overcoming complex learning challenges [41, 73], as digital natives, have wide access to information and technology [53, 74]. However, without self-organization skills, this potential can be hampered. This study reveals that students who are proactive in planning and organizing their learning activities are better able to develop critical and creative thinking skills, which are the main components of HOTS. For example, students who manage their time to reflect on the material they have learned demonstrate deeper understanding and are able to apply concepts in real-world situations [28, 63].

Therefore, it is important for educational institutions to provide training and support in developing self-organization. Programs that teach time management, learning strategies, and priority setting will be very useful for Generation Z students in developing high-level thinking skills. Given the unique characteristics of Generation Z, one of which is the ability to multitask and speed in accessing information. Generation Z is accustomed to consuming content from various platforms simultaneously, which makes them want fast (instant) and efficient access to information and services [3, 41, 73]. They also have a more inclusive view and value diversity, so they tend to be more open to various racial, gender, and cultural backgrounds and in addition mental health is also a priority for Generation Z.

According to a report from the American Psychological Association 2020, more than 90% of Gen Z reported feeling stressed, and 61% felt pressured by social pressures. They tend to be more open about discussing mental health issues and seeking support when needed. With these characteristics, it is important for educational institutions to design learning strategies that suit the needs and preferences of Generation Z. Understanding that they prioritize experience, practicality, and social values can help create a more effective and relevant learning environment for them.

V. Conclusion

A. Conclusion

Based on the results of this study, it can be concluded that the development of Higher Order Thinking Skills (HOTS) in Generation Z students in higher education is greatly influenced by various key factors, namely Student Engagement, Readiness to Learn, Self-Organization, Digital Literacy, and Academic Flow. These factors have a significant impact on improving student learning performance, with support from Learning Facilities Support (LFS), which plays a role as an important intervention in strengthening this influence. Active involvement of students in the learning process, their mental and emotional readiness, self-regulation skills, good digital literacy, and academic "flow" experiences contribute positively to HOTS. Support from learning facilities is also an important element that strengthens the relationship between these factors. However, this study is limited to several variables that influence HOTS. Further research is expected to identify other relevant variables to provide a more comprehensive understanding of the best way to improve HOTS in the context of higher education.

B. Implications

This research has implications for the development of educational programs in universities, especially in improving the Higher Order Thinking Skills (HOTS) of Generation Z students. The results of this research can be a reference for universities in formulating policies to strengthen student involvement, increase learning readiness, digital literacy and effective academic flow. In addition, this research also shows the importance of supporting adequate learning facilities as an important intervention in improving student learning performance.

With a better understanding of the factors that influence Higher Order Thinking Skills (HOTS), colleges can develop more appropriate strategies and curricula to accommodate Generation Z learning needs, thereby preparing graduates who are better prepared to face challenges in the world of work and digital life.

C. Limitations

The limitation of this research is that this research only focuses on factors that influence Higher Order Thinking Skills (HOTS) in Generation Z students at universities in Indonesia. This research has not considered other variations that may arise outside the geographical or cultural context of Indonesia. Furthermore, this study has not revealed the role of other variables that could potentially influence HOTS, such as socioeconomic background, intrinsic motivation, or alternative learning methods. Follow-up research is needed to identify additional factors that may be relevant in a broader context.

D. Future Research Advice

Subsequent research is expected to identify other variables related to Higher Order Thinking Skills (HOTS), such as technology-based teaching methods, student creativity, or social interaction on campus. In addition, further studies are also suggested to develop more innovative learning approaches and adapt national education curricula that can improve HOTS among Generation Z. This development must be supported by comprehensive studies and designs so that the curriculum can be more effective in facing educational challenges in the digital era.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Ganefri designed and developed the main idea of the research, developed the conceptual framework, and conducted a critical review of the entire article. Abna Hidayati provided suggestions for improvement, provided important input in the preparation of the methods and results sections. Hendra Hidayat managed the literature review and ensured the appropriateness of the theory used in the research. Zadrian Ardi was responsible for the research methodology and statistical analysis. Ulfia Rahmi conducted the main data analysis, as well as compiled references and bibliography, involved in the interpretation of the results. Nofrion contributed to the collection of field data, validation of research instruments, and was involved in the interpretation of the results. Andra Saputra was responsible for editing the draft of the article and coordinating with the journal in the submission and revision process. All authors had approved the final version.

Funding

This research is supported by a research center grant with research contract number 2354/UN35.15/LT/2024.

Acknowledgment

The author would like to thank Padang State University for funding and supporting this research, so that it can be carried out well.

References

[1] M. Dimock. (2019). Defining generations: Where millennials end and Generation Z begins. Pew Research Center. [Online]. Available: https://www.pewresearch.org/short-reads/2019/01/17/where-millennials-end-and-generation-z-begins/

[2] M. Hernandez-de-Menendez, C. A. E. Díaz, and R. Morales-Menendez, "Educational experiences with Generation Z," *Int. J. Interact. Des. Manuf.*, vol. 14, no. 3, pp. 847–859, 2020. doi: 10.1007/s12008-020-00674-9

[3] IDN Research Institute. (2024). Indonesia Gen Z. *IDN Res. Inst.* [Online]. p. 102. Available: https://cdn.idntimes.com/content-documents/indonesia-gen-z-report-2024.pdf

[4] S. Bell, "Project-based learning for the 21st century: Skills for the future," *Clear. House A J. Educ. Strateg.*, vol. 83, no. 2, pp. 39–43, 2010. doi: 10.1080/00098650903505415

[5] B. Trilling and C. Fadel, "Bernie trilling, Charles Fadel-21st century skills_ learning for life in our times-Jossey-Bass (2009)," *J. Sustain. Dev. Educ. Res.*, vol. 2, no. 1, p. 243, 2009.

[6] B. J. Zimmerman, "Becoming a self-regulated learner: An overview," *Theory Pract.*, vol. 5841, no. 2002, pp. 64–70, 2010. doi: 10.1207/s15430421tip4102

[7] A. F. Suryana and A. Hidayati, "Analysis of the development needs of cooperative project based learning models in the digital era," *J. Vocat. Educ. Inf. Technol*, vol. 1, no. 1, pp. 13–19, 2020. (in Indonesian)

[8] WEF. (World Economic Forum). (2023). Future of jobs report 2023. Geneva Switzerland. [Online]. Available: https://www.weforum.org/publications/the-future-of-jobs-report-2023/

[9] T. T. Hoang and P. H. Thy, "Research on factors affecting the e-entrepreneuship intention of generation z in Vietnam," *Int. J. Sci. Res. Manag.*, vol. 12, no. 05, pp. 6239–6265, 2024. doi: 10.18535/ijsrm/v12i05.em01

[10] P. Purnamawati, M. Yahya, F. A. Darmawan, and M. Akil, "Learning design based on industry 4.0 (teaching industry) to improve students' practical skills in vocational high school," in *Proc. Vocat. Eng. Int. Conf.*, 2023, pp. 376–381.

[11] G. Baskoro, I. Mariza, and I. N. Sutapa, "Innovation to improve critical thinking skills in the generation z using peeragogy as a learning approach and Artificial Intelligence (AI) as a tool," *J. Tek. Ind.*, vol. 25, no. 2, pp. 121–130, 2023. doi: 10.9744/jti.25.2.121-130

[12] C. A. Dewi, P. Pahriah, and A. Purmadi, "The urgency of digital literacy for generation z students in chemistry learning," *Int. J. Emerg. Technol. Learn.*, vol. 16, no. 11, pp. 88–103, 2021. doi: 10.3991/ijet.v16i11.19871

[13] R. S. Amaliah, A. N. Solihat, and B. Widyaningrum, "Analys of academic flow, digital literacy and self-regulated learning on academic achievement," *Educenter J. Ilm. Pendidik.*, vol. 2, no. 3, pp. 299–305, 2023. doi: 10.55904/educenter.v2i3.925

[14] P. Evdokimov and U. Garfagnini, "Higher-order learning," *Exp. Econ.*, vol. 25, no. 4, pp. 1234–1266, 2022. doi: 10.1007/s10683-021-09743-6

[15] J. Pawliczak, "Creative writing as a best way to improve writing skills of students," *Sino-US English Teach.*, vol. 12, no. 5, pp. 347–352, 2015. doi: 10.17265/1539-8072/2015.05.004

[16] K. C. Suryandari, S. Fatimah, S. Sajidan, S. B. Rahardjo, and Z. K. Prasetyo, "Project-based science learning and pre-service teachers'

science literacy skill and creative thinking," *Cakrawala Pendidikan*, pp. 345–355, 2017.

[17] H. J. Tamboto, A. C. Manongko, and J. Tarore, "The effect of entrepreneurship education and creative thinking towards entrepreneurship interest of students department of economic education, faculty of economics, Manado State University," *Int. J. Sci. Res. Manag*., vol. 10, no. 10, pp. 1245–1252, 2022. doi: 10.18535/ijsrm/v10i10.sh02

[18] A. Astriyani, P. Matematika, F. I. Pendidikan, and U. M. Jakarta, "Webinar the role of pedagogical competence and the importance of 21st century digital literacy to build a resilient generation z," in *Proc. the National Seminar on Community Service LPPM UMJ*, 2021, vol. 10, no. 3, pp. 102–107. (in Indonesian)

[19] L. Y. Hastini, R. Fahmi, and H. Lukito, "Can learning using technology improve human literacy in generation z in Indonesia?" *J. Manaj. Inform.*, vol. 10, no. 1, pp. 12–28, 2020. doi: 10.34010/jamika.v10i1.2678 (in Indonesian)

[20] T. Junanto and R. Afriani. (2016). Implementation of digital-age literacy in 21st century education in Indonesia. *Prosiding Seminar Nasional Pendidikan Sains (SNPS)*. [Online]. Available: https://media.neliti.com/media/publications/173402-ID-none.pdf (in Indonesian)

[21] L. Zhang and Y. Ma, "A study of the impact of project-based learning on student learning effects: A meta-analysis study," *Front. Psychol*., vol. 14, no. July, pp. 1–14, 2023. doi: 10.3389/fpsyg.2023.1202728

[22] S. Prayogi, U. Islam, N. Mataram, and U. P. Mandalika, "Problem-based learning utilizing assistive virtual simulation in mobile application to improve students' critical thinking skills," *Conscientia Beam*, vol. 11, no. 3, pp. 351–364, 2023. doi: 10.18488/61.v11i3.3380

[23] J. Parong, S. Barbara, R. Mayer, and S. Barbara, "Learning science in immersive virtual reality," *J. Educ. Psychol*., vol. 11, 2018. doi: 10.1037/edu0000241.

[24] O. Akinina, A. Chediia, B. Syzdykova, and S. Vdovin, "The development of entrepreneurial competencies among students of various age groups within the MOOCs environment," *Int. J. Inf. Educ. Technol.*, vol. 14, no. 10, pp. 1335–1343, 2024. doi: 10.18178/ijiet.2024.14.10.2164

[25] R. Thahir, N. Magfirah, and A. Anisa, "The relationship between high order thinking skills and science literacy ability of biology education students," *Biodik*, vol. 7, no. 3, pp. 105–113, 2021. doi: 10.22437/bio.v7i3.14386 (in Indonesian)

[26] M. L. B. Dima, Daflizar, and Ahmadi, "The implementation of Higher Order Thinking Skills (HOTS) in English language teaching," *J. English Educ. Teach*., vol. 8, no. 2, pp. 255–268, 2021.

[27] N. Nurlaila, Suparmi, and W. Sunarno, "Physics learning with PBL using problem solving and problem posing reviewed from creativity and thinking skills," Doctoral dissertation, UNS (Sebelas Maret University)), 2013. (in Indonesian)

[28] C. Cain, A. Bryant, C. Buskey, and Y. Ferguson, "Generation z, learning preferences, and technology: An academic technology framework based on enterprise architecture," *J. South. Assoc. Inf. Syst*., vol. 9, no. 1, pp. 1–14, 2022. doi: 10.17705/3jsis.00019

[29] D. Velički and V. Velički, "Characteristics and particularities of educating the net-generation," in *Proc. 2015 WEI Int. Acad. Conf.*, West East Institute, 2015, pp. 109–120.

[30] N. N. Daeid, "Educating the next generation," *Sci. Justice*, vol. 48, no. 2. 2008. doi: 10.1016/j.scijus.2008.03.007

[31] J. A. Fredricks, P. C. Blumenfeld, A. H. Paris, and J. A. Fredricks, "School engagement: Potential of the concept, state of the evidence," *Rev. Educ. Res.*, vol. 74, no. 1, pp. 59–109, 2004.

[32] R. Pérez-López, R. Gurrea-Sarasa, C. Herrando, M. J. Martín-De Hoyos, V. Bordonaba-Juste, and A. U. Acerete, "The generation of student engagement as a cognition-affect-behaviour process in a Twitter learning experience," *Australas. J. Educ. Technol*., vol. 36, no. 3, pp. 132–146, 2020. doi: 10.14742/AJET.5751

[33] The Organisation for Economic Co-operation and Development. (2019). *Active with Indonesia*. [Online]. p. 68. Available: https://www.oecd.org/indonesia/Active-with-Indonesia.pdf

[34] C. Dede and C. Dede, "Immersive interfaces for engagement and learning," *Educ. Technol*., vol. 323, no. 5910, pp. 66–69, 2009. doi: 10.1126/science.1167311

[35] N. Obiosa, "Effects of students' motivation and engagement on students' satisfaction in a lecture: Empirical analysis," *Int. J. Instr*., vol. 13, no. 3, pp. 861–876, 2020. doi: 10.29333/iji.2020.13357a

[36] G. I. Paraschiv and M.-I. Stan, "A brief survey concerning environmental action: The need for collective engagement," *Ovidius Univ. Ann. Econ. Sci. Ser*., vol. 23, no. 1, pp. 182–191, 2023. doi: 10.61801/ouaess.2023.1.24

[37] H. G. Fuertes, I. A. Evangelista, I. Jay, Y. Marcellones, and J. R. Bacatan, "Student engagement, academic motivation, and academic performance of intermediate level students," *Int. J. Nov. Res. Educ. Learn*., vol. 10, no. 3, pp. 133–149, 2023. https://doi.org/10.5281/zenodo.8037103

[38] P. H. Mirvis and M. Csikszentmihalyi, "Flow: The psychology of optimal experience," *Acad. Manag. Rev*., vol. 16, no. 3, 636, 1991. doi: 10.2307/258925

[39] L. Gruppen, D. M. Irby, S. J. Durning, and L. A. Maggio, "Interventions designed to improve the learning environment in the health professions: A scoping review," *MedEdPublish*, vol. 7, 211, 2018. doi: 10.15694/mep.2018.0000211.1

[40] Z. Asril, S. Syafril, Engkizar, and Z. Arifin, "Advancing educational practices: Implementation and impact of virtual reality in Islamic religious education," *J. Pendidik. Islam*, vol. 9, no. 2, pp. 199–210, 2023. doi: 10.15575/jpi.v9i2.20567

[41] M. Hernandez-de-Menendez, C. A. E. Díaz, and R. Morales-Menendez, "Educational experiences with generation z," *Int. J. Interact. Des. Manuf*., vol. 14, no. 3, pp. 847–859, 2020. doi: 10.1007/s12008-020-00674-9

[42] J. F. Hair, C. M. Ringle, and M. Sarstedt, *Practical Least Squares Structural Equation Modeling*, 2016.

[43] A. P. Rehmat, "Engineering the path to higher-order thinking in elementary education: A problem-based learning approach for stem integration," UNLV Theses, Diss. Prof. Pap. Capstones, no. August, p. 216, 2015.

[44] S. Farias-Gaytan, I. Aguaded, and M. S. Ramirez-Montoya, "Digital transformation and digital literacy in the context of complexity within higher education institutions: A systematic literature review," *Humanit. Soc. Sci. Commun*., vol. 10, no. 1, pp. 1–11, 2023. doi: 10.1057/s41599-023-01875-9

[45] M. Spante, S. S. Hashemi, M. Lundin, and A. Algers, "Digital competence and digital literacy in higher education research: Systematic review of concept use," *Cogent Educ.*, vol. 5, no. 1, pp. 1–21, 2018. doi: 10.1080/2331186X.2018.1519143

[46] Q. Meng, Z. Yan, J. Abbas, A. Shankar, and M. Subramanian, "Human–computer interaction and digital literacy promote educational learning in pre-school children: Mediating role of psychological resilience for kids' mental well-being and school readiness," *Int. J. Hum. Comput. Interact*., pp. 1–15, 2023. doi: 10.1080/10447318.2023.2248432

[47] S. W. Wu, H.-K. Lee, and J. Chang, H.-Y. Liang, "Computers & education current status, opportunities and challenges of augmented reality in education," *Comput. Educ*., vol. 62, pp. 41–49, 2013. doi: 10.1016/j.compedu.2012.10.024

[48] J. V Kalpakian and A. Marzouk, "Generation z: Implications for universities," *Elit. J. Int. J. Educ. Lang. Lit*., vol. 3, no. 1, pp. 35–45, 2023.

[49] D. Iftode, "Generation Z and learning styles," *SEA-Practical Appl. Sci.,* vol. 7, no. 21, pp. 255–262, 2019.

[50] A. J. Nicholas, "Preferred learning methods of generation z," *Digit. Commons @ Salve Regina Fac.*, vol. 1, no. 1, pp. 1–12, 2020.

[51] D. Schwieger and C. Ladwig, "Reaching and retaining the next generation: adapting to the expectations of gen z in the classroom," *Inf. Syst. Educ. J*., vol. 16, no. 3, 16, 2018.

[52] E. J. Cilliers, "Reflecting on social learning tools to enhance the teaching-learning experience of generation z learners," *Front. Educ*., vol. 5, no. January, pp. 1–10, 2021. doi: 10.3389/feduc.2020.606533

[53] M. Prensky, "Digital natives, digital immigrants," *Horiz.*, vol. 9, no. 5, pp. 67–85, 2001. doi: 10.4135/9781483387765.n6

[54] A. Al-Yakin and P. M. I. Seraj, "Impact of metaverse technology on student engagement and academic performance: The mediating role of learning motivation," *Int. J. Comput. Inf. Manuf*., vol. 3, no. 1, pp. 10–18, 2023. doi: 10.54489/ijcim.v3i1.234

[55] J. F. Hair Jr, G. T. M. Hult, C. M. Ringle, M. Sarstedt, N. P. Danks, and S. Ray, *Review of Partial Least Squares Structural Equation Modeling (PLS-SEM) Using R: A Workbook*, vol. 30, no. 1, 2023. doi: 10.1080/10705511.2022.2108813

[56] M. L. Yahaya, A. A. Murtala, and H. N. Onukwube, "Partial Least Squares (PLS-SEM): A note for beginners," *Int. J. Environ. Stud. Saf. Res*., vol. 4, no. 2019, pp. 1–30, 2019.

[57] K. K. K. Wong, "Partial Least Squares Structural Equation Modeling (PLS-SEM) techniques using SmartPLS," *Mark. Bull*., vol. 24, no. 1, pp. 1–32, 2013.

[58] A. D. Muryadi, "Program evaluation models in evaluation research," *Jurnal Ilmiah Penjas (Penelitian, Pendidikan Dan Pengajaran*, vol. 3, no. 1, 2017. (in Indonesian)

[59] A. Saputra, M. Iswari, F. Seni, R. Desain, and U. N. Padang, "Guidance counseling strategies to overcome academic problems of

high school students," *Int. J. Technol. Vocat. Educ*., vol. 5, no. 1, pp. 1–6, 2024.
[60] A. Saputra, N. Gistituati, A. Bentri, I. Aziz, and A. Hidayati, "Analysis of teacher barriers in the implementation of curriculum Merdeka in secondary schools," *DE_JOURNAL (Dharmas Educ. Journal)*, vol. 5, no. 1, pp. 50–57, 2024.
[61] G. Falloon, "From digital literacy to digital competence: The Teacher Digital Competency (TDC) framework," *Educ. Technol. Res. Dev*., vol. 68, no. 5, pp. 2449–2472, 2020. doi: 10.1007/s11423-020-09767-4
[62] A. M. Stjepić, M. Vukšić, and D. S. Vugec, "Digital literacy of the generation z students and their attitudes and beliefs towards ICT knowledge and skills," *Int. J. Vallis Aurea*, vol. 5, no. 1, pp. 17–29, 2019. doi: 10.2507/ijva.5.1.2.56
[63] E. Yu, "Student-inspired optimal design of online," *J. Educ. Online*, vol. 17, no. 1, 2020.
[64] A. Hidayati, A. Bentri, and Eldarni, "Supporting factors for the implementation of mobile learning for elementary school students using an authentic approach and real-world activities," *Int. J. Interact. Mob. Technol*., vol. 16, no. 5, pp. 107–120, 2022. doi: 10.3991/ijim.v16i05.26551
[65] A. Bentri and A. Hidayati, "Factors supporting digital pedagogical competence of primary education teachers in Indonesia," *Front. Educ*., no. November, pp. 1–9, 2022. doi: 10.3389/feduc.2022.929191
[66] J. Stefaniak, "A systems view of supporting the transfer of learning through e-service-learning experiences in real-world contexts," *TechTrends*, vol. 64, no. 4, pp. 561–569, 2020. doi: 10.1007/s11528-020-00487-3
[67] A. Febliza, Z. Afdal, and J. Copriady, "Improving students' critical thinking skills: Is interactive video and interactive web module beneficial?" *Int. J. Interact. Mob. Technol*., vol. 17, no. 3, pp. 70–86, 2023. doi: 10.3991/ijim.v17i03.34699
[68] S. Rahmiwati, Festiyed, and Ratnawulan, "The development of integrated science to improve students' new literacy skills in cooperative learning," *Adv. Soc. Sci. Educ. Humanit. Res.*, no. January, 2020. doi: 10.2991/assehr.k.201209.257
[69] S. Dolapcioglu and A. Doğanay, "Development of critical thinking in mathematics classes via authentic learning: An action research," *Int. J. Math. Educ. Sci. Technol.*, vol. 4, no. 10, pp. 1–24, 2020, doi: 10.1080/0020739X.2020.1819573
[70] H. Aliyu, M. Ebikabowei, and A. J. Kola, "Problem-Based learning in remote learning scenario utilizing climate change virtual reality video in mobile application to train critical thinking," *International Journal of Essential Competencies in Education*, vol. 2, no. 2, pp. 144–159, 2023.
[71] A. Sutiani, M. Situmorang, and A. Silalahi, "Implementation of an inquiry learning model with science literacy to improve student critical thinking skills," *Int. J. Instr*., vol. 14, no. 2, pp. 117–138, 2021. doi: 10.29333/iji.2021.1428a
[72] A. Khoiri, Nasokah, T. Amalia, and S. Hefi, "Critical analysis of science education in Indonesia: Problematics, solutions and basic science integrated models," *SPEKTRA: Jurnal Kajian Pendidikan Sains*, vol. 6, no. 1, pp. 19–34, 2020. (in Indonesian)
[73] N. M. Ishak, H. Ranganathan, and K. Harikrishnan, "Learning preferences of generation z undergraduates at the university of Cyberjaya," *J. Learn. Dev.*, vol. 9, no. 2, pp. 331–339, 2022. doi: 10.56059/jl4d.v9i2.584
[74] T. B. Creighton, "Digital natives, digital immigrants, digital learners: An international empirical integrative review of the literature," *Educ. Leadersh. Rev*., vol. 19, no. 1, pp. 132–140, 2018.