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DOES GENAI ENHANCE THE 4CS? A STUDY AMONG HIGHER EDUCATION STUDENTS

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Abstract

This study aims to examine empirically the influence of perceived usefulness of Generative Artificial Intelligence (GenAI) and teaching method on students' 4Cs skills (critical thinking, creativity, communication, and collaboration) in higher education. The research also investigates the mediating role of teaching method in the relationship between perceived usefulness of GenAI and 4Cs competencies. The object of this research involved 50 undergraduate students from Universitas Negeri Surabaya, Indonesia. Data were collected through a structured questionnaire consisting of three main constructs, namely perceived usefulness of GenAI, teaching method, and 4Cs skills, measured using a five-point Likert scale. The analysis was conducted using Partial Least Squares–Structural Equation Modeling (PLS-SEM) with SmartPLS software. The results indicate that perceived usefulness of GenAI does not have a significant direct effect on students' 4Cs skills. However, perceived usefulness of GenAI significantly influences teaching method, and teaching method shows a strong and significant effect on 4Cs development. Furthermore, teaching method does not significantly mediate the relationship between perceived usefulness of GenAI and 4Cs. These findings suggest that GenAI technology alone is not sufficient to enhance students' 21st-century skills without strong pedagogical integration. Teaching method is confirmed as the key factor that directly contributes to the development of critical thinking, creativity, communication, and collaboration among students. Therefore, higher education institutions are encouraged to prioritize instructional innovation and pedagogical strategies to maximize the potential benefits of GenAI for meaningful learning and skills development. The study contributes to the extension of the Technology Acceptance Model (TAM) by highlighting the importance of pedagogical design beyond technological perception in improving learning outcomes.

Keywords: *Perceved Usefulness of GenAI, Teaching Method, 4Cs, Creativity*

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INTRODUCTION

Education is the main foundation of the nation's progress because it increases the intellectual capacity, skills, and knowledge of the community. However, the world of education still faces challenges such as limited infrastructure, the use of technology, and the ability of teachers to

integrate it into learning (Partono et al., 2021). The development of the world of education today has integrated technology into the learning process. In the current era of technological advancement and globalization, education has an important role in maintaining a balance between technological development and human development (Syerlita & Siagian, 2024). In the 21st century, the focus of education shifts from mere material mastery to the development of skills relevant to global needs. The four main skills, known as 4Cs (critical thinking, creativity, communication, and collaboration), are key competencies needed so that students are able to adapt, think critically, collaborate effectively, and innovate in a dynamic world of work (Tangahu et al., 2023). Four 21st century skills known as 4Cs Include critical thinking, creativity, collaboration, and Communication, which complement each other in shaping individual abilities to face modern challenges. Critical thinking emphasizing the ability to analyze, evaluate, and solve problems logically, while creativity encouraging someone to come up with new and innovative ideas as fresh solutions (Tazkiyah, 2022). These two skills are reinforced by Collaboration, namely the ability to work together with others to achieve common goals through synergy and mutual respect. The entire process will not run effectively without Communication, which is the ability to convey and understand information, ideas, and feelings clearly and efficiently.

The ability of the 4Cs is influenced by various factors, including the teaching method and perceived usefulness of GenAI. The teaching methods applied by educators have an important role in shaping the way students think, create, collaborate, and communicate. When these methods are supported by the use of technology, especially Generative AI, which is considered useful and relevant, the learning process becomes more interactive and meaningful. Positive perceptions of the usefulness of GenAI encourage students to be more open in developing ideas, collaborating, and adapting to new ways of learning that are more creative and reflective (Tsiani et al., 2025).

In the context of 21st century education, mastering 4Cs skills is very important so that students are able to adapt to global challenges and the development of industrial 4.0 technology. However, the results of the latest research show that the skill level of 4Cs students in Indonesia is still relatively low. Based on a study by Isnaini et al. (2023), the results of the analysis of SMPN 02 Koto Baru students showed that critical thinking skills only reached 44.2%, creativity 43.6%, communication 47.2%, and collaboration 45.5%. These four aspects are categorized as a whole in low levels. These findings

indicate that students have not been able to develop high-level thinking skills, communicate effectively, and collaborate optimally in the learning process. This condition confirms the need for innovation in learning strategies that can grow and integrate 4Cs skills more effectively to meet the demands of the 21st century (Isnaini et al., 2023). The condition of low 4Cs skills does not only occur at the secondary school level, but also continues to the higher education level. Study results (Harmelia et al., 2023) It found that among students, the application of blended learning only improved critical thinking skills by 34%, creativity by 27%, and collaboration by 29%, while communication skills have not shown significant improvement. This data illustrates that students' 4Cs skills still need to be improved through learning innovations that are more effective and relevant to the demands of the 21st century. The results of PISA 2022 (Volume III: Creative Minds, Creative Schools) show that the average creative thinking score of Indonesian students is around 19 (scale 0–60), far below the OECD average (~33). Only ~31% of Indonesian students achieve baseline proficiency (Level 3) in creative thinking, while the OECD average is around 78%. This indicates that there is a big gap in creative thinking skills that needs to be addressed since primary/secondary education and is relevant for students' readiness in the future. The World Economic Forum (Future of Jobs, 2025) report reveals that analytical and critical thinking are among the most needed skills in the world of work of the future. Most companies now place creative thinking and critical thinking as top priorities in their employee development programs (a WEF report shows more than 40% of organizations make it a focus of training). In line with that, various studies on soft skills also show that critical thinking, problem-solving, and analysis skills are the most in-demand competencies by 2025. This fact emphasizes the importance of measuring students' critical thinking skills as part of their readiness to face the world of work.

Several studies have shown that teaching methods have an effect on the development of the 4Cs in Education. One relevant study examined Project-Based Learning (PjBL) in mathematics education and found that this teaching method significantly improved students' critical thinking, collaboration, communication, and creativity skills (Yulianto et al., 2024). Another quantitative study investigated the impact of STEM-project-based learning (STEM-PjBL) on students' 4C skills and found a positive influence on critical thinking, creative thinking, communication, and collaboration, as measured through a

pretest-posttest design in students (Kurniahtunnisa et al., 2023). Additional research emphasizes the importance of teacher knowledge and teaching methods that align with the application of 4C skills. Teaching methods that explicitly integrate the 4Cs in lesson plans and learning activities have been proven to improve students' competence in the area (Triana et al., 2020). In addition, a study of cross-disciplinary thematic learning shows that real-world problem-based learning activities effectively encourage the development of the 4Cs, emphasizing the role of innovative and integrated teaching methods in fostering these important skills (Lestari et al., 2023). Overall, the research supports that innovative, student-centered teaching methods such as project-based learning, STEM approaches, and cross-disciplinary thematic learning have a positive impact on the development of critical thinking, creative thinking, collaboration, and communication skills in the context of Education (Mulyopratikno & Wiyarsi, 2025). Capacity building 4Cs not only influenced by Teaching Method, but also by perceived usefulness of GenAI.

When students view GenAI as a useful technology, they are more motivated to think critically, create, collaborate, and communicate effectively in the learning process. GenAI can increase creativity through automated idea generation, encourage collaboration on technology-based projects, and strengthen communication through adaptive human-machine interaction. Positive perceptions of GenAI's usability also increase motivation, confidence, and learning engagement. Thus, the higher the perceived usefulness for GenAI, the greater the influence on strengthening the competence of the 4Cs holistically (Türker & Öztürk, 2024).

A survey study by Lee et al. found that many knowledge users report that GenAI is changing the way they do Critical Thinking — in some contexts GenAI reinforces critical thinking when used as an argument-checking tool, but also poses a risk of dependency (H. P. (Hank) Lee et al., 2025). Oliveira's research that developed the perception scale showed that students viewed ChatGPT/GenAI as having a perceived critical thinking disposition—respondents acknowledged the benefits of explaining concepts but worried about diminishing analytical skills if they relied heavily on AI (Oliveira et al., 2025). Tsiani (a study of prospective teachers/students) reported a generally positive perception of GenAI's use in learning—respondents saw GenAI's potential to increase creativity and communication, but asked for pedagogical guidance to maximize its benefits (Tsiani et al., 2025). Quasi-experimental research by Hwang et al. exploring the human–AI collaboration experience found that when

students are given a digital content creation task, GenAI supports the process Collaboration and Communication as long as the AI output is modified and reflected by the student (Hwang & Lee, 2025). A review/chapter by Öztürk discusses the relationship between GenAI and the four 4C skills, concluding that GenAI offers opportunities to develop creativity and thinking tools, but requires deliberate task design so as not to replace collaborative interactions and critical thinking exercises (Türker & Öztürk, 2024). Add 5 previous studies on GenAI's perception of the 4Cs.

Although it has been extensively researched before, studies that specifically highlight the relationship between the two factors in college students are still limited and rarely conducted. This study focuses on the influence of teaching method and perceived usefulness of GenAI on the formation of 4Cs competencies in the context of higher education.

METHOD

This study applies a quantitative approach with the aim of empirically testing the influence perceived usefulness of GenAI and Teaching Method against 21st century skills (4Cs). The sampling technique used was the student population of the State University of Surabaya in Indonesia involving 50 students of the State University of Surabaya as research respondents with a response rate of 100%. Data collection was carried out using questionnaires compiled based on the results of literature reviews and previous research. The questionnaire consists of three main components: (1) perceived usefulness of GenAI adapted from (Klarin et al., 2024), (Köhler & Hartig, 2024) and (Kinskofer & Tulis, 2025), covering aspects of efficiency, productivity, convenience, and improving the quality of learning; (2) Teaching Method adapted from (Costa et al., 2024), (Polmear et al., 2024) and (Reprint et al., 2025), including clarity of objectives, strategy variations, student involvement, and the effectiveness of learning implementation; and (3) 4Cs skills developed based on research (Thornhill-Miller et al., 2023), (Saimon et al., 2023) and (Goto & Goto, 2024). Each statement item was measured using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree) to represent respondents' level of approval of each indicator. Data analysis was carried out using the Partial Least Squares–Structural Equation Modeling (PLS-SEM) with the help of SmartPLS software. The analysis process includes two stages, namely Measurement Model Assessment (evaluation of measurement models) to assess validity and reliability, and Structural Model Assessment (structural model evaluation) to test the

relationships between variables, both direct and indirect influences, including the mediating role of variables Teaching Method between perceived usefulness of GenAI and 4Cs skills.

Table 1. Descriptive statistics of all variables.

Variables	Example Item	N	Mean	Standard Deviation
Perceved Usefulness of GenAI	GenAI helped me complete my assignments more efficiently.	7	3.68	0.98
Teaching Method	I feel motivated in the learning process because of the method used by the lecturers.	7	3.94	0.87
4Cs	I am able to identify logical problems based on relevant evidence.	7	4.09	0.80

RESULT AND DISCUSSION

Measurement Model

Preliminary analysis was carried out to evaluate the validity and reliability of the construction in the measurement model. All measured indicators were tested using a reflective measurement model approach with the help of SmartPLS software version 4.1.1.5. Validity assessments were conducted using an outer loading value test, while reliability was assessed from Cronbach's Alpha (CA), rho_A, Composite Reliability (CR), and Average Variance Extracted (AVE). The test results showed that all indicators had an outer loading value above 0.600, thus meeting the indicator's validity criteria. Furthermore, the entire construct shows Cronbach's Alpha and Composite Reliability values above 0.700, which indicates that the internal consistency of each construct is in the high category and is statistically acceptable. The AVE value for all constructs is above the threshold of 0.500, which indicates that each construct has good convergent validity. A summary of the test results of the measurement model can be seen in Table 2.

Table 2. Measurement Model

Construct	Factor Loading	CA	rho_a	CR	AVE
Perceved Usefullness of GenAI		**0.938**	**0.979**	**0.946**	**0.635**
AI1	0.834				
AI2	0.793				
AI3	0.834				
AI4	0.800				
AI5	0.776				
AI6	0.739				
AI7	0.817				
AI8	0.775				
AI9	0.754				
AI10	0.841				
Teaching Method		**0.917**	**0.935**	**0.929**	**0.567**
TM1	0.835				
TM2	0.798				
TM3	0.637				
TM4	0.778				
TM5	0.831				
TM6	0.725				
TM7	0.737				
TM8	0.710				
TM9	0.750				
TM10	0.705				
4Cs		**0.836**	**0.843**	**0.880**	**0.552**
4Cs1	0.746				
4Cs2	0.783				
4Cs3	0.663				
4Cs4	0.814				
4Cs5	0.799				
4Cs6	0.636				

Structural Model

Once the validity and reliability of the construct are confirmed, the analysis proceeds to structural model testing to evaluate the relationships between latent variables within the framework of the developed model. The test was conducted through path analysis and bootstrapping procedures with 50 respondents to assess the statistical significance of each relationship as seen in Figure 2.

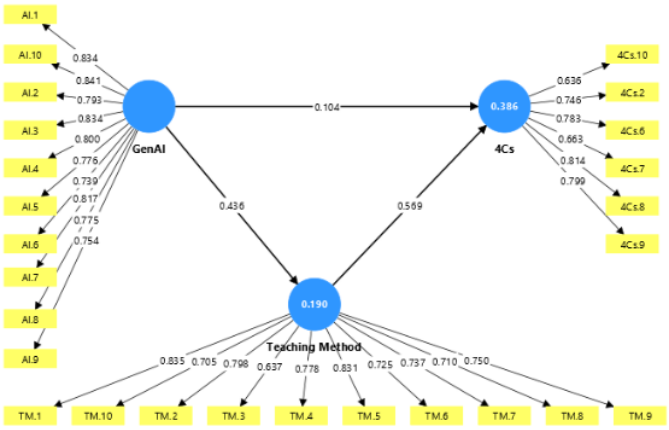

Figure 1. Structural Model

Direct Effect

The results of hypothesis testing as presented in Table 3 show some direct relationships between constructs in structural models. With a t-table significance threshold value of 1.960 (α = 0.05, bidirectional), each relationship path was statistically tested.

Table 3. Path Analysis for Direct Effect

Path Analysis	Original Sample	Standard Deviation	T Statistics	P Value	Decision
H_1: Perceived Usefulness of GenAI -> 4Cs	0.104	0.204	0.511	0.609	Not Supported
H_2: Perceived Usefulness of GenAI -> Teaching Method	0.436	0.212	2.059	0.040	Supported
H_3: Teaching Method -> 4Cs	0.569	0.142	4.009	0.000	Supported

The results of the analysis showed that the Perceived Usefulness of GenAI had a negative and insignificant effect on 4Cs with a p-value of 0.609. These results indicate that the lower the level of GenAi readiness that students have, the lower their ability to improve their 4Cs skills. Thus, the H_1 hypothesis is declared not supported.

The results of the analysis showed that the Perceived Usefulness of GenAI had a significant effect on the Teaching Method, with a p-value of 0.040. These findings indicate that students' perceptions of the usefulness of GenAI technology make a real contribution to their perception of the effectiveness of the teaching methods applied. Thus, the H_2 hypothesis is declared accepted.

Furthermore, the test results showed that the Teaching Method had a significant effect on the 4Cs, with a p-value of 0.000. These findings show that students' perception of the effectiveness of teaching methods is able to make a real contribution to

improving the 4Cs. Therefore, the H_3 hypothesis is declared accepted.

Table 4. Path Analysis for Indirect Effect

Path Analysis	Original Sample	Standard Deviation	T Statistics	P Value	Decision
H_4: Perceived Usefulness of GenAI -> Teaching Method -> 4Cs	0.248	0.135	1.841	0.066	Not Supported

The results of the analysis of the indirect influence showed that the effectiveness of the Teaching Method did not have a significant effect on the 4Cs through the Perceved Usefulness of GenAI with a p-value of 0.066. These findings indicate that students' perceptions of the usefulness of GenAI technology are not able to mediate the relationship between the effectiveness of teaching methods and the 4Cs. Thus, the H_4 hypothesis is declared rejected (not supported).

Discussion

The results showed that of the four hypotheses proposed, only two proved statistically significant, while the other two did not show significance. These findings show that students' perception of the Perceived Usefulness of GenAI does not have a direct influence on the ability of the 4Cs, but has a significant effect on the effectiveness of the Teaching Method received by students. In addition, the effectiveness of teaching methods has been proven to have an important role in improving students' 4Cs skills. Thus, Teaching Method is a key factor in the development of the 4Cs in higher education, while the influence of GenAI is indirect through the perception of the effectiveness of teaching methods.

The results of the study show that students' perception of the benefits of GenAI does not have a significant effect on critical thinking, creativity, communication, and collaboration, with the value of $p > 0.05$ which indicates a direct relationship between perception of technological usability and mastery of 4Cs skills has not been statistically proven. These findings differ from studies Klarin et al. (2024) and Larva. (2023) which shows that positive perceptions of GenAI can improve thinking flexibility, creative ideas, and complex and argumentative thinking skills. However, these results are in line with the study Qian. (2025) and S. Lee et al. (2025) which confirms that the use of GenAI without adequate pedagogical guidance can reduce

the reflectivity and originality of ideas due to dependence on AI outputs. By Technology Acceptance Model (TAM) (Davis, 1989), perceived usefulness plays more role in shaping the intention to use technology than directly affects cognitive learning outcomes. Thus, students may find GenAI useful for completing assignments, but have not used it optimally to develop high-level thinking skills such as the 4Cs (Zhai et al., 2024). These findings confirm that GenAI's positive impact on 21st-century skills requires strong pedagogical integration for the results to be empirically significant.

The results show that there is a significant influence between the perception of the usefulness of GenAI and the teaching method, where the higher the perception of students of the benefits of GenAI, the more positive their views are on the effectiveness of lecturers' teaching methods. These findings are consistent with research Al-Amri & Al-Abdullatif. (2024); Baig & Yadegaridehkordi. (2025); Gumelar et al. (2025) which states that a positive perception of GenAI can increase the readiness of students and lecturers in implementing technology-based learning. In line with that, T. Lin et al. (2025) emphasized that a positive view of AI technology plays an important role in driving the transformation of teaching methods to be more interactive, personalized, and project-oriented. Theoretically, these results reinforce the concept of the Intelligent TPACK Framework, which emphasizes that positive perceptions of technology are the main drivers of pedagogical innovation (Celik, 2023). Thus, perceived usefulness of GenAI can be understood as a factor that triggers changes towards more active and student-centered learning, so it is important for lecturers to improve literacy and pedagogical competence in the use of GenAI so that its use has an effective and meaningful impact (Setälä et al., 2025).

In addition, teaching methods have a significant effect on students' 4Cs skills ($p < 0.001$). The more effective the method applied, the higher the ability to think critically, creatively, collaboratively, and communicatively. These findings are in line with Thornhill-Miller et al. (2023) and Waly & Yogyakarta. (2024) which affirms that active, project-based learning enhances creativity and collaboration, and is supported by Rehman et al. (2024) which demonstrates the effectiveness of collaborative strategies in developing critical thinking and communication so that teaching methods become a key factor in the development of 21st century skills integrated with GenAI technology.

The results of the analysis show that the indirect influence Perceived Usefulness of GenAI to the 4Cs skills through Teaching Method insignificant ($p > 0.05$). This means that the Teaching Method has not been able

to play an effective mediator role in explaining the relationship between the Perceived Usefulness of GenAI and 21st century skills (4Cs). This condition suggests that although students may have a positive perception of the usefulness of GenAI, that perception does not automatically convert into an improvement in the 4Cs when the teaching strategies used do not directly activate their cognitive, collaborative, creative, or communicative processes (Nathaniel et al., 2025). A number of researchers emphasized that the effectiveness of mediation is highly dependent on the suitability of the pedagogical approach where the teaching method must be able to integrate technology into meaningful learning activities so that the benefits of technology can be reflected in the achievement of student competencies (Mekheimer, 2025). Thus, the Teaching Method needs to be designed to be more targeted and interactive in order to be able to continue the influence of perception on technology into a real improvement in 21st century skills (Mishra et al., 2023). This finding is different from Jung & Jo. (2025), but in line with Tsiani et al. (2025) and Hwang & Lee. (2025) which underscores the importance of the role of pedagogical design in determining the impact of GenAI. Theoretically, these results extend the TAM model by showing that perceived usefulness Not strong enough to mediate learning outcomes without the support of mature pedagogical integration (Al-Abdullatif, 2024).

Previous research has shown that when students in higher education view generative AI technology (GenAI) as perceived usefulness, it has a positive impact on the development of critical thinking skills, because GenAI can provide quick feedback, scaffolding, and reflection support that strengthens the analysis and evaluation of information-sources (Campillo-Ferrer et al., 2025). Furthermore, the perception that GenAI is beneficial also facilitates student creativity through the function of rapid ideation and diversification of options, especially for those with a low creativity baseline, although the literature emphasizes that use without proper regulation can lead to homogeneity of ideas (Rudra et al., 2025). However, the results of the study are not in line with previous studies which showed that the Perceived Usefulness of GenAI has a negative and insignificant influence on the 4Cs (Zhou et al., 2024). These findings indicate that students' perceptions of the usefulness of GenAI have not been able to contribute meaningfully in improving critical thinking, creativity, communication, and collaboration skills. The low perception of usability also reflects that students are not fully ready or able to utilize GenAI as a learning support tool that

can strengthen the 4Cs competencies (Zhou et al., 2024). These findings confirm that improving the 4Cs cannot rely solely on the perception of technological usability, but requires a more structured learning approach and a more mature use of GenAI in the academic process (Liang et al., 2024). These findings suggest that higher education institutions need to pay special attention to the perceived usefulness of GenAI as a factor that can increase the effectiveness of teaching methods. The development of the right Teaching Method can mediate this perception in order to significantly encourage the improvement of students' ability to think critically, creatively, communicate, and collaborate (4Cs). Therefore, the use of GenAI should not only be focused on technical mastery or access to technology, but also directed at learning strategies that strengthen students' cognitive, collaborative, and creative engagement. By providing structured academic support and a conducive learning environment, institutions can build an effective learning ecosystem, where the perception of GenAI's usability optimally contributes to improving students' 4Cs competencies.

CONCLUSION

Based on the research findings, it can be concluded that the perceived usefulness of GenAI does not have a direct effect on students' 4Cs skills, but it significantly influences teaching methods. Teaching methods, in turn, are proven to be the main factor that directly affects critical thinking, creativity, communication, and collaboration skills. These findings indicate that the presence of GenAI technology does not automatically enhance 21st-century competencies unless it is accompanied by well-designed pedagogical strategies that promote students' cognitive engagement.

From a theoretical standpoint, this study extends the Technology Acceptance Model (TAM) by demonstrating that perceived usefulness plays a greater role in driving the transformation of teaching methods rather than exerting a direct impact on learning outcomes. This reinforces the notion that technology functions primarily as an enabling factor, while pedagogical methods serve as the transforming factor in shaping students' competencies.

The practical implications highlight the need for higher education institutions to prioritize strengthening lecturers' pedagogical capacities through training on GenAI integration grounded in active, collaborative, and reflective learning models. Institutions should also develop academic policies that encourage ethical and meaningful use of AI. Additionally, lecturers are expected not only to adopt technology but also to orchestrate learning experiences that position GenAI as a scaffolding tool for the development of higher-order thinking skills.

For future research, it is recommended to examine other variables such as AI literacy, self-regulated learning, and cognitive engagement as mediators or moderators, as well as to expand the sample across multiple universities and employ longitudinal approaches to obtain a more comprehensive understanding of the long-term impact of GenAI on 21st-century skill development.

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