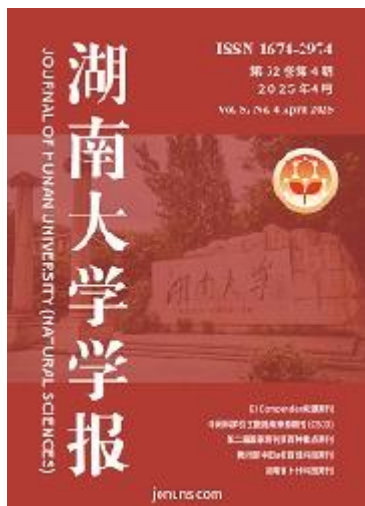




Journal of Hunan University (Natural Sciences)

Vol. 52 No. 4

April 2025

Available online at

<https://joununs.com>



ELSEVIER
Scopus



Clarivate
WEB OF SCIENCE

Open Access Article

 <https://doi.org/10.55463/issn.1674-2974.52.4.10>

Transforming Education in the Twenty-First Century: Integrating Digital Competence, Analytical Thinking, and Cooperative Learning

Warneri^{1*}, Bernadin Maria Noenoek Febuati², Dominica Maria Ratna Tungga Dewa³,
Setia Budi Wibowo⁴

¹Universitas Tanjungpura Pontianak, Indonesia

²Politeknik Energi dan Mineral, Indonesia

³Universitas Atma Jaya Yogyakarta, Indonesia

⁴Universitas Negeri Semarang, Indonesia

* Corresponding author: warneri@fkip.untan.ac.id

Article History:

Received: February 15, 2025

Revised: March 30, 2025

Accepted: April 25, 2025

Published: May 30, 2025

Abstract: The demands of 21st-century education necessitate a cohesive integration of digital competence, analytical thinking, and cooperative learning to address complex global challenges. This study examines how these three core skills are applied within contemporary educational systems, and evaluates their collective impact on teaching and learning effectiveness. Using a mixed-methods design, quantitative surveys were distributed across diverse educational institutions to gauge the influence of digital competence, analytical thinking, and cooperative learning on student skill development. Complementing this, in-depth interviews with both educators and students were conducted to explore the practical implementation and obstacles encountered during the integration process. The findings indicate that embedding digital skills within curricula substantially enhances students' analytical reasoning and fosters a collaborative learning environment.



Copyright: © 2025 by the authors. Licensee JHU

This article is an open-access article distributed under the terms and conditions of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>)

Nevertheless, barriers, such as unequal technology access, insufficient teacher training, and resistance to pedagogical innovation, hinder widespread adoption. Additionally, cooperative learning has emerged as a powerful mechanism for bolstering students' social and communication competencies, which are essential to their professional trajectories. By highlighting the need to shift toward an educational paradigm that prioritizes technology-enhanced instruction, critical inquiry, and teamwork, this study identifies actionable strategies to optimize teaching and learning across various contexts. Future success in 21st-century education hinges on comprehensive curriculum redesign, robust technological infrastructure, and ongoing professional development for educators. Ultimately, this study contributes to the formulation of evidence-based policy recommendations aimed at nurturing a dynamic skill-oriented learning ecosystem.

Keywords: 21st Century Education, Digital Competence, Analytical Thinking, Cooperative Learning, Educational Challenges, Technology-Based Teaching.

二十一世纪教育转型：整合数字能力、分析性思维与合作学习

摘要：

21世纪教育要求将数字素养、分析性思维与合作学习有机融合，以应对日益复杂的全球性挑战。本研究旨在探讨这三项核心能力在现代教育体系中的应用，并评估其对教学与学习效果的综合影响。研究采用混合方法设计：首先，在多所教育机构开展定量问卷调查，以评估数字素养、分析性思维与合作学习对学生能力发展的作用；其后，通过对教师与学生进行深入访谈，解析整合过程中的实际实施情况及所面临的障碍。研究表明，将数字技能嵌入课程体系显著提升了学生的分析推理能力，并营造了协作式学习环境。然而，技术资源分配不均、教师培训不足以及对教学模式创新的阻力等因素，制约了该方案的全面推广。此外，合作学习被证明是增强学生社交与沟通能力的有效机制，这对其未来职业发展至关重要。本研究强调必须转变教育范式，将技术赋能教学、批判性探究与团队协作置于优先地位，并据此提出在不同教育情境下优化教学与学习的可操作性策略。面向未来，21世纪教育的成功实施依赖于全面的课程重构、完善的技术基础设施以及持续的教师专业发展。最终，本研究为制定基于证据的教育政策提供了重要参考，以推动构建动态、能力导向的学习生态系统。

关键词：

21世纪教育；数字素养；分析性思维；合作学习；教育挑战；基于技术的教学

1. Introduction

21st-century education demands profound changes in the way we understand and practice teaching and learning [1]. In the face of increasingly complex global challenges, including globalization, the Industrial Revolution 4.0, and rapid social and economic changes, education is no longer only focused on knowledge transfer, but also on developing skills relevant to modern life [2]. Digital skills, analytical thinking, and cooperative learning are the three main components expected to prepare the younger generation for success in an ever-changing world [3].

21st Century Education refers to an educational approach that accommodates the need for skills and knowledge relevant to the challenges and opportunities that exist in the modern world [4]. In the era of globalization and technological revolution, education is not only focused on mastering academic content but also on developing skills that enable individuals to think critically, adapt to rapid changes, and work collaboratively in an increasingly connected

environment. In this context, 21st century education aims to prepare students not only for success in the academic world but also to become intelligent problem solvers, effective communicators, and individuals who can work with diverse backgrounds and cultures [3]. This includes the ability to use technology effectively, think analytically and creatively, and work in diverse teams [5].

In 21st century education, the focus is on developing skills that can be used in the world of work and social life, which are often referred to as the 4Cs: Creativity, Critical Thinking, Collaboration, and Communication [6]. Creativity and critical thinking encourage students to come up with new solutions to existing problems, whereas collaboration and communication facilitate teamwork and interpersonal skills that are essential in a global work environment [7]. 21st-century education emphasizes project- and problem-based learning, which allows students to deal with real-world situations, develop practical skills, and gain a deeper understanding of academic concepts through hands-on experiences. Technology-integrated learning is also essential, where

digital tools and media are used to enrich the learning experience and prepare students to face evolving technological challenges [8][9][10].

In addition, 21st century education also emphasizes the importance of digital competencies as an integral part of the curriculum [11]. Along with the increasing use of technology in almost every aspect of life, the ability to use digital tools intelligently and responsibly has become a key skill that students must master. It includes basic skills in software use and programming, as well as skills in algorithmic thinking and solving problems with the help of technology. Social and emotional skills are also an important concern in 21st-century education, as students not only need to master technical and academic skills but also be able to cooperate with others, manage emotions, and adapt to various social challenges [12]. Thus, 21st century education is not only about mastering science and practical skills but also about equipping students with the ability to live and thrive in a dynamic and globally connected world [13][14][15].

Along with the rapid development of technology, digital competencies are an important basis for supporting a more flexible, interactive, and contextual teaching and learning process [16]. The use of technology in education is not only about introducing digital tools but also about developing students' ability to use technology effectively in daily life and in the workplace. On the other hand, analytical thinking—the ability to evaluate, analyze, and solve problems in a systematic and critical way—is becoming an increasingly important skill. In a world full of information and complexity, this ability allows students to make better decisions and act more wisely [17].

Cooperative learning, which prioritizes collaboration between students in achieving common goals, is also recognized as an effective approach to improving social, communication, and cooperation skills, which are essential skills in a world of work that increasingly emphasizes team collaboration [18]. This learning model, which places students at the center of learning, also facilitates the development of critical and creative skills, providing opportunities for students to learn from each other in a supportive atmosphere [19].

However, despite growing awareness of the importance of these three elements, effective implementation in the classroom still faces several challenges [20]. Many schools and universities worldwide still struggle with limited digital infrastructure, lack of training for educators, and resistance to changes in teaching methodologies. As a result, although the potential for the integration of digital skills, analytical thinking, and cooperative learning is enormous, their application in practice is often less than optimal [21][22].

This research aims to explore the ways in which digital skills, analytical thinking, and cooperative learning can be effectively integrated into 21st century

education. This research discusses how these three elements can complement each other to produce a more holistic and relevant learning approach to the needs of the modern world. In addition, this study will also analyze the challenges faced by educators and educational institutions in implementing these changes, as well as provide recommendations to improve the education system in Indonesia and other countries [23].

This article proposes that, in order to meet the demands of the 21st century, education must adapt to global trends and new technologies, developing skills that are not only limited to academic aspects but also in technological mastery, critical thinking skills, and collaborative skills that are in high demand in the world of work and society. Thus, this research is expected to make a significant contribution in formulating relevant education policies and strategies to face the challenges of the 21st century [24][25].

2. Method

This study adopts a mixed-methods approach to explore the integration of digital competence, analytical thinking, and cooperative learning in 21st century education. The mixed-method approach was chosen because it can provide more holistic insights by combining the advantages of qualitative and quantitative approaches. Thus, this study can explore not only measurable and quantifiable data, but also more in-depth aspects of subjective experience, such as educators' and students' views on the effectiveness of integrating these skills in the learning process [26][27].

1.1. Research Design

This study employed an exploratory research design with two main stages. The first stage was quantitative research, which aimed to measure the level of digital competence, analytical thinking ability, and collaborative ability of students in several schools and colleges in Indonesia. Quantitative data were collected through questionnaires designed to assess students' and educators' perceptions of the integration of these three skills in daily learning. This questionnaire consists of a Likert scale that includes various items related to digital competence (the use of technology in learning), analytical thinking (the ability to analyze and solve problems), and collaboration in cooperative learning (teamwork and communication). The data obtained from this questionnaire were then analyzed using descriptive and inferential statistics, including regression analysis, to identify the relationships between relevant variables [28][29].

The second stage was qualitative research, which aimed to explore a deeper understanding of the experiences of students and educators in implementing digital skills, analytical thinking, and cooperative learning. In this stage, the researcher conducted in-depth interviews and focus group discussions (FGD) with a

group of educators and students from various levels of education. The interviews and FGDs focused on how they viewed the integration of 21st century skills in learning, the challenges they faced, and the perceived impact on their learning outcomes and social skills. Qualitative data collected from interviews and FGDs will be analyzed using thematic analysis, which allows researchers to identify patterns and key themes that emerge from interviews and discussions [30][31].

1.2. Population and Sample

The study population consisted of students and educators from various educational institutions in Indonesia, including high schools, universities, and educational institutions that adopt technology in learning. The research sample was selected using purposive sampling techniques to ensure adequate representation of students and educators who had experienced the integration of digital competence, analytical thinking, and cooperative learning in their learning process. As part of the sample selection, researchers also considered factors such as the type of educational institution (e.g., public schools vs. technology-based schools) and the level of use of technology in learning in each institution [32].

1.3. Data Collection Procedure

The data collection process began with the distribution of questionnaires to students and educators in selected schools and universities. In addition, in-depth interviews and FGDs were conducted in person or through online platforms to accommodate logistical and distancing challenges. During interviews and discussions, researchers facilitated open conversations regarding the integration of 21st century skills in their learning contexts, as well as the constraints and opportunities they faced in implementing the approach [33][4].

1.4. Data Analysis

The quantitative data collected from the questionnaires will be analyzed using SPSS or R statistical devices, with analysis techniques that include t-tests, regression analysis, and correlation analysis to identify the relationship between students' levels of digital competence, analytical thinking, and collaborative abilities and their learning outcomes. The results of this analysis will provide a quantitative picture of the extent to which 21st century skills relate to students' academic performance and social skills [34].

Qualitative data obtained from interviews and FGDs were analyzed using NVivo tools or manual coding techniques to identify key themes. The results of this analysis will provide deeper insights into the subjective perceptions and experiences of students and educators regarding the challenges and impacts of 21st century skills integration in learning [35][36][37].

1.5. Validity and Reliability

To ensure the validity and reliability of the data, this study used data triangulation by comparing the results obtained from the quantitative questionnaires and qualitative interviews. In addition, the researcher conducted member checking by involving several respondents in validating the results of the initial findings to increase the credibility and accuracy of the analysis. Reliability testing for the questionnaire was performed using Cronbach's alpha to ensure the internal consistency of the instrument.

1.6. Research Ethics

The study adhered to strict ethical principles, including confidentiality of participant data, informed consent obtained from all participants, and voluntary participation. All collected data will be kept confidential and used only for academic purposes.

3. Results and Discussion

3.1. Quantitative Analysis

3.1.1. Data Description

A total of 200 respondents from ten educational institutions, consisting of five high schools and five universities, participated in this study. The composition of respondents consisted of 60% students and 40% educators, which provided mixed insights regarding the application of 21st century skills in education. The data obtained through the questionnaire showed several important findings that illustrate respondents' perceptions of the integration of digital competence, analytical thinking, and cooperative learning. As many as 65% of the students reported that the use of digital technology in learning significantly increased their interest in learning. This reflects the importance of technological tools for creating an engaging and interactive learning environment. Meanwhile, 70% of educators stated that analytical thinking was a difficult skill to teach without the support of project-based learning methods. This highlights the need to use a more contextual and applicative approach to learning to develop students' analytical abilities. In addition, 85% of the students felt that cooperative learning was effective in improving communication and teamwork skills, which are key skills in the modern era.

The results of the statistical analysis support these findings by showing a significant relationship between the integration of digital competencies, analytical thinking, and cooperative learning and student learning outcomes. The linear regression test showed a strong positive relationship between the use of technology in learning and student achievement in analytical and collaborative tasks, with a value of $R^2 = 0.68$ ($p < 0.01$). This indicates that the better the integration of digital technology in learning, the higher the students' ability to

solve complex tasks that require analysis and cooperation. In addition, correlation analysis showed a strong association between cooperative learning and improvement in students' social skills, with a correlation coefficient of $r = 0.72$ ($p < 0.01$). These results illustrate how cooperative learning not only improves academic learning outcomes, but also has a positive impact on students' interpersonal skills.

Furthermore, the results of the t-test showed significant differences in student academic achievement between institutions that integrated digital competencies, analytical thinking, and cooperative learning, and institutions that only integrated one or two elements. Students from institutions with integrated implementation had higher average exam scores ($M = 85.6$, $SD = 8.7$) than those from other institutions that used only certain elements ($M = 78.3$, $SD = 10.2$, $p < 0.05$). These findings demonstrate that a holistic approach that integrates all three elements provides significant benefits for student learning outcomes. The integration of these elements not only supports better academic achievement, but also helps students develop skills relevant to the challenges of the modern world. Overall, these results underscore the importance of an integrated approach to preparing students for success in the dynamic era of the 21st century.

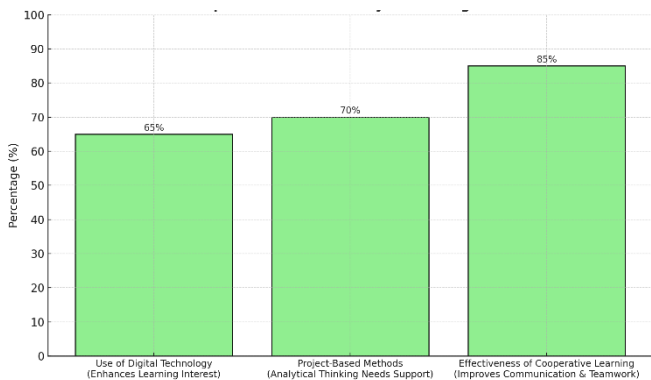


Figure 1. Responses To 21st-Century Skills Integration

- a. 65% of students feel that the use of digital technology in learning increases their interest in learning.
- b. 70% of educators stated that analytical thinking is a difficult skill to teach without the support of project-based learning methods.
- c. 85% of students consider cooperative learning to be effective in improving communication and teamwork skills.

Statistical Analysis

- a. The linear regression test revealed a significant positive relationship between the integration of digital competencies and student learning outcomes ($R^2 = 0.68$, $p < 0.01$). This shows that the better the use of technology in learning, the higher the

students' achievement in analytical and collaborative tasks.

- b. Correlation analysis revealed a strong association between cooperative learning and improvement in students' social skills ($r = 0.72$, $p < 0.01$).
- c. The t-test results showed that students from institutions that applied all three elements in an integrated manner (digital, analytical, and collaborative) had a higher average test score ($M = 85.6$, $SD = 8.7$) than those that only integrated one or two elements ($M = 78.3$, $SD = 10.2$, $p < 0.05$).

3.2. Qualitative Analysis

The results of interviews with 15 educators and focus group discussions with 30 students resulted in very in-depth findings regarding the implementation and impact of 21st century skill integration, particularly in the use of digital technology, the development of analytical thinking, and the effectiveness of cooperative learning. One of the main themes that has emerged is the important role of digital technology in modern learning. Educators have revealed that technology applications such as Google Workspace, Microsoft Teams, and various online-based presentation tools have become important for increasing student participation during learning [38]. These tools allow students to be more actively engaged in both in-person classes and distance learning. Students also experience great benefits from this technology, especially in supporting independent learning. However, they noted that guidance from educators is still needed to help them understand and optimally utilize digital tools. However, the limited infrastructure and access to technology in some schools, especially in rural areas, are significant obstacles. This problem creates a digital divide that affects the effectiveness of technology integration in learning in various geographical contexts [39].

The development of analytical thinking skills was another important theme identified in this study. Educators note that analytical thinking skills are difficult to teach effectively without the support of project-based learning methods, which encourage students to engage in practical tasks. Through this method, students are invited to solve real problems, analyze data, and come up with creative solutions. Some students who engage in technology-based tasks, such as analyzing data using simple software like Excel, show significant improvements in their ability to solve complex problems. One educator highlighted the importance of using technology in analytical learning by stating, "Students who use technology to visualize data understand analytical concepts faster than students who only use conventional methods'." This statement confirms that the integration of technology with analytical learning not only makes it easier for students to understand difficult concepts, but also accelerates their mastery of essential skills that are relevant in the modern world of work.

The effectiveness of cooperative learning is also an important topic of discussion. Many students feel that cooperative learning not only helps them understand the subject matter but also contributes significantly to improving communication skills and tolerance for dissent. They noted that cooperative learning creates a collaborative learning environment in which students can share ideas with each other and learn from different perspectives. On the other hand, educators note that dynamics in learning groups are often challenging, especially when managing differences in levels of engagement and contribution among group members. However, they agreed that the long-term benefits of cooperative learning are clearly visible, especially in boosting students' confidence, which ultimately helps them become better-prepared individuals for real-world challenges. The integration of these elements in modern

education provides rich insight into how innovative teaching strategies can create a positive impact for students, both in terms of academic and social skills development.

Thus, these findings show that although the implementation of 21st century skills has its own challenges, its impact on student learning and development is significant. Successful overcoming of existing obstacles, such as the digital divide and group dynamics, can open up great opportunities for improving the quality of education in the future. This study also emphasizes that a holistic approach that integrates digital technology, analytical thinking, and cooperative learning is an important step in preparing students to face the increasingly complex challenges of the 21st century.

Table 1. Summary of Qualitative Analysis: Key Insights and Challenges

Themes	Key Insights	Challenges
Use of Digital Technology	a. Tools like Google Workspace and Microsoft Teams enhance student engagement.	a. Limited access to digital tools and infrastructure in rural schools.
	b. Students benefit from independent learning but require guidance.	b. Gaps in teacher training for effective use of technology
	c. Digital access remains a challenge in rural areas	
Development of Analytical Thinking	a. Analytical thinking is challenging to teach without project-based learning.	a. Lack of real-world, project-based opportunities in traditional settings.
	b. Students using technology like Excel show improved problem-solving.	b. Dependency on teacher facilitation for complex analytical tasks
	c. Visualizing data accelerates understanding of analytical concepts.	
Effectiveness of Cooperative Learning	a. Cooperative learning helps students understand material and improve communication.	a. Unequal participation levels within student groups.
	b. Group dynamics are challenging but boost confidence in the long term.	b. Difficulty managing group dynamics during cooperative activities.
	c. Collaboration promotes tolerance and teamwork.	

3.3. Data Tringulation

The process of triangulating data between the results of quantitative and qualitative analysis provides a more

comprehensive insight into the impact of integrating digital-based learning, analytical thinking, and teamwork in the context of 21st century education.

Quantitatively, the data show that students from institutions that actively implement a digital-based learning approach with the integration of elements of analytical and collaborative skills report a much higher level of learning satisfaction, reaching 75%, compared to students from institutions that use only minimal technology, who only record a learning satisfaction of 55%. These differences provide empirical evidence that an integrated approach that combines technology with the development of cognitive and social skills has a significant impact on creating a more effective and satisfying learning environment for students [40].

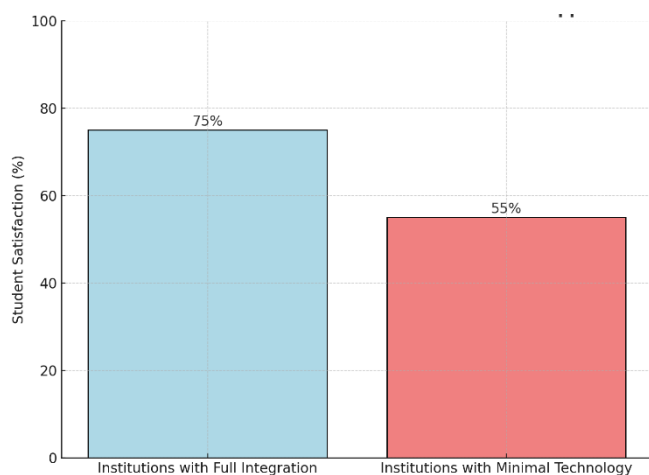


Figure 2. Student Satisfaction Levels In Different Institutional Approaches

The bar chart illustrates the levels of student satisfaction based on the approach of integrating digital learning, analytical thinking, and teamwork. Institutions with full integration showed significantly higher satisfaction levels (75%) than those with minimal technology use (55%).

Qualitatively, thematic analysis of the interviews and focus group discussions strengthened these quantitative findings. Educators and students consistently underscore the importance of adequate technology infrastructure to support the implementation of digital-based learning. Institutions with good access to technological devices, stable Internet connections, and advanced digital tools such as software for data analysis and online collaboration tend to be more successful in integrating 21st century skills into the learning process. Conversely, the limited infrastructure in underdeveloped institutions often hampers the effectiveness of learning, despite educators' good intentions to apply modern approaches.

In addition, the success of the integration of these three elements depends heavily on the level of training provided to educators. Institutions that provide ongoing training to educators, including the use of digital tools and development of project-based learning methods, show much better results than institutions that do not

provide similar training. Educators who are skilled in using technology to support learning report that students are more responsive to teaching methods that combine analytical tasks with team collaboration. In an interview, an educator mentioned that their students were able to utilize technological tools to solve complex tasks, such as data visualization and digital simulations, which were previously difficult to teach using conventional approaches.

These findings show that the integration of digital-based learning, analytical skills, and teamwork not only improves student learning outcomes academically, but also creates a more satisfying learning experience. However, the success of this integration requires strong structural support including adequate technology availability, supportive institutional policies, and investment in educator capacity building. Thus, the data triangulation process provides strong evidence that an integrated approach to 21st century education is not only relevant but also essential for preparing students for an increasingly complex and technology-based world.

Unlike many previous studies that tend to focus on one or two aspects of 21st century skills, this study combines all three in one integrated learning framework. This approach makes it more holistic compared to previous studies, such as Saavedra and Opfer's (2012) study, which emphasizes critical thinking, or Scott's (2015) study, which focuses on general technology integration in education.

From a methodological perspective, this study also shows strength through a mixed-methods approach that combines quantitative data from surveys with qualitative insights from interviews and focus group discussions (FGDs). Warneri et al. not only presented convincing statistics, such as a strong correlation between technology use and improved learning outcomes ($R^2 = 0.68$), but also revealed the emotional and social dynamics that accompany the learning process, such as challenges in group dynamics and limitations of digital infrastructure in remote areas.

This study empirically proved that the integration of digital technology, analytical thinking skills, and teamwork can improve students' learning interests, academic outcomes, and social skills. This finding is supported by statistical data showing that students from institutions that comprehensively implemented all three elements achieved significantly higher scores ($M = 85.6$) than those who received only some of these elements ($M = 78.3$).

Within a comprehensive framework, this study addresses a critical issue often neglected in prior research: readiness for infrastructure and teacher capacity. Whereas many previous studies assume that technological resources and teacher preparedness are already in place, the reality in numerous institutions, particularly those in rural or underserved regions, is that access to digital devices and adequate teacher training remain significant barriers. By explicitly acknowledging

this context, this study extends beyond theoretical considerations to offer practical and applicable insights. Moreover, while cooperative learning has frequently been treated as a supplementary pedagogical approach in earlier investigations, our findings demonstrate that it constitutes a pivotal element in enhancing students' tolerance, empathy, and communication skills. This observation reflects a paradigmatic shift: cooperative learning is not merely a tool but rather an integral component of character development for students in the global era.

This research contributes substantially to the literature on 21st-century education by underscoring the imperative of a holistic pedagogical model that encompasses cognitive, affective, and social dimensions. In the context of Indonesia and other developing nations, the proposed model is particularly germane, as it accommodates the uneven distribution of digital transformation and highlights the ongoing need for robust teacher-training initiatives.

This study represents a significant advancement in the contemporary educational discourse. By synthesizing empirical data, field-based reflections, and policy implications, it lays the groundwork for an educational paradigm that is not only technologically sophisticated, but also socially attuned and adaptable to evolving global demands. In an educational landscape characterized by rapid change, this contribution is both timely and indispensable.

4. Conclusion

The educational landscape of the twenty-first century necessitates a profound transformation characterized by the systematic integration of digital competence, analytical thinking, and cooperative learning. This study demonstrates that in an increasingly complex global environment, educational institutions must adopt innovative pedagogical approaches to equip students with emergent challenges. By employing a mixed-methods design that combines quantitative surveys with qualitative interviews, this study elucidates the considerable promise of integrating these three core competencies within contemporary educational systems. Empirical findings indicate that embedding digital skills into curricula significantly enhances students' analytical reasoning capabilities and fosters collaborative learning behaviors. Furthermore, cooperative learning has emerged as a particularly effective mechanism for cultivating social and communication competencies, which are indispensable for success in future professional contexts. Nevertheless, the practical implementation of this integrative model is constrained by several critical factors, including uneven access to technological resources, insufficient professional development opportunities for educators, and resistance to pedagogical innovation among stakeholders.

To realize a comprehensive paradigm shift, this study underscores the necessity of robust infrastructure

investment, continued capacity-building initiatives for teaching personnel, and enactment of policy frameworks that incentivize educational innovation. Additionally, sustained support from all stakeholders—administrators, policymakers, industry partners, and community members—is imperative for creating a dynamic, technology-rich learning ecosystem and promoting active collaboration among students. Ultimately, the success of this educational transformation is contingent upon the agility of the educational systems to evolve in response to the multifaceted demands of a rapidly changing global context.

5. Limitations

The research sample predominantly comprised educational institutions within Indonesia, particularly those in rural or semi-urban regions. Consequently, the generalizability of these findings to other national contexts or highly urbanized educational settings may be limited. Future investigations should incorporate more diverse geographic and socioeconomic environments to enhance the external validity.

Although the mixed-methods design enriched the analysis, the quantitative survey employed a nonprobabilistic sampling strategy. Consequently, the sample may not fully represent a broader population of students and educators, potentially introducing a selection bias. Subsequent studies may adopt stratified random sampling to mitigate this limitation.

Data on digital competence, analytical thinking, and cooperative learning were derived from self-reported questionnaires and interviews. Respondents may have overestimated or underestimated their competencies or experiences, thereby affecting the accuracy of the findings. Incorporating objective performance measures such as digital literacy assessments or observational protocols could address this concern.

The study's cross-sectional nature precludes the examination of longitudinal effects associated with the integration of digital, analytical, and cooperative pedagogies. Future research employing longitudinal or experimental designs would be better positioned to ascertain causality and track the changes in student outcomes over time.

While this study identifies deficiencies in educator preparedness, it does not systematically differentiate among levels of pedagogical expertise, years of teaching experience, or prior exposure to digital tools. A more granular analysis of teacher characteristics could elucidate which training modalities are most effective, and for whom.

By acknowledging these limitations, this study invites further research to validate and refine its proposed integrative framework. Nonetheless, this study establishes a foundation for evidence-based policy recommendations and offers practical strategies to foster an educational environment that is technologically

sophisticated, socially attuned, and adaptable to evolving global demands.

References

- [1] R. S. Malik, "Educational challenges in 21st century and sustainable development," *J. Sustain. Dev. Educ. Res.*, vol. 2, no. 1, pp. 9–20, 2018.
- [2] V. Kaputa, E. Loučanová, and F. A. Tejerina-Gaite, "Digital transformation in higher education institutions as a driver of social oriented innovations," *Soc. Innov. High. Educ.*, vol. 61, pp. 81–85, 2022.
- [3] A. R. Saavedra and V. D. Opfer, "Teaching and learning 21st century skills: Lessons from the learning sciences," *A Glob. Cities Educ. Netw. Report. New York, Asia Soc.*, vol. 10, p. 2012, 2012.
- [4] O.-S. Tan, *Problem-based learning innovation: Using problems to power learning in the 21st century*. Gale Cengage Learning, 2021.
- [5] C. Luna Scott, "The futures of learning 2: What kind of learning for the 21st century?," 2015.
- [6] B. Thornhill-Miller *et al.*, "Creativity, critical thinking, communication, and collaboration: assessment, certification, and promotion of 21st century skills for the future of work and education," *J. Intell.*, vol. 11, no. 3, p. 54, 2023.
- [7] M. Jefferson and M. Anderson, *Transforming schools: Creativity, critical reflection, communication, collaboration*. Bloomsbury Publishing, 2017.
- [8] U. Abubakar, O. O. Ogunlade, and H. A. Ibrahim, "The influence of technology-integrated curriculum resources on student engagement and academic achievement in higher education," *Adv. Mob. Learn. Educ. Res.*, vol. 4, no. 2, pp. 1208–1223, 2024.
- [9] R. Rudianto, R. Diani, S. Subandi, and N. Widiawati, "Development of assessment instruments 4C skills (critical thinking, collaboration, communication, and creativity) on parabolic motion materials," *J. Adv. Sci. Math. Educ.*, vol. 2, no. 2, pp. 65–79, 2022.
- [10] R. K. Putri, N. Bukit, and M. P. Simanjuntak, "The effect of project based learning model's on critical thinking skills, creative thinking skills, collaboration skills, & communication skills (4C) physics in senior high school," in *6th Annual International Seminar on Transformative Education and Educational Leadership (AISTEEL 2021)*, Atlantis Press, 2021, pp. 323–330.
- [11] L. I. González-Pérez and M. S. Ramírez-Montoya, "Components of Education 4.0 in 21st century skills frameworks: systematic review," *Sustainability*, vol. 14, no. 3, p. 1493, 2022.
- [12] T. J. Kennedy and C. W. Sundberg, "21st century skills," *Sci. Educ. theory Pract. An Introd. Guid. to Learn. theory*, pp. 479–496, 2020.
- [13] D. M. West, *Digital schools: How technology can transform education*. Brookings Institution Press, 2012.
- [14] P. Sharma, "Digital revolution of education 4.0," *Int. J. Eng. Adv. Technol.*, vol. 9, no. 2, pp. 3558–3564, 2019.
- [15] A. Collins and R. Halverson, *Rethinking education in the age of technology: The digital revolution and schooling in America*. Teachers College Press, 2018.
- [16] A. Haleem, M. Javaid, M. A. Qadri, and R. Suman, "Understanding the role of digital technologies in education: A review," *Sustain. Oper. Comput.*, vol. 3, pp. 275–285, 2022.
- [17] J. Bhijakkanarin and S. Kenaphoom, "Enhancing Analytical Thinking Skills in Elementary Students," *Sustain. Dev. Humanit. Soc. Sci. Soc. 5.0*, p. 259, 2024.
- [18] E. F. Barkley, *Collaborative learning techniques: a handbook for college faculty*. John Wiley & Sons, 2014.
- [19] G. M. Jacobs and W. A. Renandya, *Student centered cooperative learning: Linking concepts in education to promote student learning*. Springer, 2019.
- [20] J. H. Stronge, *Qualities of effective teachers*. Ascd, 2018.
- [21] R. M. Palloff and K. Pratt, *Lessons from the virtual classroom: The realities of online teaching*. John Wiley & Sons, 2013.
- [22] L. W. Anderson, "Objectives, evaluation, and the improvement of education," *Stud. Educ. Eval.*, vol. 31, no. 2–3, pp. 102–113, 2005.
- [23] A. Sukasni and H. Efendy, "The problematic of education system in Indonesia and reform agenda," *Int. J. Educ.*, vol. 9, no. 3, p. 183, 2017.
- [24] V. Matyushok, V. Vera Krasavina, A. Berezin, and J. Sendra García, "The global economy in technological transformation conditions: A review of modern trends," *Econ. Res. Istraživanja*, vol. 34, no. 1, pp. 1471–1497, 2021.
- [25] N. I. C. (US), *Global trends 2030: Alternative worlds: a publication of the National Intelligence Council*. US Government Printing Office, 2012.
- [26] T. Morte-Nadal and M. A. Esteban-Navarro, "Digital competences for improving digital inclusion in e-government services: A mixed-methods systematic review protocol," *Int. J. Qual. Methods*, vol. 21, p. 16094069211070936, 2022.
- [27] A.-S. Poncette, D. L. Glauert, L. Mosch, K. Braune, F. Balzer, and D. A. Back, "Undergraduate medical competencies in digital health and curricular module development: mixed methods study," *J. Med. Internet Res.*, vol. 22, no. 10, p. e22161, 2020.
- [28] J. L. Myers, A. D. Well, and R. F. Lorch Jr, *Research design and statistical analysis*. Routledge, 2013.

- [29] D. G. Puspita and S. Sugiyono, "Strategies to Improve Education Quality at Junior High Schools," *KnE Soc. Sci.*, pp. 182–194, 2021.
- [30] A. Vanhove, E. Opdecam, and L. Haerens, "Fostering social skills in the Flemish secondary accounting education: Perceived challenges, opportunities, and future directions," *Account. Educ.*, vol. 33, no. 4, pp. 414–449, 2024.
- [31] L. Soubra, M. A. Al-Ghouti, M. Abu-Dieyeh, S. Crovella, and H. Abou-Saleh, "Impacts on student learning and skills and implementation challenges of two student-centered learning methods applied in online education," *Sustainability*, vol. 14, no. 15, p. 9625, 2022.
- [32] J. Cabero-Almenara, F. D. Guillén-Gámez, J. Ruiz-Palmero, and A. Palacios-Rodríguez, "Teachers' digital competence to assist students with functional diversity: Identification of factors through logistic regression methods," *Br. J. Educ. Technol.*, vol. 53, no. 1, pp. 41–57, 2022.
- [33] S. K. W. Chu, R. B. Reynolds, N. J. Tavares, M. Notari, and C. W. Y. Lee, *21st century skills development through inquiry-based learning from theory to practice*. Springer, 2021.
- [34] W. Ahmed, "Understanding self-directed learning behavior towards digital competence among business research students: SEM-neural analysis," *Educ. Inf. Technol.*, vol. 28, no. 4, pp. 4173–4202, 2023.
- [35] B. Wolff, F. Mahoney, A. L. Lohiniva, and M. Corkum, "Collecting and analyzing qualitative data," *CDC F. Epidemiol. Manual; Oxford Univ. Press Oxford, UK; New York, NY, USA*, pp. 213–228, 2019.
- [36] W. Boateng, "Evaluating the efficacy of focus group discussion (FGD) in qualitative social research," *Int. J. Bus. Soc. Sci.*, vol. 3, no. 7, 2012.
- [37] K. Elmusharaf, "Qualitative data collection techniques," *Train. Course Sex. Reprod. Heal. Res. Geneva*, 2012.
- [38] O. S. Asfour and A. M. Alkharoubi, "Challenges and opportunities in online education in Architecture: Lessons learned for Post-Pandemic education," *Ain Shams Eng. J.*, vol. 14, no. 9, p. 102131, 2023.
- [39] V. Chang, C. Gütl, and M. Ebner, "Trends and opportunities in online learning, MOOCs, and cloud-based tools," *Second Handb. Inf. Technol. Prim. Second. Educ.*, pp. 935–953, 2018.
- [40] A. Oleinik, "Mixing quantitative and qualitative content analysis: Triangulation at work," *Qual. Quant.*, vol. 45, no. 4, pp. 859–873, 2011.
- [1] R. S. Malik, "21世纪教育与可持续发展中的教育挑战", 《可持续发展教育研究》, 第2卷, 第1期, 页9–20, 2018年。
- [2] V. Kaputa, E. Loučanová, 和 F. A. Tejerina-Gaite, "高等教育机构的数字化转型作为社会导向创新的驱动力", 《高等教育中的社会创新》, 第61期, 页81–85, 2022年。
- [3] A. R. Saavedra 和 V. D. Opfer, "21世纪技能的教学与学习：来自学习科学的经验教训", 《全球城市教育网络报告》, 卷10, 亚洲协会出版, 纽约, 2012年。
- [4] O.-S. Tan, 《基于问题的学习创新：利用问题驱动21世纪学习》, 盖尔·森吉奇学习出版社, 2021年。
- [5] C. Luna Scott, "学习的未来2：21世纪需要何种学习？", 2015年。
- [6] B. Thornhill-Miller 等, "创造力、批判性思维、沟通与协作：面向未来工作与教育的21世纪技能评估、认证与推广", 《智能学报》, 第11卷, 第3期, 页54, 2023年。
- [7] M. Jefferson 和 M. Anderson, 《学校转型：创造力、批判性反思、沟通与协作》, 布卢姆斯伯里出版社, 2017年。
- [8] U. Abubakar, O. O. Ogunlade, 和 H. A. Ibrahim, "技术整合课程资源对高等教育中学生参与度和学业成绩的影响", 《移动学习与教育研究进展》, 第4卷, 第2期, 页1208–1223, 2024年。
- [9] R. Rudianto, R. Diani, S. Subandi, 和 N. Widiawati, "基于抛物运动材料的4C技能（批判性思维、协作、沟通与创造力）评估工具开发", 《高级科学与数学教育期刊》, 第2卷, 第2期, 页65–79, 2022年。
- [10] R. K. Putri, N. Bukit, 和 M. P. Simanjuntak, "基于项目学习模式对高中物理学生批判性思维、创造性思维、协作能力与沟通能力（4C）的影响", 发表于《第六届年度国际变革教育与领导力研讨会论文集（AISTEEL 2021）》, 亚特兰蒂斯出版社, 2021年, 页323–330。
- [11] L. I. González-Pérez 和 M. S. Ramírez-Montoya, "教育4.0在21世纪技能框架中的组成要素：系统综述", 《可持续性》, 第14卷, 第3期, 文章1493, 2022年。

参考文献

- [12] T. J. Kennedy 和 C. W. Sundberg, “21世纪技能”, 载于《科学教育:理论与实践——学习理论入门指南》, 页 479–496, 2020年。
- [13] D. M. West, 《数字化学校:技术如何改变教育》, 布鲁金斯学会出版社, 2012年。
- [14] P. Sharma, “教育4.0的数字革命”, 《国际工程与先进技术期刊》, 第 9 卷, 第 2 期, 页 3558–3564, 2019年。
- [15] A. Collins 和 R. Halverson, 《技术时代的教育再思考:数字革命与美国教育》, 师范学院出版社, 2018年。
- [16] A. Haleem, M. Javaid, M. A. Qadri, 和 R. Suman, “数字技术在教育中作用的理解:综述”, 《可持续运营与计算》, 第 3 期, 页 275–285, 2022年。
- [17] J. Bhijakkanarin 和 S. Kenaphoom, “提升小学生分析性思维能力”, 《可持续发展人文社会科学5.0》, 页 259, 2024年。
- [18] E. F. Barkley, 《协作学习技术:高校教师手册》, 约翰·威利父子出版社, 2014年。
- [19] G. M. Jacobs 和 W. A. Renandya, 《以学生为中心的合作学习:将教育理念与学生学习相结合》, 施普林格出版社, 2019年。
- [20] J. H. Stronge, 《有效教师的素质》, 美国教育发展出版社, 2018年。
- [21] R. M. Palloff 和 K. Pratt, 《虚拟课堂的经验教训:在线教学的现实》, 约翰·威利父子出版社, 2013年。
- [22] L. W. Anderson, “目标、评估与教育改进”, 《教育评估研究》, 第 31 卷, 第 2–3 期, 页 102–113, 2005年。
- [23] A. Sukasni 和 H. Efendy, “印度尼西亚教育体系的问题及改革议程”, 《国际教育期刊》, 第 9 卷, 第 3 期, 页 183, 2017年。
- [24] V. Matyushok, V. Vera Krasavina, A. Berezin, 和 J. Sendra García, “技术变革条件下的全球经济:现代趋势综述”, 《经济研究》, 第 34 卷, 第 1 期, 页 1471–1497, 2021年。
- [25] 美国国家情报委员会, 《2030全球趋势:替代世界》, 美国政府印刷办公室, 2012年。
- [26] T. Morte-Nadal 和 M. A. Esteban-Navarro, “提升电子政务服务中数字包容性的数字能力:混合方法系统综述方案”, 《国际定性方法期刊》, 第 21 卷, 文章 16094069211070936, 2022年。
- [27] A.-S. Poncette, D. L. Glauert, L. Mosch, K. Braune, F. Balzer, 和 D. A. Back, “本科医学数字健康能力与课程模块开发:混合方法研究”, 《医学互联网研究杂志》, 第 22 卷, 第 10 期, 文章 e22161, 2020年。
- [28] J. L. Myers, A. D. Well, 和 R. F. Lorch Jr, 《研究设计与统计分析》, 劳特利奇出版社, 2013年。
- [29] D. G. Puspita 和 S. Sugiyono, “提高初中教育质量的策略”, 《KnE社会科学》, 页 182–194, 2021年。
- [30] A. Vanhove, E. Opdecam, 和 L. Haerens, “培养佛兰芒语中等会计教育中的社交技能:面临的挑战、机遇与未来方向”, 《会计教育》, 第 33 卷, 第 4 期, 页 414–449, 2024年。
- [31] L. Soubra, M. A. Al-Ghouti, M. Abu-Dieyeh, S. Crovella, 和 H. Abou-Saleh, “在线教育中应用的两种以学生为中心的学习方法对学生学习和技能的影响及实施挑战”, 《可持续性》, 第 14 卷, 第 15 期, 文章 9625, 2022年。
- [32] J. Cabero-Almenara, F. D. Guillén-Gámez, J. Ruiz-Palmero, 和 A. Palacios-Rodríguez, “教师在帮助具有功能多样性学生方面的数字能力:通过逻辑回归方法识别影响因素”, 《英国教育技术期刊》, 第 53 卷, 第 1 期, 页 41–57, 2022年。
- [33] S. K. W. Chu, R. B. Reynolds, N. J. Tavares, M. Notari, 和 C. W. Y. Lee, 《通过探究式学习发展21世纪技能:从理论到实践》, 施普林格出版社, 2021年。
- [34] W. Ahmed, “理解商科研究生针对数字能力的自主学习行为:SEM-神经网络分析”, 《教育信息技术》, 第 28 卷, 第 4 期, 页 4173–4202, 2023年。
- [35] B. Wolff, F. Mahoney, A. L. Lohiniva, 和 M. Corkum, “定性数据的收集与分析”, 载于《CDC实地流行病学手册》, 牛津大学出版社, 牛津, 英国; 纽约, 纽约, 美国, 页 213–228, 2019年。
- [36] W. Boateng, “评估焦点小组讨论(FGD)在定性社会研究中的有效性”, 《国际工商与社会学期刊》, 第 3 卷, 第 7 期, 2012年。
- [37] K. Elmusharaf, “定性数据收集技术”, 载于《性与生殖健康研究培训课程》, 日内瓦, 2012年。
- [38] O. S. Asfour 和 A. M. Alkharoubi, “建筑学在线教育中的挑战与机遇:后疫情时代教育的

经验教训”，《艾因夏姆斯工程学报》，第 14 卷，第 9 期，文章 102131，2023 年。
[39] V. Chang, C. Gütl, 和 M. Ebner, “在线学习、大规模开放在线课程与云端工具中的趋势与机遇”，载于《基础与中等教育信息技术第二手册》，页 935–953，2018 年。
[40] A. Oleinik, “定量与定性内容分析的混合：三角测量法的实践”，《定性与定量研究》，第 45 卷，第 4 期，页 859–873，2011 年。

Word count: 8,007 words, excluding references.

Peer review information:

Whether the manuscript was fast tracked? - No

Number of reviewer report submitted in first round:
3 reports
Number of revision rounds: 3 rounds
Final revised version submitted: April 25, 2025

Disclaimer/Publisher’s Note:

The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of the Journal of Hunan University (Natural Sciences and/or the editor(s)). The Journal of Hunan University (Natural Sciences and/or the editor(s)) disclaims responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the manuscript.