JPPIPA 11(8) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

The Relationship between Students' 21st Century Skills and Learning Outcomes on Virus Material for Grade X of Senior High School Stage E

RinaWidiana[1*], Diana Susanti[2], Yola Asri[2]

[1] Universitas PGRI Sumatera Barat, Fakultas Program Pasca Sarjana, Study Lingkungan, Padang, Indonesia.
[2] Universitas PGRI Sumatera Barat, Fakultas Sains dan Teknologi, Pendidikan Biologi, Padang, Indonesia.

Received: June 2, 2025
Revised: August 11, 2025
Accepted: August 27, 2025
Published: August 31, 2025

Corresponding Author:
Rina Widiana
rinaroesdi68@gmail.com

DOI: 10.29303/jppipa.v11i8.11560

Abstract: This study investigates the relationship between 21st-century skills and students' learning outcomes on the topic of viruses in Grade X at SMA Negeri 1 Rao, Pasaman Barat, Indonesia. Employing a quantitative approach with a correlational research design, data were obtained from two instruments: a 21st-century skills questionnaire and a summative test on the virus topic. The questionnaire measured four core dimensions: critical thinking, creativity, collaboration, and communication. Data analysis was conducted using Pearson's product–moment correlation to assess the strength and significance of the relationship between the variables. The results indicated a very weak and statistically non-significant correlation between 21st-century skills and summative learning outcomes. These findings suggest that while 21st-century skills are vital for fostering deep conceptual understanding and the practical application of scientific knowledge, they are not adequately captured by assessments focused primarily on rote memorization and factual recall. The study highlights the need for integrating learning approaches that embed competency-based evaluation, such as project-based learning, case studies, and collaborative problem-solving tasks. Such approaches would enable a more comprehensive measurement of students' abilities and better align assessment practices with the demands of contemporary education.

Keywords: 21st century learning skills; Learning outcomes; Viruses.

Introduction

Over the past decades, education has encountered increasingly complex challenges due to globalization and the rapid advancement of technology. These global transformations, shaped by social, economic, and cultural changes alongside developments in information and communication technology, require that education uphold universal scientific values such as adaptability, evidence-based reasoning, collaboration, and lifelong learning (Pickering, 1997; Tusha et al., 2024; Zhang, 2007). Learners today must acquire not only academic proficiency but also transferable competencies essential for success in professional and daily life. For this reason, modern education is expected to foster critical thinking, collaboration, communication, creativity, and problem-solving to ensure individuals can adapt and thrive in a fast-changing, interconnected society(Barraket, 2004; Law et al., 2011; Silaban et al., 2024).

To meet these educational demands, Indonesia's 2013 Curriculum (K13) promotes the development of higher-order thinking skills (HOTS) to prepare students for complex real-world challenges (Adam et al., 2023; Primahesa et al., 2023; Risti & Irawati, 2022; Santosa et al., 2023; Zhu et al., 2025).

Within this framework, biology—particularly the topic of viruses in Grade X—offers an effective platform for cultivating such skills. Students are expected to gain comprehensive knowledge of virology, including virus types, structures, transmission modes, and impacts on human health, while also practicing analytical reasoning and problem-solving in relevant contexts(Grinde, 2013;

How to Cite:
Widiana, R., Susanti, D., & Asri, Y. (2025). The Relationship between Students' 21st Century Skills and Learning Outcomes on Virus Material for Grade X of Senior High School Stage E. *Jurnal Penelitian Pendidikan IPA*, *11*(8), 694–702. https://doi.org/10.29303/jppipa.v11i8.11560

Kaczorowska & Van Der Hoek, 2020a, 2020b; Woolhouse & Brierley, 2017; Yang et al., 2022).

Nevertheless, despite curricular emphasis on these competencies, instructional practices in many schools remain dominated by memorization-based teaching and assessment methods. Such approaches do not adequately reflect the role of 21st-century skills in enhancing students' mastery of complex biological concepts like viruses. Considering that viral outbreaks are global challenges requiring cross-disciplinary collaboration, the abilities to work in teams, communicate effectively, and generate creative solutions are not only academically relevant but also socially indispensable. Yet, it is still unclear to what extent these skills are represented in measurable learning outcomes (Hirons et al., 2020; Kaczorowska & Van Der Hoek, 2020b; Kalinichenko et al., 2022; Kutter et al., 2018; Skowron et al., 2022).

Considering these challenges, recent scholarship underscores the importance of integrating academic content with competencies that equip students to navigate multifaceted and unpredictable global issues (Feyza & Seyda, 2023; Kalemkuş, 2021; Saavedra & Opfer, 2012). Saavedra & Opfer, 2012). Critical thinking enhances students' comprehension of viral mechanisms, while creativity supports the development of innovative strategies for prevention and control (Dilekçi & Karatay, 2023; González-Pérez & Ramírez-Montoya, 2022; Mudinillah et al., 2024; Pellegrino et al., 2013; Qian & Clark, 2016).

The urgency of addressing this matter has been reinforced by recent global health crises, which have revealed that scientific knowledge alone is insufficient without the capacity for critical reasoning, interdisciplinary collaboration, and effective communication. Within the Indonesian high school context, empirical studies examining the correlation between 21st-century skills and biology learning outcomes are still limited. Consequently, the present study investigates the relationship between these competencies and Grade X students' performance on the virus topic at SMA Negeri 1 Rao, Pasaman Barat. The results are anticipated to provide valuable insights for integrating competency-based approaches into science education, ensuring alignment with contemporary global demands while enhancing the relevance of learning experiences.

Method

This quantitative study, conducted in the odd semester of the 2024/2025 academic year at SMA Negeri 1 Rao, Pasaman Barat, employed a correlational research design to examine the relationship between students' 21st-century skills and their learning outcomes on the topic of viruses. The population consisted of all Grade X students, who were considered academically homogeneous; therefore, one class was selected as the sample through random sampling.

The research utilized the 21st Century Skills Questionnaire, which measures four core competencies: (1) Critical Thinking, (2) Creativity, (3) Collaboration, and (4) Communication (Budiyanto et al., 2024; Novia et al., 2024; Tang et al., 2020; Thornhill-Miller et al., 2023). The instrument used a three-point Likert scale: (1) Inadequate, (2) Acceptable, and (3) Extremely Acceptable, allowing respondents to self-assess based on their learning experiences (Cázares, 2010; Christensen & Knezek, 2017; Jamieson, 2004; Shroff et al., 2019; Wilden & Porsch, 2020; Yamamoto & Kinoshita, 2019).

Learning outcomes were measured using essay and multiple-choice tests assessing knowledge of virus concepts, transmission, and health impacts.

The research stages included:

1. Administering the 21st-century skills questionnaire**:** After the completion of instruction on the virus topic in the odd semester of the 2024/2025 academic year, students in the selected Grade X class are given the validated 21st Century Skills Questionnaire. The instrument measures four core competencies—critical thinking, creativity, collaboration, and communication—using a three-point Likert scale (1 = Inadequate, 2 = Acceptable, 3 = Extremely Acceptable). Students respond based on self-reflection of their learning experiences during the virus topic lessons.
2. Conducting the learning outcome assessment: Immediately after students finish the virus topic, a summative assessment is administered, consisting of multiple-choice and essay questions. The test evaluates mastery of core concepts, mechanisms, modes of transmission, and the impact of viruses on human health. The assessment is designed to measure not only factual recall but also conceptual understanding relevant to the topic.
3. Recording and organizing data from both instruments: Responses from the 21st-century skills questionnaire and scores from the learning outcome assessment are collected, verified for completeness, and entered into a statistical software database. Each student's dataset is coded to match questionnaire responses with corresponding test scores, ensuring readiness for subsequent descriptive and inferential statistical analysis, including Pearson correlation tests.

Data analysis employed descriptive statistics to present score distributions and Pearson's product–moment correlation to examine the relationship between skills and outcomes (Antonov et al., 2024; Asri et al., 2024; Hafeez, 2021; Pana & Escarlos, 2017).

Result and Discussion

The processed research data can be seen in Table 1.

Table 1. Data on the relationship between learning outcomes and students' 21st century learning skills

Correlations		Summative Outcomes	21st Century Learning Students
Learning out comes	Pearson Correlation	1	-.051
	Sig. (2-tailed)		.762
	N	37	37
Pembelajaran Abad 21	Pearson Correlation	-.051	1
	Sig. (2-tailed)	.762	
	N	37	37

*. Correlation is significant at the 0.05 level (2-tailed).

The Pearson Correlation (Pearson Correlation) between Summative Learning Outcomes and 21st Century Learning is -0.051, indicating a weak relationship between the two variables, according to the correlation test results in Table 1. This suggests that the observed 21st-century learning and the summative exam outcomes of pupils have a very weak and negligible link. The connection is not statistically significant, as indicated by the significance of the correlation (Sig. 2-tailed) of 0.762, which is significantly higher than 0.05. Put another way; there may not be enough significant correlation between summative outcomes and 21st-century learning to support sound judgments or conclusions. The study is based on data from 37 students, as shown by the number of samples (N) 37.

The results of the correlation test indicate that with a negative correlation of -0.051, there is a very weak and negligible correlation, suggesting that the association is tiny and unimportant. The high significance (0.762) suggests that there is no statistically significant correlation between summative test outcomes and 21st-century learning. The relationship between 21st century learning skills possessed by students and learning outcomes can be seen in Table 2.

Table 2. The relationship between 21st-century learning skills of critical thinking and student learning outcomes

Correlations		Summative Outcomes	Critikal thingking
Learning out comes	Pearson Correlation	1	-.319
	Sig. (2-tailed)		.054
	N	37	37
Critikal thingking	Pearson Correlation	-.319	1
	Sig. (2-tailed)	.054	
	N	37	37

*. Correlation is significant at the 0.05 level (2-tailed).

A Pearson correlation study between the variables "Learning outcomes" (Summative Outcomes) and "Critical Thinking" is displayed in the table. The two variables have a weak negative association, as indicated by the Pearson correlation coefficient of -0.319. The association is not statistically significant at the 5% level, according to the significance (two-tailed) value of 0.054, slightly over the generally accepted significance level of 0.05. There are 37 data points for both variables (N = 37).

Table 3. The relationship between 21st-century learning skills of creativity and student learning outcomes

Correlations		Summative Outcomes	Creativity
Learning out comes	Pearson Correlation	1	-.374*
	Sig. (2-tailed)		.023
	N	37	37
Creativity	Pearson Correlation	-.374*	1
	Sig. (2-tailed)	.023	
	N	37	37

*. Correlation is significant at the 0.05 level (2-tailed).

The table displays the results of a Pearson correlation study between the variables "Learning Outcomes" and "Creativity." These two variables have a somewhat negative association, as indicated by the Pearson correlation coefficient of -0.374. The association appears statistically significant at the 5% level, as indicated by the significance (two-tailed) value of 0.023, less than the generally accepted significance level of 0.05. There are 37 data points for both variables (N = 37).

Table 4. The relationship between 21st-century learning skills of collaboration and student learning outcomes

	Correlations	Summative Outcomes	Collaboration
Learning out comes	Pearson Correlation	1	-.089
	Sig. (2-tailed)		.599
	N	37	37
Collaboration	Pearson Correlation	-.089	1
	Sig. (2-tailed)	.599	
	N	37	37

*. Correlation is significant at the 0.05 level (2-tailed).

The table shows a Pearson correlation analysis between "Learning Outcomes" and "Collaboration." The Pearson correlation coefficient is -0.089, indicating a weak negative correlation between the two variables. The significance (two-tailed) value is 0.599, much higher than the commonly used significance level of 0.05, suggesting that the correlation is not statistically significant. Both variables have 37 data points (N = 37).

Table 5. The relationship between 21st-century learning skills of communication and student learning outcomes

Correlations

		Summative Outcomes	Communi-cation
Learning out comes	Pearson Correlation	1	-.412*
	Sig. (2-tailed)		.011
	N	37	37
Communication	Pearson Correlation	-.412*	1
	Sig. (2-tailed)	.011	
	N	37	37

*. Correlation is significant at the 0.05 level (2-tailed).

A Pearson correlation analysis between "Communication" and "Learning Outcomes" is shown in the table. The two variables have a somewhat negative association, as indicated by the Pearson correlation coefficient of -0.412. The association appears statistically significant at the 5% level, as indicated by the significance (two-tailed) value of 0.011, which is less than the generally accepted significance level of 0.05. There are 37 data points for both variables (N = 37).

Thus, no discernible or meaningful relationship exists between students' summative exam scores and 21st-century learning, encompassing abilities like communication, creativity, teamwork, and critical thinking.This demonstrates how outdated exam-based assessment techniques do not accurately represent students' abilities in the modern world(Matei & Coman, 2023; Meylani, 2024; Muhammad et al., 2024). Teachers' teaching strategies still emphasize lectures and Q&A sessions despite using scientific learning models in their research. While group learning exercises are also conducted, not every student participates. The lack of a substantial association between contemporary learning and learning outcomes in the scientific learning model can be attributed to several interconnected issues(Aliah et al., 2023; Bagban et al., 2017). Despite emphasizing critical, creative, collaborative, and communication skills and the efficient use of technology, 21st-century learning has not been effectively applied in the field.

Teachers' ignorance of the notion or inability to apply it to everyday instruction could be one of the causes. The scientific learning approach, which strongly emphasizes observation, experimentation, and deriving conclusions, may not be successful in altering student learning results if improperly used(Antonio, 2022; Berliana et al., 2023; Putri, 2022a). More than simply technology proficiency is needed for 21st-century learning; students must also be able to solve problems, think critically, and cooperate in groups(Khotima et al., 2022; Walipah et al., 2024). Students should be encouraged to understand the effects of viruses on society, the economy, and health, for instance, when the subject matter is about viruses. However, their results may be limited if teachers rely on scientific learning models that emphasize laboratory methods and experiments without connecting them to real-world circumstances.

The absence of technology utilization in educational contexts may impede the connection between 21st-century learning and intended learning outcomes. Incorporating technology into education is essential in the contemporary era(Bulman & Fairlie, 2015; Darío & Medina, 2024; Escueta et al., 2020; Lai & Bower, 2019; Trust, 2018). Students may utilize statistical software to analyze data regarding virus transmission or develop a digital presentation elucidating the virus's mechanisms and societal responses to it(Bozkurt, 2020; Ghavifekr & Yue, 2022; Joshi, 2023; Mandal et al., 2022; Sani et al., 2024). Failure to implement this may result in students merely memorizing fundamental concepts without the ability to apply them in practical contexts.

Educators should consider the method of material delivery. A structured scientific process is typically attained via a systematic approach within the scientific learning model(Penelitian et al., 2023; Putri, 2022b; Saputra & Sari, 2022). Students are expected to not only follow established processes but also adapt to contemporary changes. The learning model must be adaptable and capable of accommodating diverse approaches that engage students in a range of theoretical and practical contexts(Khairudin & Tanjung, 2024). A static approach will hinder the scientific learning model's ability to connect modern learning with learning outcomes.

Contemporary education prioritizes students' capacity to analyze, evaluate, and critically think about lessons. Students possessing strong critical thinking skills will be more adept at identifying virus transmission, the influencing factors, and potential solutions to mitigate its spread(Anggraeni et al., 2023; Makhzoum & Jabbour, 2020; Sarwanto et al., 2021; Sholikhah et al., 2024). Consequently, these 21st-century skills enhance conceptual understanding and facilitate broader material application. Traditional summative assessments, including written exams emphasizing memorization and foundational knowledge, may inadequately represent students' competencies in contemporary contexts (Agustine et al., 2020; Ali-Abadi et al., 2020; Amanda* et al., 2023; Plummer et al., 2022; Sarwanto et al., 2021).

Students possessing contemporary skills may exhibit enhanced critical and creative problem-solving abilities. However, their capacity to retain concepts and facts assessed could influence their test performance(Kinasih & Ratnawati, 2024; Susanti et al., 2021; Susanti & Fitriani, 2018; Vogler et al., 2018; Widiana et al., 2017). The capacity of students to

collaborate and communicate influences their discussions regarding virus material and group work dynamics. Project-based learning and group discussions, integral components of contemporary education, facilitate collaborative idea exchange and joint exploration of subjects among students(Lee et al., 2015; Ninad et al., 2023; Sappaile et al., 2025). This improves their comprehension of viral content. Consequently, learning outcomes from traditional educational approaches may inadequately represent students' creativity and critical thinking skills. Integrative and skills-based contemporary learning methods enhance students' comprehension and application of the material (Johnsen et al., 2023; Lee et al., 2015; Ninad et al., 2023; Wahbeh et al., 2021).

Learning in the 21st century prioritizes process-oriented assessment over mere outcomes. In virus education, assessments should evaluate students' memorization of viral information and problem-solving abilities related to halting, spreading, and preventing viruses. Student learning outcomes will not accurately represent the mastery of essential skills in contemporary education if evaluations are limited to written assignments or tests that exclude modern competencies. This will occur regardless of the application of the scientific learning model.

Conclusion

The correlation test results between student learning outcomes and modern learning regarding viruses for grade X high school indicate that modern skills such as creativity, collaboration, critical thinking, and communication are essential in the learning process. Still, their relationship with summative learning outcomes is not significant. The correlation test results suggest that these factors do not directly influence the outcomes of structured, fact-based examinations. However, critical thinking and collaboration skills enable students to engage in creative thought, idea sharing, and deeper problem analysis and resolution. This indicates that while 21st-century skills are crucial in educational contexts like viruses, summative exam results emphasizing specific knowledge may not adequately represent the application of these skills. To enhance students' understanding comprehensively, an integrated learning approach is essential. This method combines the cultivation of contemporary skills with project-oriented or discussion-oriented assessments.

Acknowledgments
Thank you to SMA Negeri 1 RAO for providing the time and facilities to carry out this research and to Universitas PGRI West Sumatra.

Author Contributions
The effort to investigate and examine the connection between students' 21st-century skills and learning outcomes in viral content in high school grade X constitutes the author's contribution to this study. The author contributes to the planning, executing, and analyzing research findings that offer a more profound comprehension of the significance of cultivating 21st-century abilities within the biology curriculum. By providing fresh perspectives on enhancing student learning outcomes by incorporating critical, creative, collaborative, and communication skills into biology lessons, the author also helps to create pertinent learning theories and practices. Through this study, the author helps create more efficient curricula and instructional strategies for high schools.

Funding
The Faculty of Science and Technology, Faculty of Postgraduate Program, and Universitas PGRI Sumatera Barat assisted in the study. We thank the university administration for providing facilities and resources critical to this study's success. Regarding the funding of this study, there is no conflict of interest.

Conflicts of Interest
The authors declare that no conflicts of interest are associated with this research. All authors participated in this research independently of any external influences that could influence the results or interpretation of the data. There are no financial, personal, or professional relationships that could bias the research.

References

Adam, U., Lameed, S., Ayodele, B., & Muraina, I. (2023). Beyond the Confines of Achievement in Secondary School Biology: Higher-order thinking in Focus. *Journal of Educational Sciences*. https://doi.org/10.31258/jes.7.1.p.12-26

Agustine, J., Nizkon, N., & Nawawi, S. (2020). Analisis keterampilan berpikir kritis peserta didik SMA kelas X IPA pada materi virus. *Assimilation: Indonesian Journal of Biology Education*. https://doi.org/10.17509/aijbe.v3i1.23297

Ali-Abadi, T., Babamohamadi, H., & Nobahar, M. (2020). Critical thinking skills in intensive care and medical-surgical nurses and their explaining factors. *Nurse Education in Practice*, *45*, 102783. https://doi.org/10.1016/j.nepr.2020.102783

Aliah, N., Natsir, N., Tinggi, S., Admiistrasi, I., Makassar, Y., Universitas, Z., & Madura, T. (2023). Development of Innovative Assessment Methods in the Context of Modern Learning. *International Journal of Education, Language, Literature, Arts, Culture, and Social Humanities*. https://doi.org/10.59024/ijellacush.v1i4.424

Amanda*, F. F., Sumitro, S., Lestari, S. R., & Ibrohim, I. (2023). Enhancing Critical Thinking And Problem Solving Skills By Complexity Science-Problem

Based Learning Model. *Multidisciplinary Journal of Educational Research*. https://doi.org/10.17583/remie.9409

Anggraeni, D., Prahani*, B., Suprapto, N., Shofiyah, N., & Jatmiko*, B. (2023). Systematic Review of Problem Based Learning Research in Fostering Critical Thinking Skills. *Thinking Skills and Creativity*. https://doi.org/10.1016/j.tsc.2023.101334

Antonio, R. (2022). Effectiveness of Blended Instructional Approach in Improving Students' Scientific Learning Outcomes: A Meta-Analysis. *Journal of Higher Education Theory and Practice*. https://doi.org/10.33423/jhetp.v22i5.5217

Antonov, O., Gordiichuk, S., Kovalchuk, V., Papizhuk, V., & Poplavska, S. (2024). Study of the effectiveness of modern learning technologies in preparing future professionals. *Revista Amazonia Investiga*. https://doi.org/10.34069/ai/2024.75.03.11

Asri, Asniwati, & Irwan. (2024). The Impact of Learning Skills on Academic Achievement and Learning Outcomes in High School. *Journal for Lesson and Learning Studies*. https://doi.org/10.23887/jlls.v7i1.68104

Bagban, T., Patil, S., Gat, A., & Shirgave, S. (2017). On Selection of Assessment Methods in Outcome Based Education (OBE). *Journal of Electrical Engineering & Technology*, *30*, 327–332. https://doi.org/10.16920/JEET/2017/V30I3/110610

Barraket, J. (2004). *E-learning and access : getting behind the hype*. https://consensus.app/papers/elearning-and-access-getting-behind-the-hype-barraket/5f0e32f5728b500b934ba2247c2637e6/

Berliana, G. Y., Sugiyanto, S., & Fardhani*, I. (2023). Student's Learning Outcomes and Scientific Literacy Improvement Through the Implementation of Reading to Learn and Discovery Learning Models. *Jurnal Penelitian Pendidikan IPA*. https://doi.org/10.29303/jppipa.v9i5.2573

Bozkurt, A. (2020). Educational Technology Research Patterns in the Realm of the Digital Knowledge Age. *Journal of Interactive Media in Education*, *2020*. https://doi.org/10.5334/JIME.570

Budiyanto, Kabri, K., Harapan, E., & Purwanto, M. (2024). 21st Century English Learning: a Revolution in Skills, Critical Thinking, Creativity, and Visual Communication. *Asian Journal of Applied Education (AJAE)*. https://doi.org/10.55927/ajae.v3i1.7841

Bulman, G., & Fairlie, R. (2015). Technology and Education: Computers, Software, and the Internet. *ERN: Technology (Topic)*. https://doi.org/10.1016/B978-0-444-63459-7.00005-1

Cázares, A. (2010). Proficiency and attitudes toward information technologies' use in psychology undergraduates. *Comput. Hum. Behav.*, *26*, 1004–1008. https://doi.org/10.1016/j.chb.2010.02.015

Christensen, R., & Knezek, G. (2017). Validating the Technology Proficiency Self-Assessment Questionnaire for 21st Century Learning (TPSA C-21). *Journal of Digital Learning in Teacher Education*, *33*, 20–31. https://doi.org/10.1080/21532974.2016.1242391

Darío, D., & Medina, P. H. (2024). A Neutrosophic multi-criteria approach for implementing technology in education. *International Journal of Neutrosophic Science*. https://doi.org/10.54216/ijns.240418

Dilekçi, A., & Karatay, H. (2023). The Effects Of The 21st Century Skills Curriculum On The Development Of Students' Creative Thinking Skills. *Thinking Skills and Creativity*. https://doi.org/10.1016/j.tsc.2022.101229

Escueta, M., Nickow, A., Oreopoulos, P., & Quan, V. (2020). Upgrading Education with Technology: Insights from Experimental Research. *Journal of Economic Literature*, *58*, 897–996. https://doi.org/10.1257/jel.20191507

Feyza, N., & Seyda, S. Y. (2023). 21st Century Skills and Learning Environments: ELT Students Perceptions. *Educational Research and Reviews*. https://doi.org/10.5897/err2023.4332

Ghavifekr, S., & Yue, W. (2022). Technology Leadership in Malaysian Schools: The Way Forward to Education 4.0 - ICT Utilization and Digital Transformation. *Int. J. Asian Bus. Inf. Manag.*, *13*, 1–18. https://doi.org/10.4018/ijabim.20220701.oa3

González-Pérez, L. I., & Ramírez-Montoya, M. (2022). Components of Education 4.0 in 21st Century Skills Frameworks: Systematic Review. *Sustainability*. https://doi.org/10.3390/su14031493

Grinde, B. (2013). Herpesviruses: latency and reactivation – viral strategies and host response. *Journal of Oral Microbiology*, *5*. https://doi.org/10.3402/jom.v5i0.22766

Hafeez, M. (2021). *Systematic Review on Modern Learning Approaches, Critical Thinking Skills and Students Learning Outcomes*. https://doi.org/10.23887/ijerr.v4i1.33192

Hirons, A., Khoury, G., & Purcell, D. (2020). Human T-cell lymphotropic virus type-1: a lifelong persistent infection, yet never truly silent. *The Lancet. Infectious Diseases*. https://doi.org/10.1016/S1473-3099(20)30328-5

Jamieson, S. (2004). Likert scales: how to (ab)use them. *Medical Education*, *38*. https://doi.org/10.1111/J.1365-2929.2004.02012.X

Johnsen, M. M. W., Sjølie, E., & Johansen, V. (2023). Learning to Collaborate in a Project-based Graduate Course: A Multilevel Study of Student Outcomes. *Research in Higher Education*, 1–24. https://doi.org/10.1007/s11162-023-09754-7

Joshi, S. (2023). TECHNOLOGY IN EDUCATION. *VIDYA - A JOURNAL OF GUJARAT UNIVERSITY*. https://doi.org/10.47413/vidya.v2i2.197

Kaczorowska, J., & Van Der Hoek, L. (2020a). Human anelloviruses: diverse, omnipresent and commensal members of the virome. *FEMS Microbiology Reviews*, *44*, 305–313. https://doi.org/10.1093/femsre/fuaa007

Kaczorowska, J., & Van Der Hoek, L. (2020b). Human anelloviruses: diverse, omnipresent and commensal members of the virome. *FEMS Microbiology Reviews*, *44*, 305–313. https://doi.org/10.1093/femsre/fuaa007

Kalemkuş, J. (2021). Investigation of Science Curriculum Learning Outcomes in Terms of 21st Century Skills. *Anadolu Journal Of Educational Sciences International*. https://doi.org/10.18039/ajesi.800552

Kalinichenko, S., Komkov, D., & Mazurov, D. (2022). HIV-1 and HTLV-1 Transmission Modes: Mechanisms and Importance for Virus Spread. *Viruses*, *14*. https://doi.org/10.3390/v14010152

Khairudin, A., & Tanjung, A. (2024). The Influence of Children Learning in Science Learning Models to Improve Student Learning Outcomes. *Holistic Science*. https://doi.org/10.56495/hs.v4i2.656

Khotima, D. A., Su'ad, S., Santoso, S., & Pratama, H. (2022). The Effectiveness of Android-Based Science Learning Model to Increase Student Learning Outcomes. *Asian Pendidikan*. https://doi.org/10.53797/aspen.v2i1.5.2022

Kinasih, T., & Ratnawati, N. (2024). The effectiveness of the project based learning model in improving students' collaboration skills on creative economic materials. *Jurnal Teori Dan Praksis Pembelajaran IPS*. https://doi.org/10.17977/um022v9i12024p1

Kutter, J., Spronken, M., Fraaij, P., Fouchier, R., & Herfst, S. (2018). Transmission routes of respiratory viruses among humans. *Current Opinion in Virology*, *28*, 142–151. https://doi.org/10.1016/j.coviro.2018.01.001

Lai, J., & Bower, M. (2019). How is the use of technology in education evaluated? A systematic review. *Comput. Educ.*, *133*, 27–42. https://doi.org/10.1016/J.COMPEDU.2019.01.010

Law, N., Yuen, A., & Fox, R. (2011). *Education Innovations Beyond Technology*. 217–232. https://doi.org/10.1007/978-0-387-71148-5_11

Lee, D., Huh, Y., & Reigeluth, C. (2015). Collaboration, intragroup conflict, and social skills in project-based learning. *Instructional Science*, *43*, 561–590. https://doi.org/10.1007/S11251-015-9348-7

Makhzoum, V., & Jabbour, M. (2020). Critical Thinking and It is Role in Facing Coronavirus. *International Journal of Educational Research Review*, *5*, 389–406. https://doi.org/10.24331/ijere.770575

Mandal, M., Srinivas, K., & Srinivas, P. (2022). Education Technology in Schools. *The International Review of Information Ethics*. https://doi.org/10.29173/irie492

Matei, F.-L., & Coman, A. R. M. (2023). Modern assessment methods in primary education. *Journal of Education, Society & Multiculturalism*, *4*, 211–224. https://doi.org/10.2478/jesm-2023-0011

Meylani, R. (2024). A Comparative Analysis of Traditional and Modern Approaches to Assessment and Evaluation in Education. *Batı Anadolu Eğitim Bilimleri Dergisi*. https://doi.org/10.51460/baebd.1386737

Mudinillah, A., Kuswandi, D., Erwin, E., Sugiarni, S., Winarno, W., Annajmi, A., & Hermansah, S. (2024). Optimizing Project-Based Learning in Developing 21st Century Skills: A Future Education Perspective. *Qubahan Academic Journal*. https://doi.org/10.48161/qaj.v4n2a352

Muhammad, I. M. S., Tomalá, M. P. C., Coello, C. R. M., Silva, S. A. C., & Del Rocío Cerón Silva, C. (2024). Assessment methods and their impact on learning outcomes in education. *LATAM Revista Latinoamericana de Ciencias Sociales y Humanidades*. https://doi.org/10.56712/latam.v5i5.2865

Ninad, K., Ugandhara, G., Hemant, K., Seema, J., & Sujata, A. (2023). Improvement And Implementation Of Contemporary Education System. *Journal of Engineering Education Transformations*. https://doi.org/10.16920/jeet/2023/v37is1/23165

Novia, F., Nurdianti, D., & Purwanto, M. (2024). English Learning and Innovation Skills in 21st: Implementation of Critical Thinking, Creativity, Communication, and Collaboration. *Asian Journal of Applied Education (AJAE)*. https://doi.org/10.55927/ajae.v3i2.8318

Pana, G., & Escarlos, G. (2017). Contemporary Teaching Strategies On Students' Attitude, Academic Performance And Acquisition Of The 21st Century Skills. *International Journal of Scientific & Technology Research*, *6*, 332–337. https://consensus.app/papers/contemporary-teaching-strategies-on-students-%E2%80%99-attitude-pana-escarlos/4c9217e54caa5721851a82b05c47674b/

Pellegrino, J., Hilton, M., & Skills, S. C. (2013). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*. https://consensus.app/papers/education-for-life-and-work-developing-transferable-pellegrino-hilton/0c09015079755930a749879c739603c9/

Penelitian, J., Ipa, P., Febriya, D., Asrizal, & Usmeldi. (2023). Connected Type Integrated Science Learning Model of Student Learning Outcomes: Meta-Analysis. *Jurnal Penelitian Pendidikan IPA*. https://doi.org/10.29303/jppipa.v9i12.5213

Pickering, J. (1997). The Internet in universities: liberation or desensitization? *Computers & Geosciences*, *23*, 513–519. https://doi.org/10.1016/S0098-3004(97)00019-8

Plummer, K., Kebritchi, M., Leary, H., & Halverson, D. (2022). Enhancing Critical Thinking Skills through Decision-Based Learning. *Innovative Higher Education*, *47*, 711–734. https://doi.org/10.1007/s10755-022-09595-9

Primahesa, A., Sajidan, S., & Ramli, M. (2023). Improving higher order thinking skills in high school biology: A systematic review. *Biosfer*. https://doi.org/10.21009/biosferjpb.26724

Putri, I. P. (2022a). Literature Review: The Effect Of Project Based Learning Learning Models On Student Learning Outcomes In Science Learning. *Universe*. https://doi.org/10.24036/universe.v3i2.213

Putri, I. P. (2022b). Literature Review: The Effect Of Project Based Learning Learning Models On Student Learning Outcomes In Science Learning. *Universe*. https://doi.org/10.24036/universe.v3i2.213

Qian, M., & Clark, K. (2016). Game-based Learning and 21st century skills: A review of recent research. *Comput. Hum. Behav.*, *63*, 50–58. https://doi.org/10.1016/j.chb.2016.05.023

Risti, I. S., & Irawati, H. (2022). Effect Of Problem Based Learning On Metacognitive And Higher Thinking Ability In High School Biology: Study Of Literature. *Jurnal Atrium Pendidikan Biologi*. https://doi.org/10.24036/apb.v7i2.12463

Saavedra, A., & Opfer, V. (2012). Learning 21st-Century Skills Requires 21st-Century Teaching. *Phi Delta Kappan Magazine*, *94*, 13–18. https://doi.org/10.1177/003172171209400203

Sani, J., Kamal, Md. M., Biswas, T. K., Chowdhury, S., Roy, S., & Sarwar, S. (2024). Technologies Used in Education. *International Journal For Multidisciplinary Research*. https://doi.org/10.36948/ijfmr.2024.v06i03.22020

Santosa, T., Festiyed, F., Zulyusri, Z., & Razak, A. (2023). The Development of HOTS Instruments In Biology Learning. *Jurnal Mangifera Edu*. https://doi.org/10.31943/mangiferaedu.v8i1.166

Sappaile, B., Hartinah, G., Hendrik, H., & Sumanik, E. (2025). The Impact of Project-Based Learning on Students' Collaboration Skills in Secondary Schools. *International Journal of Educational Research Excellence (IJERE)*. https://doi.org/10.55299/ijere.v4i1.1268

Saputra, H. Y., & Sari, M. (2022). the effect of the guided inquiry learning model on science learning outcomes. *Universe*. https://doi.org/10.24036/universe.v3i2.215

Sarwanto, S., Fajari, L., & Chumdari, C. (2021). Critical Thinking Skills And Their Impacts On Elementary School Students. *Malaysian Journal of Learning and Instruction*. https://doi.org/10.32890/mjli2021.18.2.6

Sholikhah, O. H., Suranto, S., & Santosa, S. (2024). Profile of Students' Critical and Creative Thinking Skills on Virus Material: The Need for Learning Innovation. *Jurnal Penelitian Pendidikan IPA*. https://doi.org/10.29303/jppipa.v10i10.7222

Shroff, R., Ting, F., & Lam, W. (2019). Development and validation of an instrument to measure students' perceptions of technology-enabled active learning. *Australasian Journal of Educational Technology*. https://doi.org/10.14742/AJET.4472

Silaban, F., Manurung, M., Simanjuntak, R., & Yunita, S. (2024). Pembelajaran Ilmu Pengetahuan Sosial pada Era Globalisasi. *Indo-MathEdu Intellectuals Journal*. https://doi.org/10.54373/imeij.v5i3.1302

Skowron, K., Bauza-Kaszewska, J., Grudlewska-Buda, K., Wiktorczyk-Kapischke, N., Zacharski, M., Bernaciak, Z., & Gospodarek-Komkowska, E. (2022). Nipah Virus–Another Threat From the World of Zoonotic Viruses. *Frontiers in Microbiology*, *12*. https://doi.org/10.3389/fmicb.2021.811157

Susanti, D., & Fitriani, V. (2018). Effectiveness of f The Practical Handbook Based on o n Problem Based Learning. *International Journal of Progressive Sciences and Technologies (IJPSAT)*, *10*(1), 67–70.

Susanti, D., Fitriani, V., & Sari, L. Y. (2021). Curriculum and Student Analysis of Interactive Electronic Book Based on Project in Strategy and Design of Learning Subject. *Jurnal Penelitian Pendidikan IPA*, *7*(3), 344. https://doi.org/10.29303/jppipa.v7i3.684

Tang, T., Vezzani, V., & Eriksson, V. (2020). Developing critical thinking, collective creativity skills and problem solving through playful design jams. *Thinking Skills and Creativity*. https://doi.org/10.1016/j.tsc.2020.100696

Thornhill-Miller, B., Camarda, A., Mercier, M., Burkhardt, J.-M., Morisseau, T., Bourgeois-

Bougrine, S., Vinchon, F., Hayek, S. El, Augereau-Landais, M., Mourey, F., Feybesse, C., Sundquist, D., & Lubart, T. (2023). Creativity, Critical Thinking, Communication, and Collaboration: Assessment, Certification, and Promotion of 21st Century Skills for the Future of Work and Education. *Journal of Intelligence*, *11*. https://doi.org/10.3390/jintelligence11030054

Trust, T. (2018). Why Do We Need Technology in Education? *Journal of Digital Learning in Teacher Education*, *34*, 54–55. https://doi.org/10.1080/21532974.2018.1442073

Tusha, Colaco, P., Katyal, A., Gupta, A., Walia, A., Madan, P., & Lamoria, J. (2024). Assessing the Impact of Cultural Differences on Educational Technology Acceptance. *Evolutionary Studies In Imaginative Culture*. https://doi.org/10.70082/esiculture.vi.1178

Vogler, J., Thompson, P., Davis, D., Mayfield, B., Finley, P., & Yasseri, D. (2018). The hard work of soft skills: augmenting the project-based learning experience with interdisciplinary teamwork. *Instructional Science*, *46*, 457–488. https://doi.org/10.1007/S11251-017-9438-9

Wahbeh, D., Najjar, E., Sartawi, A., Abuzant, M., & Daher, W. (2021). The Role of Project-Based Language Learning in Developing Students' Life Skills. *Sustainability*. https://doi.org/10.3390/SU13126518

Walipah, W., Firdaus, R., & Chasanah, F. (2024). Effectiveness of Problem-Based Learning and Discovery Learning Models on Learning Outcomes of Social Science Students. *Tarbiyah : Jurnal Ilmiah Kependidikan*. https://doi.org/10.18592/tarbiyah.v13i1.12848

Widiana, R., Susanti, S., & Susanti, D. (2017). Student Needs to Practicum Guidance in Physiology of Animals Based on Guided Inquiry. *Journal of Physics: Conference Series*, *895*(1). https://doi.org/10.1088/1742-6596/895/1/012005

Wilden, E., & Porsch, R. (2020). Teachers' self-reported L1 and L2 use and self-assessed L2 proficiency in primary EFL education. *Studies in Second Language Learning and Teaching*, *10*, 631–655. https://doi.org/10.14746/SSLLT.2020.10.3.9

Woolhouse, M., & Brierley, L. (2017). Epidemiological characteristics of human-infective RNA viruses. *Scientific Data*, *5*. https://doi.org/10.1038/sdata.2018.17

Yamamoto, C., & Kinoshita, Y. (2019). Self-Assessment Surveys – A Tool for Independent Learning in Lower-tier Dependent Classrooms. *Studies in Self-Access Learning Journal*. https://doi.org/10.37237/100306

Yang, J., Gong, Y., Zhang, C., Sun, J., Wong, G., Shi, W.-F., Liu, W., Gao, G., & Bi, Y. (2022). Co-existence and co-infection of influenza A viruses and coronaviruses: Public health challenges. *The Innovation*, *3*. https://doi.org/10.1016/j.xinn.2022.100306

Zhang, J. (2007). A cultural look at information and communication technologies in Eastern education. *Educational Technology Research and Development*, *55*, 301–314. https://doi.org/10.1007/S11423-007-9040-Y

Zhu, H., Jibo, & Yang, G. (2025). Research on Improving and Assessing Higher-Order Thinking Skills among Secondary School Students in Biology. *International Journal of New Developments in Education*. https://doi.org/10.25236/ijnde.2025.070105