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### Integrating STEM in Physics Learning to Improve 21<sup>st</sup> Century Skills: A Systematic Literature Review

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**Abstract:** 21st century skills need to be mastered by learners for education to be of high quality and relevant to the demands of the times. These skills include critical thinking, creative thinking, the ability to collaborate, as well as effective communication skills, all of which are important in facing global challenges and the complexity of the modern workplace. The purpose of this study was to evaluate article reviews on the incorporation of STEM (Science, Technology, Engineering, and Mathematics) into physics teaching to support the development of these skills. The method used was a systematic literature review with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) design consisting of four main stages, namely identification, screening, validity, and inclusion. The Scopus database was used as a search source for relevant scientific articles. A total of 1613 papers discussing STEM integration in physics education were found from 2018 to 2024. Of these, 25 papers were selected based on screening criteria and topic suitability. Based on the data synthesis of these articles, it can be concluded that the application of the STEM approach in physics learning significantly supports the development of 21st century skills. In addition to the four key skills, this integration also has the potential to strengthen civic values and character education through contextualized and interdisciplinary learning approaches. Collaboration between the STEM approach and other innovative learning models, such as problem-based learning or project-based learning, is considered effective in creating deep and meaningful learning experiences for students.

**Keywords:** 21<sup>st</sup> century skills, education, literature review, physics, STEM

### Integrasi STEM dalam Pembelajaran Fisika untuk Meningkatkan Keterampilan Abad 21: Tinjauan Literatur Sistematis

**Abstrak:** Keterampilan abad ke-21 perlu dikuasai oleh peserta didik agar pendidikan dapat bermutu dan relevan dengan tuntutan zaman. Keterampilan ini mencakup berpikir kritis, berpikir kreatif, kemampuan berkolaborasi, serta keterampilan komunikasi yang efektif, yang semuanya penting dalam menghadapi tantangan global dan kompleksitas dunia kerja modern. Tujuan dari penelitian ini adalah untuk mengevaluasi tinjauan artikel tentang penggabungan STEM (*Science, Technology, Engineering, and Mathematics*) dalam pengajaran fisika guna mendukung pengembangan keterampilan. Metode yang digunakan adalah kajian pustaka sistematis dengan desain PRISMA (*Preferred Reporting Items for Systematic Reviews and Meta-Analyses*) yang terdiri dari empat tahapan, yaitu identifikasi, penyaringan, validitas, dan inklusi. Basis data Scopus digunakan sebagai sumber pencarian artikel ilmiah yang relevan. Sebanyak 1613 makalah yang membahas integrasi STEM dalam pendidikan fisika ditemukan dalam rentang tahun 2018 hingga 2024. Terdapat 25 makalah terpilih berdasarkan kriteria penyaringan dan kesesuaian topik. Berdasarkan sintesis data dari artikel-artikel tersebut, dapat disimpulkan bahwa penerapan pendekatan STEM dalam pembelajaran fisika secara signifikan mendukung pengembangan keterampilan abad ke-21. Selain empat keterampilan utama, integrasi ini juga berpotensi memperkuat nilai kewarganegaraan dan pendidikan karakter melalui pendekatan pembelajaran yang kontekstual dan interdisipliner. Kolaborasi antara pendekatan STEM dan model pembelajaran inovatif lainnya, seperti *problem-based learning* atau *project-based learning*, dinilai efektif dalam menciptakan pengalaman belajar yang mendalam dan bermakna bagi peserta didik.

**Kata kunci:** fisika, keterampilan abad 21, pendidikan, STEM, tinjauan pustaka

## INTRODUCTION

Education has become an important part of life. As the times progress, education is expected to form a quality and sustainable human resource (Tanjung, 2020). The ability to think, including problem-solving, information analysis, and idea generation, is a key component of human resource quality. Besides, an individual also needs to have the skills to apply science to life (Asrizal et al., 2023). This is supported by the application of learning that enhances the skills of the 21<sup>st</sup> century.

Learning in school should train students ready to face life in the future. The learning model of the 21<sup>st</sup> century that develops soft skills is the STEM (Science, Technology, Engineering, and Mathematic). The implementation of this learning promotes a comprehensive understanding of the interrelationship between science and knowledge through the learning experience of 21<sup>st</sup> century skills (Asrizal et al., 2022).

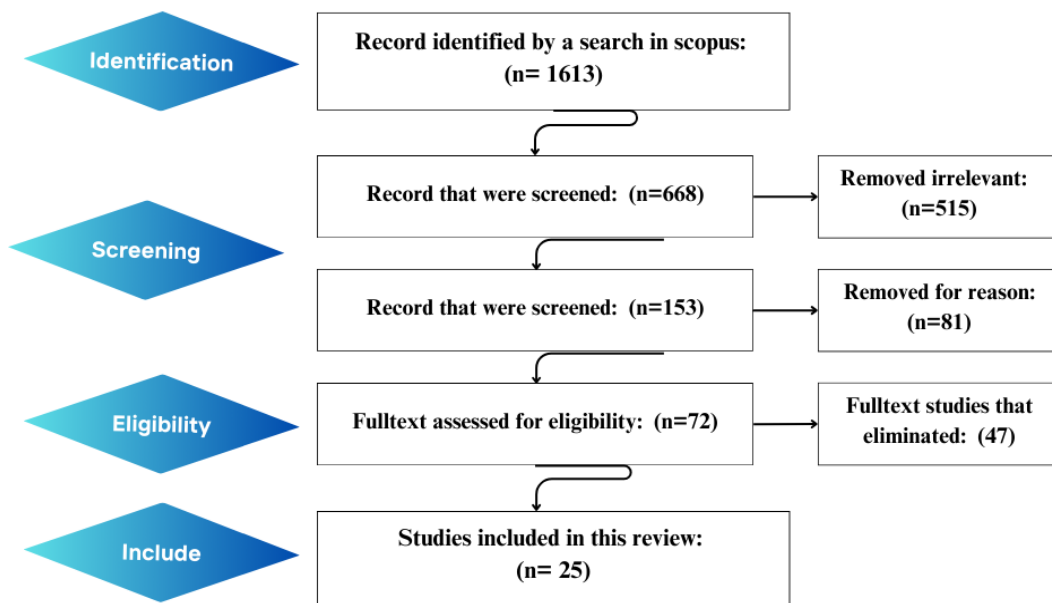
Some of these abilities, including collaboration, collaboration and communication, can be developed in the learning process (Thibaut et al., 2018). STEM education develops students' ability to think creatively and apply their ideas to the newest technologies in order to solve challenges. One of the demands of 21st-century learning is the integration of technology as a learning medium to develop learners' skills (Yusuf, et al., 2015). This integration encourages interdisciplinary learning and the application of real-world contexts in science education. STEM learning plays an important role in physics learning. Through the STEM approach, it can also create contextual learning (Pathoni et al., 2022). It involves researching and comprehending the events that occur in daily life and the surrounding environment. Additionally, students are able to connect theory to real-world applications when STEM is used in physics instruction.

The successful implementation of STEM learning requires the support of suitable learning media that align with students' characteristics and learning needs. STEM learning can be done by utilizing learning media that are appropriate to the needs of students (Sari et al., 2023). The implementation entails students actively participating in the physics learning process in order to meet the goals.

To address current educational challenges, instructional approaches are required to foster active participation and learner autonomy. The STEM approach involves students in learning. STEM learning can encourage students to explore their abilities. The STEM approach becomes crucial when there is a paradigm shift from student-centered to teacher-centered (Leshner, 2018). It aims to make students more participatory during the learning process. This paradigm shift has prompted the adoption of a variety of learning approaches, including the STEM approach in order to improve the skills of the 21<sup>st</sup> century. Based on the description, the research was conducted to study the integration of STEM approaches in physics learning into the skills of the 21<sup>st</sup> century.

## METHOD

This study does a literature review using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) design as a technique. The four primary stages of the PRISMA design are inclusion, eligibility, screening, and identification (Liberati et al., 2009). The purpose of these four stages is to guarantee that the literature selection procedure is conducted in a methodical and open manner.



**Figure 1.** Flowchart Report Items for PRISMA Systematic Literature Review

The first phase is the identification done by collecting data. Data sources used in this research are secondary data such as articles and proceedings obtained from the Scopus database. The keywords used in the search include “STEM” AND “physics education” AND “21<sup>st</sup> century skills” In this phase, a total of 1613 articles are obtaining.

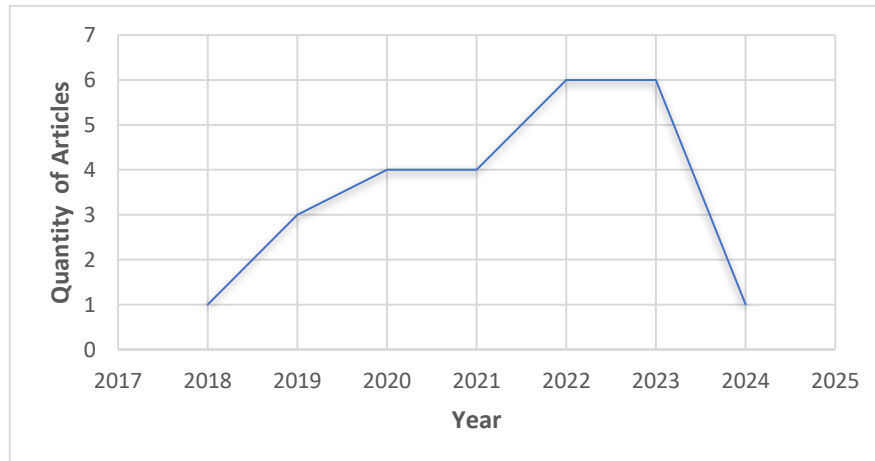
**Table 1.** Data Inclusion Criteria

No.	Criteria	Description
1	Subject	Physics
2	Years	2018-2024
3	Type of interference	Study that applies the STEM approach
4	Design of Research	Experimental, quantitative, qualitative, research and development methods (R&D)
5	Finding	Articles that apply the STEM approach to supporting the skills of the 21 <sup>st</sup> century

Title and abstract analysis is performed to select articles that match the criteria in Table 1. The analysis process is carried out automatically using filters in the Scopus database. There were 515 articles that were not relevant to the research criteria, including the year of publication, the subject, and the design of the research. Based on the analysis of the type of interference, there are 81 articles that are not related to the skills of the 21<sup>st</sup> century. At this stage, 72 articles were obtained which analyzed its effectiveness. The third stage is the ability to evaluate the content of the article until it matches the topic. The validity analysis process is done by reading the entire article that has been filtered at the previous stage. At this stage, 25 relevant articles were obtained and used as the final database used as a reference to this study. All articles that have qualified are analyzed to obtain a synthesis or conclusion in this study.

## RESULTS AND DISCUSSION

The research is based on articles and seminar proceedings that examine physical learning activities with the STEM approach. Based on data analysis from the Scopus database, there are 25 articles and seminary proceeding published in international journals used in this research. The results of the trend analysis of publications from 2018 to 2024.



**Figure 2.** Articles Classified by Publication Year

According to Figure 2. shows that 25 articles were used in the literature review in this study. The publication trend of STEM approaches in physics learning has increased from 2018 to 2020. Most of the entire article uses experimental research methods. At the start of the Covid-19 pandemic, there were 4 articles, or 16% of the total, on STEM approaches to 21<sup>st</sup> century physics learning skills. The number of such publications was higher than in the previous year, but there was no increase from 2020 and 2021. This is due to the adaptation of online learning. Then, in 2022 and 2023 there was an increase, that is, 6 articles or 24% of the total of articles. It states that post-pandemic covid-19 is more research on the application of STEM approaches in physics learning. However, in 2024, one article was found to match the subject of this research. That is, there is still little research into the application of STEM approaches to physics learning. It's an opportunity for researchers to study further about the STEM approach to physics learning.

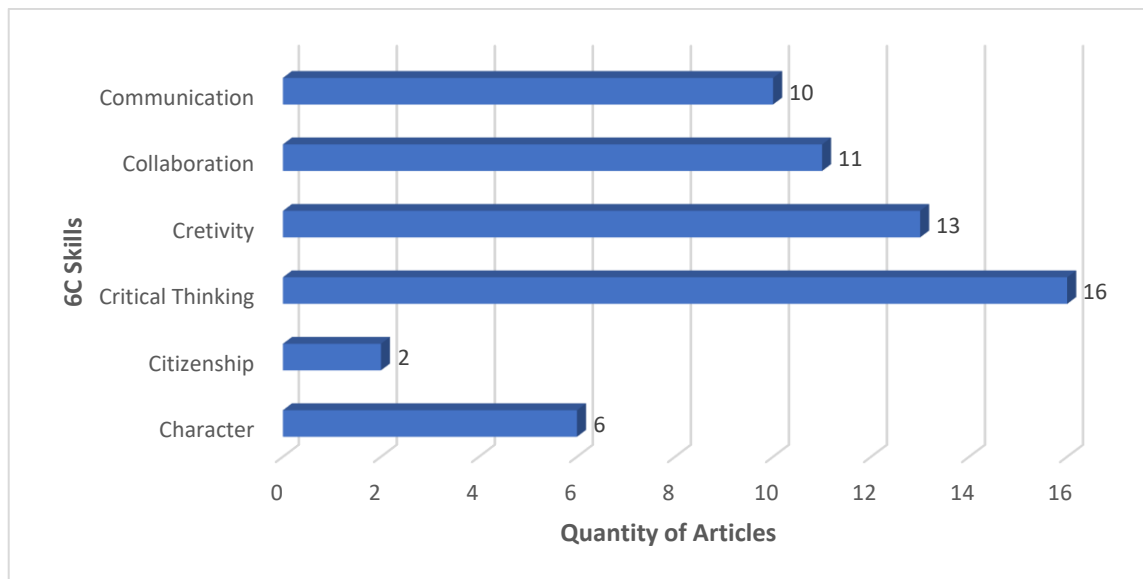
Research on STEM in physics learning has been done from the Asian, American, and European continents. Figure 3 shows the application of STEM approaches in physics learning by scholars from 11 countries. Results that support the skills of the 21<sup>st</sup> century were found mostly in Indonesia, which is 11 or 44% of all articles. The United States found 3 or 12%, while Malaysia and Mexico found 2 or 8% of articles respectively according to research topics.



**Table 2.** Integrating STEM

Model	Author	21 <sup>st</sup> Century Skills
Problem based learning	Dominguez et al. (2024); Snyder et al. (2022); Dwi Yulianti et al. (2020); Chanrak & Pimvichai (2023); D. Yulianti et al. (2022); Wibowo et al. (2022); D. Yulianti et al. (2020)	Collaboration, critical thinking, creative, communication, culture, character
Inquiry learning	Khalil et al. (2023); Irwandi et al. (2018); Asrizal et al. (2022); González-Peña et al. (2021); Dyrberg & Holmegaard (2019); Suganda et al. (2023); Ulfa et al. (2021)	Communication, creative, critical thinking, character
Project based learning	(Claesson et al., 2021); (Boyle, 2019); (Mulyati et al., 2023); (Pebriana et al., 2024); (Widyasmah et al., 2020); (Parno et al., 2023); (Cheng & Lo, 2022)	Character, creative, critical thinking, collaboration
Cooperative learning	(Benabentos et al., 2021)	Communication, collaboration, critical thinking, creative
5E Instruction	(Conradty et al., 2020)	Character
7E learning cycle	(Parno et al., 2019)	Critical thinking dan creative

According to Table 2, the problem-based learning model improves 21<sup>st</sup> century skills that include 6C Skills. The application of the problem based learning model provides experience to learners to solve problems. The integration of STEM in the problem base learning model encourages students to analyze problems, identify information, and evaluate solutions. STEM integration in the application of an inquiry model, project based learning, and cooperative learning influences 4C skills. In addition, the frequency of articles stating the influence of STEM approaches on each 21<sup>st</sup> century skills.



**Figure 5.** The Impact of STEM on 21<sup>st</sup> Century Skills

Integration of STEM (Science, Technology, Engineering, and Mathematic) into physics learning can enhance the 6C skills of the 21<sup>st</sup> century. The bar diagram in Figure 5 shows that 16 articles state that STEM integration improves critical thinking skills. There are 13 articles stating that STEM integration improves the creativity of learners such as creating innovative ideas or products and finding creative solutions to solve problems. There are 11 articles that stated that the integration of STEM improves collaborative skills such as collaborative work and appreciation of stakeholders in teamwork. In total there are 10 articles that state that the Integration enhances communication skills, such as communicating ideas, information, and opinions both orally and in writing. In all, there are 6 articles that indicate that the integration of STEM enhances educational characteristics such as integrity, honesty, responsibility, and motivation for learners. Two of the articles state that STEM integration enhances citizenship such as awareness and social responsibility to contribute to local and global communities. Based on the analysis, critical thinking skills are mostly enhanced with the integration of STEM in physics learning. Related studies also state that students' STEM perceptions are positive and also have an indirect effect on career awareness (Topsakal et al., 2022). While, STEM integration has little influence on citizenship skills because not much has been studied.

## CONCLUSION AND SUGGESTIONS

Based on systematic literature review, it can be concluded that the application of STEM (Science, Technology, Engineering, and Mathematic) approaches in physics learning supports 21<sup>st</sup> century skills, some of which include critical thinking, creative thinking, collaboration, communication, citizenship, and character education. The most enhanced skill is critical thinking. This can be supported by collaborative learning models such as problem-based learning, inquiry learning, project-based Learning, collaborative learning, and 7E learning cycle. Meanwhile, STEM integration has little impact on citizenship skills because not much has been studied. It's an opportunity for future researchers to do related research. The results of this study can be used as a consideration for educators in implementing physics learning methods in schools.

## BIBLIOGRAPHY

- Asrizal, A., Annisa, N., Festiyed, F., Ashel, H., & Amnah, R. (2023). STEM-integrated Physics Digital Teaching Material to Develop Conceptual Understanding and New Literacy of Students. *Eurasia Journal of Mathematics, Science and Technology Education*, 19(7), 1-14. <https://doi.org/10.29333/ejmste/13275>
- Asrizal, A., Mardian, V., Novitra, F., & Festiyed, F. (2022). Physics Electronic Teaching Material-integrated STEM Education to Promote 21st-Century Skills. *Cypriot Journal of Educational Sciences*, 17(8), 2899-2914. <https://doi.org/10.18844/cjes.v17i8.7357>
- Benabentos, R., Hazari, Z., Stanford, J. S., Potvin, G., Marsteller, P., Thompson, K. V., Cassone, V. M., Murasko, D., & Kramer, L. (2021). Measuring the Implementation of Student-centered Teaching Strategies in Lower- and Upper-division STEM Courses. *Journal of Geoscience Education*, 69(4), 342-356. <https://doi.org/10.1080/10899995.2020.1768005>
- Boyle, J. (2019). Teaching gravitational waves in the lower secondary school. Part III. Monitoring the Effect of a STEM Intervention on Students' Attitude, Self-efficacy and Achievement. *Physics Education*, 54(2), 025007. <https://doi.org/10.1088/1361-6552/aaf771>
- Chanrak, T., & Pimvichai, J. (2023). The Development of STEM Integrated with Local

- Context and 21st Century Skills for Teaching Fluids for Grade 12 Science Students. *Journal of Physics: Conference Series*, 2582(1), 012059. <https://doi.org/10.1088/1742-6596/2582/1/012059>
- Cheng, M. F., & Lo, Y. H. (2022). Innovative STEM Curriculum to Enhance Students' Engineering Design Skills and Attitudes Towards STEM. In *Concepts and Practices of STEM Education in Asia*. 1(2), 117-137. [https://doi.org/10.1007/978-981-19-2596-2\\_7](https://doi.org/10.1007/978-981-19-2596-2_7)
- Claesson, L., Kans, M., Håkansson, L., & Nilsson, K. (2021). STEM Education on Equal Terms Through the Flipped Laboratory Approach. *Advances in Intelligent Systems and Computing*, 1231 AISC.1(2), 46-62. [https://doi.org/10.1007/978-3-030-52575-0\\_4](https://doi.org/10.1007/978-3-030-52575-0_4)
- Conradty, C., Sotiriou, S. A., & Bogner, F. X. (2020). How Creativity in STEAM Modules Intervenes with Self-efficacy and Motivation. *Education Sciences*, 10(3), 1-15. <https://doi.org/10.3390/educsci10030070>
- Dominguez, A., De la Garza, J., Quezada-Espinoza, M., & Zavala, G. (2024). Integration of Physics and Mathematics in STEM Education: Use of Modeling. *Education Sciences*, 14(1), 1-20. <https://doi.org/10.3390/educsci14010020>
- Dyrberg, N. R., & Holmegaard, H. T. (2019). Motivational Patterns in STEM Education: a Self-determination Perspective on First Year Courses. *Research in Science and Technological Education*, 37(1), 90-109. <https://doi.org/10.1080/02635143.2017.1421529>
- González-Peña, O. I., Morán-Soto, G., Rodríguez-Masegosa, R., & Rodríguez-Lara, B. M. (2021). Effects of a Thermal Inversion Experiment on STEM Students Learning and Application of Damped Harmonic Motion. *Sustainability (Switzerland)*, 13(2), 919. <https://doi.org/10.3390/su13020919>
- Irwandi, Oktavia, R., Rajibussalim, Halim, A., & Melvina. (2018). Light Emitting Diode (LED) as an Essential Prop Component for STEM Education in the 21st Century: A Focus For Secondary School Level. *Journal of Physics: Conference Series*, 1088(1), 012060. <https://doi.org/10.1088/1742-6596/1088/1/012060>
- Khalil, R. Y., Tairab, H., Qablan, A., Alarabi, K., & Mansour, Y. (2023). STEM-Based Curriculum and Creative Thinking in High School Students. *Education Sciences*, 13(12), 1195. <https://doi.org/10.3390/educsci13121195>
- Leshner, A. I. (2018). Student-centered, Modernized Graduate STEM Education. *Science*, 360(6392), 969-970. <https://doi.org/10.1126/science.aau0590>
- Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P. A., Clarke, M., Devereaux, P. J., Kleijnen, J., & Moher, D. (2009). The PRISMA Statement for Reporting Systematic Reviews and Meta-analyses of Studies that Evaluate Healthcare Interventions: Explanation and Elaboration. *BMJ (Clinical Research Ed.)*, 339. <https://doi.org/10.1136/bmj.b2700>
- Muliyati, D., Prastiawan, F., & Mutoharoh, M. (2023). Development of STEM Project-Based Learning Student Worksheet for Physics Learning on Renewable Energy Topic. *Journal of Physics: Conference Series*, 2596(1), 012078. <https://doi.org/10.1088/1742-6596/2596/1/012078>
- Parno, Supriana, E., Yuliati, L., Widarti, A. N., Ali, M., & Azizah, U. (2019). The Influence of STEM-based 7E Learning Cycle on Students Critical and Creative Thinking Skills in Physics. *International Journal of Recent Technology and Engineering*, 8(2), 761-769. <https://doi.org/10.35940/ijrte.B1158.0982S919>
- Parno, Yuliati, L., Nurazizah, S., & Ali, M. (2023). The Effect of STEM Approach in Project Based Learning Model on Student's Problem Solving Skills on Static Fluid

- Topic. *AIP Conference Proceedings*, 2614(1), 050052.  
<https://doi.org/10.1063/5.0125795>
- Pathoni, H., Ashyar, R., Maison, & Huda, N. (2022). Measuring Lecturer'S Perception In Stem Approach Based Contextual Learning Implementation. *Journal of Technology and Science Education*, 12(1), 132-146. <https://doi.org/10.3926/jotse.1297>
- Pebriana, I. N., Rahmayanti, Millen, Supahar, Rahman, & Setiaji. (2024). STEM Based Physics Project Based Learning E-module to Enhance Students' Learning Motivation and Creative Thinking Skill. *AIP Conference Proceedings*, 2622(1), 060003. <https://doi.org/10.1063/5.0181029>
- Sari, S. W. J., Palittin, I. D., & Henukh, A. (2023). Development of Student Worksheets Based on Etno-STEM on Sound Waves. *Kasuari: Physics Education Journal (KPEJ)*, 6(1), 37-45. <https://doi.org/10.37891/kpej.v6i1.345>
- Snyder, C., Hutchins, N. M., Biswas, G., Narasimham, G., Emara, M., & Yett, B. (2022). Instructor Facilitation of STEM+CT Discourse: Engaging, Prompting, and Guiding Students' Computational Modeling in Physics. *Proceedings of International Conference of the Learning Sciences, ICLS*, 631-638. <https://dx.doi.org/10.22318/icls2022.631>
- Suganda, T., Parno, Sunaryono, Yuliati, L., & Latifah, E. (2023). Building Students' Scientific Argumentation Skills Through the Model ADI Integrated STEM Approach and Formative Assessment. *AIP Conference Proceedings*, 2614(1), 050056. <https://doi.org/10.1063/5.0125798>
- Tanjung, B. N. (2020). Human Resources (HR) In Education Management. *Budapest International Research and Critics in Linguistics and Education (BirLE) Journal*, 3(2), 1240-1249. <https://doi.org/10.33258/birle.v3i2.1056>
- Thibaut, L., Ceuppens, S., De Loof, H., De Meester, J., Goovaerts, L., Struyf, A., Boeve-de Pauw, J., Dehaene, W., Deprez, J., De Cock, M., Hellinckx, L., Knipprath, H., Langie, G., Struyven, K., Van de Velde, D., Van Petegem, P., & Depaepe, F. (2018). Integrated STEM Education: A Systematic Review of Instructional Practices in Secondary Education. *European Journal of STEM Education*, 3(1), 1-12. <https://doi.org/10.20897/ejsteme/85525>
- Topsakal, I., Yalçın, S. A., & Çakir, Z. (2022). The Effect of Problem-based STEM Education on the Students' Critical Thinking Tendencies and Their Perceptions for Problem Solving Skills. *Science Education International*, 33(2), 136-145. <https://doi.org/10.33828/sei.v33.i2.1>
- Ulfa, Z., Irwandi, I., Syukri, M., Munawir, A., & Halim, A. (2021). Improving ISLE-based STEM Learning Outcomes for Building the 21st Century Skills and Characters Through a Lesson Study: A Case Study on Torque and Moment of Inertia. *Journal of Physics: Conference Series*, 1882(1), 012153. <https://doi.org/10.1088/1742-6596/1882/1/012153>
- Wibowo, F. C., Priane, W. T., Darman, D. R., Guntara, Y., & Ahmad, N. J. (2022). Dissemination of Virtual Microscopic Simulation (VMS) to Sparking in STEM for Facilitating 21st- Century Skills (21-CS). *Journal of Physics: Conference Series*, 2377(1), 012074. <https://doi.org/10.1088/1742-6596/2377/1/012074>
- Widyasmah, M., Abdurrahman, & Herlina, K. (2020). Implementation of STEM Approach Based on Project-based Learning to Improve Creative Thinking Skills of High School Students in Physics. *Journal of Physics: Conference Series*, 1467(1), 012072. <https://doi.org/10.1088/1742-6596/1467/1/012072>
- Yulianti, D., Sugianto, & Ngafidin, K. M. (2022). Scratch Assistes Physics Learning With a STEM Approach in the Pandemic Era to Develop 21<sup>st</sup> century learning Skills.

- Jurnal Pendidikan IPA Indonesia*, 11(1), 185-194.  
<https://doi.org/10.15294/jpii.v11i1.32607>
- Yulianti, D., Wiyanto, Rusilowati, A., & Nugroho, S. E. (2020). The Development of High School Physics Teaching Material Based on STEM to Facilitate the Development of 21st Century Learning Skills. *Proceedings of the 7th Mathematics, Science, and Computer Science Education International Seminar, MSCEIS 2019*, 1-8.  
<https://doi.org/10.4108/eai.12-10-2019.2296350>
- Yulianti, D, Rusilowati, A., & Nugroho, S. E. (2020). Development of Physics Learning Teaching Materials Based on Science Technology Engineering and Mathematics to Develop 21st Century Learning Skills. *Periódico Tchê Química*, 17(34), 711-717.  
<https://doi.org/10.52571/PTQ.v17.n34.2020.735>
- Yusuf, I., Widyaningsih, S. W., & Purwati, D. (2015). Pengembangan Perangkat Pembelajaran Fisika Modern Berbasis Media Laboratorium Virtual berdasarkan Paradigma Pembelajaran Abad 21 dan Kurikulum 2013. *Pancaran Pendidikan*, 4(2), 189-200. <https://www.researchgate.net/publication/318721780>