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The Urgency of Teaching Future Essential Skills to Mathematics and Science Education Students to Enhance the Quality of Teaching in the Modern Education Era

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Abstract: This research aims to explore the important skills that mathematics and science education students must possess to enhance the quality of teaching in the modern education era. This study uses a qualitative approach with a systematic literature review method. The focus of the study is on annual publication trends, research methods, and skills emphasized in mathematics and science education, from the Scopus database during the 2015-2024 period. A total of 50 papers were analyzed to present ideas, findings, and knowledge literature with an academic focus. This data analysis was conducted using thematic analysis, namely research focused on exploring how essential skills are implemented or integrated in mathematics and science education. The results of the research show that the peak of the research trend on important future skills for mathematics and science students will be in 2023 and will still be ongoing in 2024. The methods most frequently used in the last 15-year research period are quantitative, followed by non-empirical, qualitative, mixed, and research and development. Future skills such as critical thinking, creative thinking, problem solving, collaboration, and communication are very important to teach prospective teachers in improving the quality of teaching. This study also revealed that STEM learning is most widely used to teach future skills. In the future, this research can become a reference or point of reference in preparing the skills that must be taught to prospective teachers today for quality education in the future with the role of professional teachers.

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Introduction

It is now more urgent than ever to teach math and science education students important skills for the future. To future challenges, it is necessary to strengthen skills, content, context in science learning (Berg et al., 2021). This is because we are in an era of rapid and disruptive digital transformation. Technological developments such as artificial intelligence, big data, and the internet of things (IoT) require data analysis skills, critical thinking, and complex problem solving, all of which are rooted in mathematics and science. Without these skills, students risk being left behind in an increasingly digital world of work and society (Li, 2022). Digital competency or literacy is important (Whitney-Smith, 2023). Therefore, equipping them with the skills of the future is not just an option, but an urgent need to ensure they are ready to global challenges and become innovators in fields increasingly influenced by science and technology.

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The concept of critical future skills for today's mathematics and science education students includes the abilities needed to face technological change and global challenges. A key component in science education to face global challenges is scientific literacy skills as student preparation (Vieira & Tenreiro-Vieira, 2016). Other skills include critical thinking, data analysis, programming, and effective collaboration and communication skills in a scientific context. By understanding and mastering these skills, students can become adaptive and innovative problem solvers, able to apply mathematics and science concepts in various complex and dynamic situations. Mastery of these skills also enables them to contribute to the creation of sustainable and competitive solutions in an increasingly digitalized and interconnected world (Amin et al., 2023).

Previous research trends regarding future skills for mathematics and science education students continue to receive attention. Like research: 1) (Sarkar et al., 2016) Education in the 21st century must focus on increasing graduate employability, as has become an important issue in higher education, 2) (Afandi et al., 2019) emphasizes the importance of a 21st century educational framework that requires critical thinking, creativity, collaboration, communication, and digital literacy skills for prospective science teachers, 3) (Lavi et al., 2021), learning and innovation skills, information, media, and technology skills, as well as life and professional skills, are very important in preparing students for the world of work, 4) (Tripon, 2022), Sustainable education demands a change in the way of learning that places more emphasis on improving computational thinking skills. Computing becomes effective in a STEM context that is integrated with the curriculum and computer science (Gilchrist et al., 2021). However, no one has addressed future skills specifically for mathematics and science education students. Therefor, this research aims to explore the important skills that mathematics and science education students must possess to enhance the quality of teaching in the modern education era.

Research Method

This research uses the qualitative approach with systematic literature review (SLR) method. The data analyzed includes the number of annual publications, methods, skills, and implementation of learning in educational contexts. The stages of the SLR method include identification, evaluation, and interpretation of relevant research, followed by designing research questions that are appropriate to the topic being studied (Dinter et al., 2021). Before starting the initial stage, researchers first searched for articles related to future skills in the Scopus database for the period 2015 to 2024. Article searches were carried out using the keywords: "crucial skills for mathematics and science education students," "essential skills for mathematics education students and science," “21st century skills for math and science education students," and “skills for math and science education students.” This step aims to explore the skills needed in the future (Rawboon et al., 2021). The process of identifying the title, abstract, keywords, and content of the article is carried out manually to ensure the relevance of the paper to the research objectives. The sample of papers selected was limited to the context of mathematics and science education.

Specific criteria have been established to determine which documents are eligible for analysis. These inclusion criteria were determined based on the research objectives. As stated by (Dalglish et al., 2020) it is important to apply a "read" approach to obtain documents that meet certain criteria and ensure thoroughness in the analysis of the paper. Therefore, this research sets the following criteria: Papers must be published in reputable international journals, indexed international journals, or accredited national journals. The scope of research covers the fields of science, mathematics, computer science, social sciences, physics, biology,

chemistry, education, and science education. In addition, the journal must be in English and published in a journal or proceedings from January 2015 to August 2024.

Data analysis is a data processing process that aims to identify relevant and useful information. This process involves grouping documents based on their characteristics. Data grouping is carried out to reveal important information and findings from the documents analyzed (Yanti & Anas Thohir, 2024). This data analysis was conducted using thematic analysis, namely research focused on exploring how essential skills are implemented or integrated in mathematics and science education. Then through several steps, including data classification based on the number of annual publications, methods used, skills applied, and implementation of learning in the educational context.

Results and Discussion

The Annual Research Trends Related to Future Skills From 2015 to Mid-2024

Research on future skills is very important to prepare individuals and society to face rapid changes in the world of work due to technological developments, globalization, and social dynamics. By understanding the skills that will be needed in the future, such as digital literacy, critical thinking, creativity, and adaptability, education and training can be tailored to develop these abilities. The development of research related to future skills is shown in Figure 1 as follows:

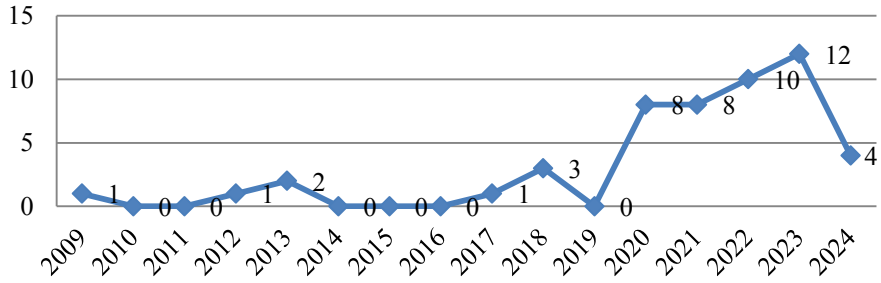

Figure 1. Publications number related to future skills for mathematics and science education students

Figure 1. depicts the annual number of publications related to skills in mathematics and science education from 2009 to 2024. There is a significant increase in the number of publications, especially after 2015 to 2018. However, in 2019, there was a significant decrease, which can be attributed to the impact of the COVID pandemic -19. The pandemic has focused society on the health and safety of themselves and their families, so that attention to developing skills in mathematics and science education has been neglected. As expressed (Idin, 2020) many students have been unable to access high-quality science education since the COVID-19 pandemic occurred. The pandemic created the greatest disruption to education systems in history, affecting nearly 1.6 billion students in more than 190 countries.

The peak of the spike will occur in 2023, with the number of publications reaching 12. This increase in the number of publications reflects the increasing interest and attention towards developing skills in mathematics and science education among academics and researchers. In the last five years, the skills development achieved through content has been transformed through the integration of TPACK (Bahtiar et al., 2023).

The Diversity of Research Methods Related to Future Skills

The variety of research methods related to future skills shows the diversity used by researchers to investigate and understand skills that can be useful in the future. Some commonly used methods are shown in Figure 2.

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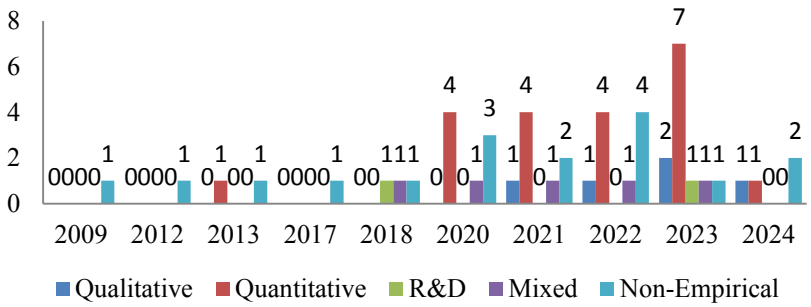

Figure 2. The research methods diversity related to future skills for students in mathematics and science

Figure 2 illustrates various research methods used in analysis results studies, including qualitative, quantitative, R&D, mixed, and non-empirical methods. The graph shows that quantitative research is the most popular and frequently chosen method in efforts to measure the effectiveness of skills in education. Meanwhile, non-empirical approaches are also quite widely used, especially in the form of literature or theory studies. This diversity of research methods helps educational researchers and practitioners understand the effectiveness of various learning models (Yanti & Anas Thohir, 2024). The advantage of quantitative methods lies in their ability to generalize research results to a wider population through the use of representative samples.

Based on an analysis of papers published between 2015 and mid-2024, quantitative methods show the highest frequency compared to other methods such as R&D, qualitative, mixed-method, or literature reviews. Each research method has its own advantages and disadvantages. Quantitative research has the advantage of focusing on descriptive empirical statements about reality, not about what should happen (Taherdoost, 2022).

The Diversity of Skills that Future Students in Mathematics and Science

The rapid progress of science and technology increasingly highlights the challenge of the need for in-depth science education and the important role of teachers in this process (Taştan et al., 2018). The educational challenge focuses on the main soft skills of competency known as the 4Cs, namely creative, critical, collaboration, and communication. 4C is needed to demand the world of work in the future (Thornhill-Miller et al., 2023). Therefore, there is a lot of published research examining future skills in mathematics and science education. Figure 3 shows the diversity of skills that are studied in the papers for the 2015-2024 period.

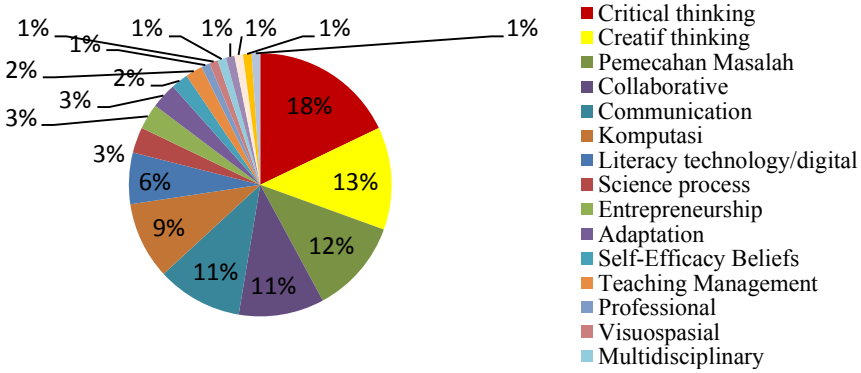

Figure 3. Skills future in mathematics and science

Figure 3 displays the key skills emphasized in mathematics and science education and the teaching methods used to develop those skills. Some of the most discussed skills include critical thinking (18%), creative thinking (13%), and problem solving (12%). Apart from these skills, other skills such as collaborative and communication skills, each at 11%. The rest discuss other skills such as computing skills, digital literacy, science process skills, entrepreneurship, adaptation, self-efficacy, teaching management, professional, visuospatial, multidisciplinary, time discipline, building a network, scientific literacy, and data literacy.

Education no longer focuses on teaching but on encouraging critical thinking (Welter et al., 2023). Critical thinking skills are the most discussed skills. Critical thinking skills are needed by students in facing an ever-changing world (Scott, 2023). Through critical thinking, students can understand complex concepts, make decisions based on evidence, and develop a deeper understanding of nature. Critical thinking skills can be raised through the right learning approach (Fuad et al., 2017). Creative thinking is the second skill that is widely discussed. Creative thinking in science learning is the key to generating new ideas, innovation, and effective problem solving. In fact, creative, and critical thinking skills can often be used interchangeably (Yazar Soyadı, 2015). After creative thinking skills, the next important skill for the future is problem solving skills. These skills help students share ideas, motivate others, and uphold integrity (Iskandar et al., 2023). The higher the problem-solving abilities a student has, the better his academic achievement will be (Suratno et al., 2020). So, problem-solving skills need to be developed through computing with robotics in technology workshops (Budiyanto et al., 2021).

Meanwhile, skills such as: computing skills, digital literacy, science process skills, entrepreneurship, adaptation, self-efficacy, teaching management, professional, visuospatial, multidisciplinary, time discipline, building a network, scientific literacy, and data literacy are less widely discussed. Skills such as reading, writing, and arithmetic, as well as mastery of content, are often considered more important basic skills than the more specialized skills mentioned. Additionally, skills such as self-efficacy, multidisciplinarity, and building a network are more complex skills, and sometimes more difficult to define or measure. As mentioned (Jardim, 2021) research needs to describe and systematize skills considering the current phenomenon of globalization and transformation. This may make researchers less interested in discussing it.

Learning Methods Used to Teach Future Skills in Mathematics and Science Students

The learning method used to teach future skills in mathematics and science focuses on the future skills presented in Figure 3. The following learning methods that can be used to teach future skills for mathematics and science education students are presented in Table 1.

Table 1. Learning Methods used to teach Future Skills in Mathematics and Science Students

No	Learning Method	Future Skills
1	STEM	Collaborative, critical thinking, creative thinking, problem solving, computation, digital literacy, communication, profesional, teaching management, time discipline, problem solving, adaptation, build a network, data literacy, scientific literacy.
2	Project Based Learning (PjBL)	Collaborative, critical thinking, creative thinking, problem solving, communication, adaptation.
3	Problem Based Learning (PBL)	Critical thinking, problem solving, self-efficacy beliefs.
4	Problem Posing Models	Collaborative, creative thinking,

		communication
5	Problem Based Distance Learning (PBDL)	Critical thinking
6	Model Scaffold	Science process skill
7	Simulation-based mathematics	Entrepreneurship
8	Grup Discussion	Multidisiplinary (Social, Personal, Methodological)
9	Learning based aplication AR	Videospasial

The STEM (Science, Technology, Engineering, and Mathematics) method can be used to teach various important skills such as collaboration, critical thinking, and creative thinking by encouraging students to work in teams to solve real-world problems (Suratno et al., 2020); (Borg Preca et al., 2023); (Lubna et al., 2023); (Eshaq, 2024) (Subali et al., 2023); (Peters-burton & Stehle, 2019); (Hoon et al., 2022); (Abina et al., 2024); (Blotnicky et al., 2018). Dilanjutkan oleh (Yıldız et al., 2024) that education is suitable for using STEM. This STEM method teaches the most future skills. In the future, teachers teach STEM as professional development (Kang, 2019). Through a problem solving approach, students learn to apply computational thinking, data literacy, and digital literacy to solve complex challenges. 8 Despite this, STEM continues to grow (Gao et al., 2020). STEM education is developed to improve students' knowledge and skills (Baran et al., 2016). STEM also trains scientific literacy, enabling students to understand and use data effectively. Additionally, communication, adaptation, and networking skills are developed when students share their ideas and results. Time discipline and teaching management are also part of the STEM learning process, preparing students for a professional world that requires critical thinking, collaborative, and organized skills. The application of STEM in science teaching has a significant impact on the development of 21st century skills (Asrizal et al., 2023); (Nasri et al., 2020).

Apart from that, the second most widely discussed project-based learning (PjBL) method is to teach future skills such as collaborative, critical thinking, creative thinking, problem solving, communication, and adaptation (Jannah et al., 2023); (Zulyusri et al., 2023); (Serin, 2019); (Päivi et al., 2017). In PjBL, students learn by working on real projects that are relevant to the world around them. This process requires them to work collaboratively in teams, enabling the development of strong communication skills and effective collaboration. PjBL also encourages critical and creative thinking because students must analyze information, formulate new ideas, and design innovative solutions to solve the challenges they face. Problem solving is the main focus in this method, where students face real-world problems that do not have a single answer, forcing them to think independently and work together to find solutions.

Other methods, such as problem-based learning (PBL), problem-posing, problem-based distance learning, scaffold models, simulation-based mathematics, group discussions, and AR application-based learning, are also alternative methods that can be used to teach future skills. However, each of these methods has a unique approach and different advantages in teaching future skills. Problem-based learning (PBL), for example, focuses on solving real problems that involve critical thinking and problem solving (Lee et al., 2023), similar to problem-posing, which emphasizes students' ability to formulate their own questions and challenges, encouraging creativity and analysis. Problem-based distance learning introduces elements of distance learning, which foster adaptation and digital literacy skills that are increasingly important in a globally connected world. In line with the concept of collaborative constructivism, learning that involves discussion and dialogue is able to

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empower students' critical and creative thinking, and improve their abilities (Supena et al., 2021). Finally, what is no less important in learning is providing opportunities for students to carry out experiments. Experimentation will better nurture their curiosity (Wartono et al., 2018).

Furthermore, the scaffold model provides students with gradual support, which is slowly released as they progress, helping to develop independence in critical thinking and problem solving. Simulation based mathematics allows students to learn through practical simulations, which not only improve conceptual understanding but also collaboration and communication skills through team-based scenarios. Group discussions emphasize collaborative discussions that strengthen interpersonal communication skills and collective critical thinking abilities, while learning based applications AR (Augmented Reality) bring a new dimension to learning, provide interactive visual experiences, and increase student involvement and creativity in understanding complex material. Although each method is different, they all focus on developing future skills such as collaboration, adaptation, problem solving, science process skills, entrepreneurship, multidisciplinary (Social, Personal, Methodological), video-spatial which are relevant to the world of work and modern challenges (Ulger, 2018); (Martinez, 2022); (Del Cerro Velázquez & Méndez, 2021).

The results of this study have significant conceptual implications, namely emphasizing the importance of integrating future essential skills in mathematics and science education as an adaptive step to the demands of the modern era (Sitopu et al., 2024). This concept illustrates that teaching in these fields should not only focus on conceptual knowledge but should also include the development of 21st-century skills such as critical thinking, collaboration, communication, and digital literacy. Practically, the implication is the need for reform of the mathematics and science education curriculum to ensure that prospective educators are equipped with innovative learning approaches that are relevant to the needs of the times. This includes teacher training, development of technology-based teaching materials, and learning evaluations that assess the ability to apply these skills. Thus, the results of this study provide strategic guidance for educational policy makers and academic institutions to improve the quality of teaching in order to support a generation of competent educators in the modern era.

Conclusion

This review highlights the peak of the research trend on important future skills for mathematics and science students will be in 2023 and will still be ongoing in 2024. The methods most frequently used in the last 15-year research period are quantitative, followed by non-empirical, qualitative, mixed, and research and development. Future skills such as critical thinking, creative thinking, problem solving, collaboration, and communication are very important to teach prospective teachers in improving the quality of teaching. This study also revealed that STEM learning is most widely used to teach future skills. In the future, this research can become a reference or point of reference in preparing the skills that must be taught to prospective teachers today for quality education in the future with the role of professional teachers.

Recommendation

Advice to lecturers is to integrate future skills, such as critical thinking, creativity, and digital literacy, into the curriculum through interdisciplinary approaches, technology-based learning, and evaluations that assess students' practical abilities. Policymakers need to support this with education policies that prioritize 21st-century skills, provide technology infrastructure, build

partnerships with the industry sector, and monitor policy implementation. Researchers are expected to develop innovative learning models with the aim of teaching the effectiveness of future skills and conduct cross-cultural studies to identify globally relevant best practices. This step aims to improve the quality of mathematics and science education to suit the needs of the modern era.

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References

Abina, A., Temeljotov Salaj, A., Cestnik, B., Karalič, A., Ogrinc, M., Kovačič Lukman, R., & Zidanšek, A. (2024). Challenging 21st-Century Competencies for STEM Students: Companies' Vision in Slovenia and Norway in the Light of Global Initiatives for Competencies Development. *Sustainability (Switzerland)*, *16*(3). https://doi.org/10.3390/su16031295

Afandi, Sajidan, Akhyar, M., & Suryani, N. (2019). Development Frameworks of the Indonesian Partnership 21 st - Century Skills Standards for Prospective Science Teachers: a Delphi Study. *Jurnal Pendidikan IPA Indonesia*, *8*(1), 89–100. https://doi.org/10.15294/jpii.v8i1.11647

Amin, A. M., Adiansyah, R., & Hujjatusnaini, N. (2023). The Contribution of Communication and Digital Literacy Skills to Critical Thinking. *Jurnal Pendidikan Sains Indonesia*, *11*(3), 697–712. https://doi.org/10.24815/jpsi.v11i3.30838

Asrizal, Usmeldi, & Azriyanti, R. (2023). Meta-Analysis of the Influence of the STEM-Integrated Learning Model on Science Learning on 21st Century Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 339–347. https://doi.org/10.29303/jppipa.v9i8.3094

Bahtiar, B., Yusuf, Y., Doyan, A., & Ibrahim, I. (2023). Trend of Technology Pedagogical Content Knowledge (TPACK) Research in 2012-2022: Contribution to Science Learning of 21st Century. *Jurnal Penelitian Pendidikan IPA*, *9*(5), 39–47. https://doi.org/10.29303/jppipa.v9i5.3685

Baran, E., Canbazoglu Bilici, S., & Mesutoglu, C. (2016). Moving STEM Beyond Schools: Students' Perceptions About an Out-of-School STEM Education Program. *International Journal of Education in Mathematics, Science and Technology*, *4*(1), 9. https://doi.org/10.18404/ijemst.71338

Berg, T. B., Achiam, M., Poulsen, K. M., Sanderhoff, L. B., & Tøttrup, A. P. (2021). The Role and Value of Out-of-School Environments in Science Education for 21st Century Skills. *Frontiers in Education*, *6*(May), 1–8. https://doi.org/10.3389/feduc.2021.674541

Blotnicky, K. A., Franz-Odendaal, T., French, F., & Joy, P. (2018). A study of the Correlation Between STEM Career Knowledge, Mathematics Self-Efficacy, Career Interests, and Career Activities on the Likelihood of Pursuing a STEM Career Among Middle School Students. *International Journal of STEM Education*, *5*(1).

Borg Preca, C., Baldacchino, L., Briguglio, M., & Mangion, M. (2023). Are STEM Students Creative Thinkers? *Journal of Intelligence*, *11*(6), 1–15. https://doi.org/10.3390/jintelligence11060106

Budiyanto, C. W., Fenyvesi, K., Lathifah, A., & Yuana, R. A. (2021). Computational Thinking Development: Benefiting from Educational Robotics in STEM Teaching. *European Journal of Educational Research*, *10*(3), 1199–1213.

https://doi.org/10.12973/eu-jer.11.4.1997

Dalglish, S. L., Khalid, H., & McMahon, S. A. (2020). Document Analysis in Health Policy Research: the Read Approach. *Health Policy and Planning*, *35*(10), 1424–1431. https://doi.org/10.1093/heapol/czaa064

Del Cerro Velázquez, F., & Méndez, G. M. (2021). Application in Augmented Reality for Learning Mathematical Functions: a Study for the Development of Spatial Intelligence in Secondary Education Students. *Mathematics*, *9*(4), 1–19. https://doi.org/10.3390/math9040369

Dinter, R. van, Tekinerdogan, B., & Catal, C. (2021). Automation of systematic literature reviews: A systematic literature review. *Information and Software Technology*, *136*(October 2020), 106589. https://doi.org/10.1016/j.infsof.2021.106589

Eshaq, H. A. (2024). The Effect of Using STEM Education on Students' Mathematics Achievement. *Journal of Pedagogical Research*, *8*(1), 75–82. https://doi.org/10.33902/JPR.202423476

Fuad, N. M., Zubaidah, S., Mahanal, S., & Suarsini, E. (2017). Improving Junior High Schools' Critical Thinking Skills Based on Test Three Different Models of Learning. *International Journal of Instruction*, *10*(1), 101–116. https://doi.org/10.12973/iji.2017.1017a

Gao, X., Li, P., Shen, J., & Sun, H. (2020). Reviewing Assessment of Student Learning in Interdisciplinary STEM Education. *International Journal of STEM Education*, *7*(1). https://doi.org/10.1186/s40594-020-00225-4

Gilchrist, P. O., Alexander, A. B., Green, A. J., Sanders, F. E., Hooker, A. Q., & Reif, D. M. (2021). Development of a Pandemic Awareness STEM Outreach Curriculum: Utilizing a Computational Thinking Taxonomy Framework. *Education Sciences*, *11*(3). https://doi.org/10.3390/educsci11030109

Hoon, T. S., a/p Narayanan, G., Aris, S. R. B. S., Ibrahim, N., & Isa, B. Bin. (2022). Science, Technology, Engineering, and Mathematics (STEM) Education in University: Pre-service Teachers' Perceptions. *Asian Journal of University Education*, *18*(3), 637–648. https://doi.org/10.24191/ajue.v18i3.18951

Idin, S. (2020). New Trends in Science Education within the 21st Century Skills Perspective. *Education Research Highlights in Mathematics, Science and Technology*, 150–159.

Iskandar, R., Setiawan, R., Maksum, A., Nisphia, J., & Amelia, W. (2023). Leadership Literacy in the Digital Era : A Study of Teacher and Student Understanding. *Jurnal Kependidikan: Jurnal Hasil Penelitian Dan Kajian Kepustakaan Di Bidang Pendidikan, Pengajaran Dan Pembelajaran*, *9*(3), 967. https://doi.org/10.33394/jk.v9i3.8674

Jannah, D. R., Sahrina, A., & Utomo, D. H. (2023). The Effect of STEM Integrated Project Based Learning Model on Students' Critical Thinking Ability in Geography Subjects. *Jurnal Pendidikan Dan Pembelajaran*, *30*(01), 54–61.

Jardim, J. (2021). Entrepreneurial skills to be successful in the global and digital world: Proposal for a frame of reference for entrepreneurial education. *Education Sciences*, *11*(7). https://doi.org/10.3390/educsci11070356

Kang, N. H. (2019). A Review of the Effect of Integrated STEM or STEAM (Science, Technology, Engineering, Arts, and Mathematics) Education in South Korea. *Asia-Pacific Science Education*, *5*(1), 1–22. https://doi.org/10.1186/s41029-019-0034-y

Lavi, R., Tal, M., & Dori, Y. J. (2021). Perceptions of STEM Alumni and Students on Developing 21st Century Skills Through Methods of Teaching and Learning. *Studies in Educational Evaluation*, *70*, 101002. https://doi.org/10.1016/j.stueduc.2021.101002

Lee, M., Larkin, C. J. K., & Hoekstra, S. (2023). Impacts of Problem-Based Instruction on Students' Beliefs about Physics and Learning Physics. *Education Sciences*, *13*(3).

Li, L. (2022). Reskilling and Upskilling the Future-ready Workforce for Industry 4.0 and Beyond. *Information Systems Frontiers*, *0123456789*. https://doi.org/10.1007/s10796-022-10308-y

Lubna, Suhirman, & Prayogi, S. (2023). Evaluation of STEM Students' Critical Thinking in Terms of Cognitive Ctyle Through Problem-Based Distance Learning. *Journal of Education and E-Learning Research*, *10*(3), 557–568.

Martinez, C. (2022). Developing 21st Century Teaching Skills: a Case Study of Teaching and Learning Through Project-Based Curriculum. *Cogent Education*, *9*(1). https://doi.org/10.1080/2331186X.2021.2024936

Nasri, N. M., Nasri, N., & Talib, M. A. A. (2020). Towards Developing Malaysia STEM Teacher Standard: Early Framework. *Universal Journal of Educational Research*, *8*(7), 3077–3084. https://doi.org/10.13189/ujer.2020.080736

Päivi, H., Sanna, J., Kati, M.-S., Arto, A., Piia, N., & Teemu, V. (2017). This is an Electronic Reprint of The Original Article . This Reprint may Differ from The Original in Pagination and Typographic Detail. *International Journal of Special Education*, *30*(2), 70–84.

Peters-burton, E. E., & Stehle, S. M. (2019). Developing Student 21 st Century Skills in Selected Exemplary Inclusive STEM High Schools. *International Journal of STEM Education*, *1*, 1–15.

Rawboon, K., Yamazaki, A. K., Klomklieng, W., & Thanomsub, W. (2021). Future Competencies for Three Demanding Careers of Industry 4.0: Robotics engineers, Data Scientists, and Food Designers. *The Journal of Competency-Based Education*, *6*(2), 1–12. https://doi.org/10.1002/cbe2.1253

Sarkar, M., Overton, T., Thompson, C., & Rayner, G. (2016). Graduate Employability: Views of Recent Science Graduates and Employers. *International Journal of Innovation in Science and Mathematics Education*, *24*(3), 31–48.

Scott, C. L. (2023). What Kind of Pedagogies for the 21st Century? *International Journal for Business Education*, *164*(1), 1–21.

Serin, H. (2019). Project Based Learning in Mathematics Context. *International Journal of Social Sciences & Educational Studies*, *5*(3), 232–236. https://doi.org/10.23918/ijsses.v5i3p232

Sitopu, J. W., Khairani, M., Roza, M., Judijanto, L., & Aslan. (2024). the Importance of Integrating Mathematical Literacy in the Primary Education Curriculum : a Literature Review. *Journal of Information Systems and Management (JISMA)*, *2*(1), 121–134.

Subali, B., Ellianawati, Faizah, Z., & Sidiq, M. (2023). Indonesian National Assessment Support: Can RE-STEM Android app Improve Students' Scientific Literacy Skills? *International Journal of Evaluation and Research in Education*, *12*(3), 1399–1407.

Supena, I., Darmuki, A., & Hariyadi, A. (2021). The Influence of 4C (Constructive, Critical, Creativity, Collaborative) Learning Model on Students' Learning Outcomes. *International Journal of Instruction*, *14*(3), 873–892. https://doi.org/10.29333/iji.2021.14351a

Suratno, S., Wahono, B., Chang, C. Y., Retnowati, A., & Yushardi, Y. (2020). Exploring a Direct Relationship between Students' Problem-Solving Abilities and Academic Achievement: a STEM Education at a Coffee Plantation Area. *Journal of Turkish Science Education*, *17*(2), 211–224. https://doi.org/10.36681/tused.2020.22

Taherdoost, H. (2022). What are Different Research Approaches? Comprehensive Review of

Qualitative, Quantitative, and Mixed Method Research, Their Applications, Types, and Limitations. *Journal of Management Science & Engineering Research*, *5*(1), 53–63. https://doi.org/10.30564/jmser.v5i1.4538

Taştan, S. B., Davoudi, S. M. M., Masalimova, A. R., Bersanov, A. S., Kurbanov, R. A., Boiarchuk, A. V., & Pavlushin, A. A. (2018). The Impacts of Teacher's Efficacy and Motivation on Student's Academic Achievement in Science Education Among Eecondary and High School Students. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(6), 2353–2366. https://doi.org/10.29333/ejmste/89579

Thornhill-Miller, B., Camarda, A., Mercier, M., Burkhardt, J. M., Morisseau, T., Bourgeois-Bougrine, S., Vinchon, F., El Hayek, S., 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*(3). https://doi.org/10.3390/jintelligence11030054

Tripon, C. (2022). Supporting Future Teachers to Promote Computational Thinking Skills in Teaching STEM—A Case Study. *Sustainability (Switzerland)*, *14*(19). https://doi.org/10.3390/su141912663

Ulger, K. (2018). The Effect of Problem-Based Bearning on the Creative Thinking and Critical Thinking Disposition of Students in Visual Arts Education. *Interdisciplinary Journal of Problem-Based Learning*, *12*(1), 3–6.

Vieira, R. M., & Tenreiro-Vieira, C. (2016). Fostering Scientific Literacy and Critical Thinking in Elementary Science Education. *International Journal of Science and Mathematics Education*, *14*(4), 659–680. https://doi.org/10.1007/s10763-014-9605-2

Wartono, W., Hudha, M. N., & Batlolona, J. R. (2018). How are the Physics Critical Thinking Skills of the Students Taught by Using Inquiry-Discovery Through Empirical and Theorethical Overview? *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(2), 691–697. https://doi.org/10.12973/ejmste/80632

Welter, V. D. E., Emmerichs-Knapp, L., & Krell, M. (2023). Are We on the Way to Successfully Educating Future Citizens?—A Spotlight on Critical Thinking Skills and Beliefs about the Nature of Science among Pre-Service Biology Teachers in Germany. *Behavioral Sciences*, *13*(3). https://doi.org/10.3390/bs13030279

Whitney-Smith, R. M. (2023). The Emergence of Computational Thinking in National Mathematics Curricula: An Australian Example. *Journal of Pedagogical Research*, *7*(2), 41–55. https://doi.org/10.33902/JPR.202318520

Yanti, F. A., & Anas Thohir, M. (2024). Higher Order Thinking Skills in Science Learning: a Systematic Review From 2014-2023. *International Journal of Evaluation and Research in Education*, *13*(4), 2419–2427. https://doi.org/10.11591/ijere.v13i4.28082

Yazar Soyadı, B. B. (2015). Creative and Critical Thinking Skills in Problem-based Learning Environments. *Journal of Gifted Education and Creativity*, *2*(2), 71–71. https://doi.org/10.18200/jgedc.2015214253

Yıldız, G., Yıldırım, A., Akça, B. A., & Kök, A. (2024). International Review of Research in Open and Distributed Learning Research Trends in Mobile Learning Research Trends in Mobile Learning Abstract. *International Review of Research in Open and Distributed Learning*, *21*(03), 174–196.

Zulyusri, Z., Elfira, I., Lufri, L., & Santosa, T. A. (2023). Literature Study: Utilization of the PjBL Model in Science Education to Improve Creativity and Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 133–143. https://doi.org/10.29303/jppipa.v9i1.2555