Vol 13(1) (2024): 10-27
DOI: http://dx.doi.org/10.24235/sc.educatia.v13i1.18062

SCIENTIAE EDUCATIA: JURNAL PENDIDIKAN SAINS

https://www.syekhnurjati.ac.id/jurnal/index.php/sceducatia

STEM Approach to 4C Skills in Elementary School Students: A Systematic Literature Review

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article info

Article history:
Received: 30 June 2024
Received in revised form: 22 July 2024
Accepted: 11 September 2024
Available online: 20 September 2024

Keywords:
Collaboration
Communication
Creative Product
Critical Thinking
STEM

abstract

The STEM approach is increasingly significant in elementary school learning because it can develop 4C skills such as critical thinking, creativity, collaboration, and communication. This study aims to identify the STEM approach to developing 4C skills in elementary school students through a Systematic Literature Review (SLR) using the PRISMA method with a time period of 2014-2024. This study reviews articles and journals published in the last ten years, focusing on methods and results relevant to the STEM approach in elementary schools. The analysis shows that the STEM approach to improving 4C skills in elementary schools can be grouped into three product categories: simple technology, simple technology from used goods, and prototypes. The most common category is simple technology, which promotes critical thinking, creativity, communication, and collaboration, all of which are important in the STEM approach. The findings show that simple technologies such as raft boats, animal recycling concept dioramas, and electrical conduction from plastic bottles significantly increase student engagement and motivation. The study concluded that the STEM approach can improve students' 4C skills (critical thinking, creativity, communication, and collaboration), and it is important to use products that can encourage students to integrate 4C skills with STEM, resulting in creative and innovative products. Schools and teachers must implement these technology-based tools and methods to maximize students' learning potential.

1. Introduction

In the era of the Industrial Revolution 4.0, changes are happening and happening very quickly. New things that were previously unimaginable are now emerging thanks to the rapid development of technology. This change must, of course, be felt in the world of education so that students can adjust to the changes they will face after graduation. As the pioneers and vanguard of education, teachers must be able to adapt to these dynamics. The crucial use of technology requires teachers who are proficient in utilizing technology to support the learning process. In addition to mastering technology, teachers must also understand the challenges and relevant policies in the Industrial Revolution 4.0 era (Kamilla et al., 2022). According to Fuaddudin (2020), education is expected to develop life skills in students, which is the expertise teachers possess (Muslim et al., 2023).

Policy changes in the current industry 4.0 era, according to Aryana (2019), education implements 21st-century learning that focuses on 21st-century skills known as 4C skills: critical thinking, collaboration, creativity, and communication (Miftach, 2018). These four skills are skills that students must master to compete and adapt in the 21st century (Meilani et al., 2020). According to Erdem et al. (2019), 4C skills are needed to learn, innovate, and face and adapt to challenges in this era. Meanwhile, Aryana (2019) also emphasizes that 4C skills are soft skills whose application is more useful in everyday life than hard skills. So, the learning process must be designed to center on the development of 4C skills, with an approach that places students at the center of teaching and learning activities, not just teacher-centered (Ilma et al., 2023).

The 21st century requires analytical, problem-solving, critical thinking, and creative skills. These skills are essential to help students connect concepts and learning materials so that they can face and solve problems that arise in the classroom (Beers, 2011). One effective way to develop these skills is to design innovative learning activities involving active student engagement. One of them is the STEM approach. Science, technology, engineering, and math are being promoted as learning methods to acquire skills relevant to current needs. The STEM approach is a learning method that emphasizes learning in the context of problem-solving (Thovawira et al., 2021).

STEM is one of the most relevant approaches for developing 21st-century skills. Based on research by Arifin et al. (2021), Science, Technology, Engineering and Mathematics (STEM) was initiated by the National Science Foundation of the United States in the 1990s (Ilma et al., 2023). In addition, Saputri and Herman (2022) explained that STEM is an innovative learning approach that integrates science, technology, engineering, and mathematics in the learning process, focusing on solving real-world problems (Khalishah & Mahmudah, 2022). This means that through the STEM approach, students memorize concepts and understand the relationship between scientific concepts and their applications in everyday life. STEM allows students to think critically, creatively, and innovatively during learning (Thovawira et al., 2021). Furthermore, Fiterani et al. (2021) stated that the application of the STEM approach can motivate students to design, develop, and apply technology and improve cognitive, emotional, and application skills of knowledge (Rusminati & Juniarso, 2023).

Based on the definition that has been presented, it can be concluded that STEM is a learning approach that integrates observation and experimentation (science) with the utilization of available facilities (technology), as well as the application of scientific techniques mastered (engineering) to solve problems systematically (mathematics) (Astuti et al., 2021). The STEM approach, which is also applied in developed countries such as the United States, has significantly impacted student development, making them more active, innovative, and creative. In addition, this approach contributes to students' productivity and academic achievement at school (Kocakaya & Ensari, 2018; Oktapiani & Hamdu, 2020; Permanasari et al., 2016; Wang & Chiang, 2020).

The STEM approach allows students to learn academic concepts by integrating four disciplines. By combining these fields, students are expected to achieve 4C skills. Applying the STEM approach at the primary school level is still not optimal, and some students do not fully understand this concept. Research results from Hamdu (2016) show a lack of sources related to theory and preparation, examples of learning tools, and teachers' understanding of the 4C skills expected later. Technology development requires 4C skills to introduce STEM learning from various references and books (Lestari, Sarwi, & Sri, 2018). The STEM approach is still very early for elementary school teachers who often have limited or no knowledge of STEM. Recently in practice, STEM has been widely applied in developed countries such as the United States and Finland to be productive (Musnidar, 2018). However, in Indonesia, the STEM concept is applied through an integrative thematic learning model with a scientific approach. According to (Nurlenasari et al., 2019) in Indonesia, the STEM approach is very suitable for implementation in elementary schools because it is in line with the 2013 curriculum and Merdeka Curriculum; the 13 curriculum integrates several subjects and applies them in the context of real life (Yusri, 2020).

The characteristics of the STEM approach are very suitable for implementation at the primary school level. This approach allows students to develop practical application skills and critical thinking, enhancing their curiosity and empathy. Through STEM-based learning, students become more concerned about each other and feel more responsible for the natural and social environment (Kusuma et al., 2022). The STEM approach encourages students to develop critical thinking, problem-solving, and practical data management skills. Therefore, it is very important to utilize STEM as a digital learning method, especially in developing 21st century skills relevant to current demands (Fiorintina et al., 2023). The STEM approach to the 4C skills plays an important role, and the STEM approach is recognized as a practical approach to be applied to the current implementation of integrating the STEM approach.

From the results of previous research related to the STEM approach, it can be concluded that the STEM approach needs to be implemented in learning, especially in elementary schools, as early education in order to achieve 4C skills in 21st-century learning. Based on these problems, which is the novelty of this research in finding and collecting several literature studies relevant to the research topic that researchers take to discuss the application of the STEM approach to 4C skills in elementary school students, namely collecting the latest studies and there are products resulting from the implementation of STEM to make it easier and also useful for further research.

2. Method

The method used in this research is a Systematic Literature Review (SLR). According to Brereton et al. (2007), a Systematic Literature Review is a literature method that identifies, assesses, and interprets findings on a research topic to answer research questions (Wakhid et al., 2023). The article search used PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) in this study. Moher et al. (2009) explained that the PRISMA method consists of 4 stages: data search, data screening, data eligibility, and looking for similarities and differences in the data obtained (Ramdhani, 2021; Ubaidillah et al., 2023). Thus, the SLR study includes research questions (RQ), an article search strategy, article selection criteria, an article selection process, data collection, and data analysis of various articles obtained. This SLR recommends from several international literature that STEM can improve 4C skills in elementary school students. The SLR method can systematically review and identify journals, with each process following predetermined steps. SLR can facilitate research in finding relevant study literature to facilitate researchers and emphasize taking research topics because there are supporting literature studies.

Research Question

The research questions (RQ) of the Systematic Literature Review (SLR), namely:

1. How does STEM approach 4C skills in elementary school?
2. How is the product produced using the STEM approach to 4C skills in elementary school?

Article search strategy

In search of articles in national and international journals from the ERIC database, Google Scholar, Mendeley, and Springer between 2014-2024, The articles selected matched the research questions. The keywords to search for articles included "STEM / STEM approach," "STEM approach in elementary school," and "STEM approach to students' 4C skills in elementary school". Based on these keywords, the articles obtained from the database were related to the STEM approach to 4C skills in elementary schools.

Article Search Criteria

To obtain articles that are by the SLR study material, the following selection criteria apply in this study:

a. Inclusion Criteria
   1. Articles by year of publication published in 2014-2024
   2. English article
   3. Articles match keywords
   4. Selected articles are articles and journals
   5. Articles based on those that discuss the STEM approach in primary schools
   6. The article produces the product
b. Exclusion Criteria
   1. Articles by year of publication that were published before 2014
   2. Non-English articles
   3. The article does not match the keywords
   4. Selected articles are not articles and journals
   5. Unsubstantiated articles that do not address STEM approaches in primary schools
   6. The article does not produce a product

Article Search Process

The flow of the literature search process was adapted from the PRISMA article search image (Taufik et al., 2019). This study used articles from the ERIC database, Google Scholar, Mendeley, and Springer, with 182 articles. The articles were filtered using predetermined criteria: year of publication, English language articles, keywords, articles, and journals. Discussed the STEM approach in elementary school and the results of products tailored to RQ. The screening results of 182 articles became 21, for a picture of the literature search process can be seen in Figure 1.

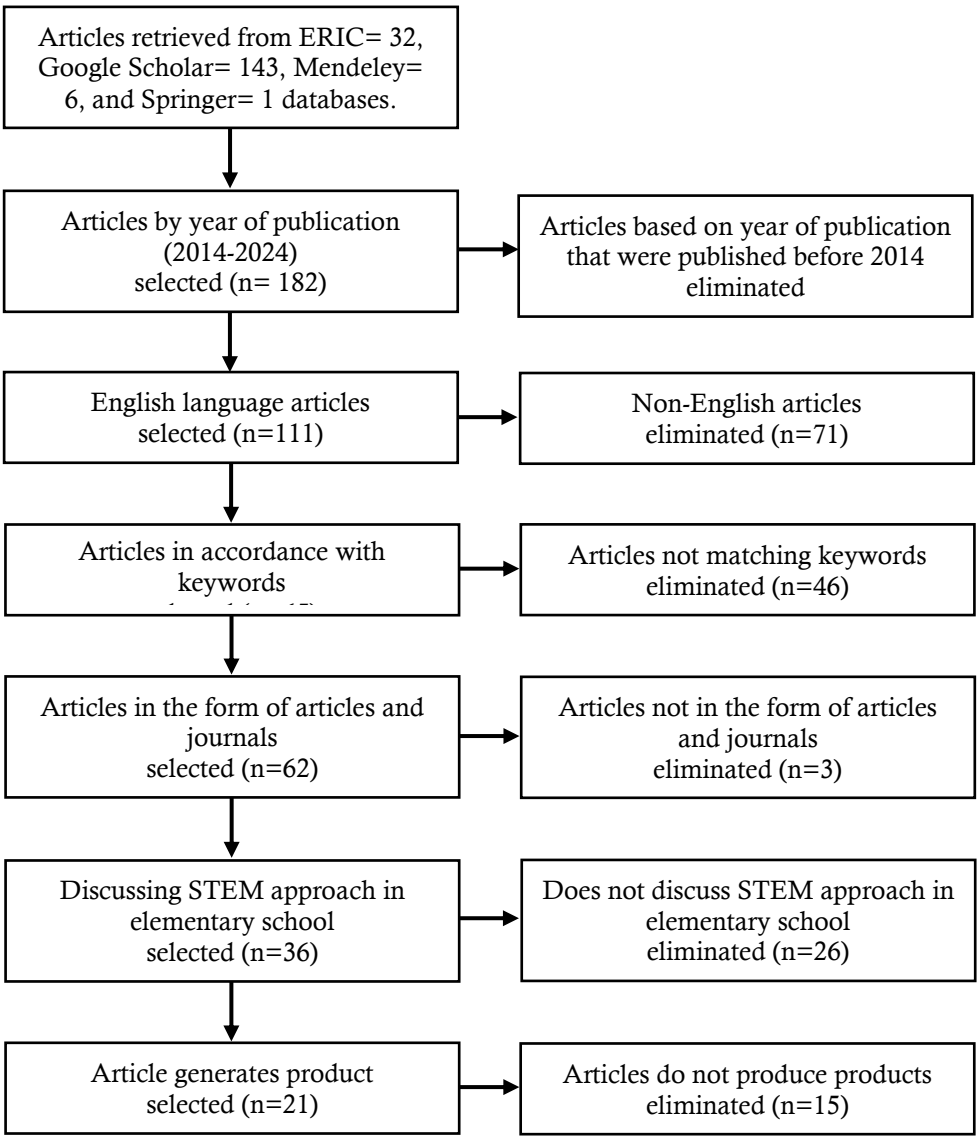


Figure 1. Literature search process flow

Figure 1 explains that a total of 182 articles were retrieved from several databases: ERIC (32), Google Scholar (143), Mendeley (6), and Springer (1), published between 2014 and 2024. 111 English articles were selected, while 71 non-English articles were eliminated. Next, 65 articles relevant to the keywords were selected, and 46 inappropriate articles were eliminated. Of the 65 articles, 62 articles and journals were selected, and 3 articles that were not in the form of articles or journals were eliminated. Of the 62 articles, 36 articles that discussed STEM approaches in primary schools were selected, while 26 irrelevant articles were eliminated. Finally, 21 articles that produced products were selected, while 15 articles that did not produce products were eliminated.

Data Collection and Data Analysis

From the search results of articles obtained from the ERIC database, Google Scholar, Mendeley, and Springer. The data was collected in a Microsoft Excel 2010 spreadsheet. 36 articles discussed the STEM approach in elementary schools. Analyzed based on title, year, author, publisher, research objectives, research methods, dependent and independent variables, application of the STEM approach to students' 4C skills, and product results. Then, the final result is 21 articles analyzed, based on journal name, source, quartile, and number of articles, which can be seen in Table 1.

Table 1. Article classification

Journal Name	Source	Quartiles	Number of Articles
International Journal of Elementary Education	Google Scholar, SINTA, SJR, Scopus	Q3	496
Journal of Professional Teacher Education	Google Scholar	Q4	10
Journal of Scholarship: Journal of Mathematics Education	Google Scholar, SINTA	Q4	1.213
AKSIOMA: Journal of Mathematics Education Study Program	Mendeley, SINTA	Q2	1.294
Journal of Primary Education	Google Scholar, SINTA	Q3	1.109
Journal of Science Education Research	Google Scholar, SINTA	Q2	3.070
Journal CEUR Workshop Proceedings	Google Scholar, SJR	Q1	66.597
Journal of Science Learning	ERIC, SINTA, Scopus	Q3	192
Journal of Science Learning	ERIC, SINTA	Q3	192
Journal of Physics: Conference Series	Google Scholar	Q4	15
Journal Of Mathematics Education (JPM)	Google Scholar	Q3	163
International Technology and Education Journal	ERIC, SJR, Google Scholar	Q4	51
Journal of Science Learning	ERIC, SINTA	Q3	192
TOJET: The Turkish Online Journal of Educational Technology	ERIC, SJR	Q3	1.417
Asian Journal of Education and Training	ERIC	Q4	359
Journal of Science Learning	ERIC, SINTA	Q3	192
Journal of Research in Education	ERIC	Q1	217.320
Journal of Physics: Conference Series	Google Scholar	Q4	15
Journal EDULEARN18 Proceedings	Google Scholar	-	1.693
Asia-Pacific Forum on Science Learning and Teaching	Google Scholar, SJR, SINTA, Scopus	Q4	289
International Journal of STEM Education	SJR, Scopus, Springer, Web of Science	Q1	490

The data in Table 1 shows variations from Q1 to Q4 with varying numbers of articles. Q1 journals such as the Journal of Research in Education, Journal CEUR Workshop Proceedings, and the International Journal of STEM Education are highly reputable and influential. Most journals focus on education and STEM, reflecting research trends. The number of articles varies from very many to very few, depending on the scope and selectivity of each journal.

3. Result and Discussion

The data analysis used in this study is according to RQ in SLR. The results of the data analysis of the 21 articles are shown in Table 2.

Table 2. Analysis of STEM approach implementation (n=21 articles)

Author	STEM Approach to 4C Skills	Products
Cahyana et al. (2020)	Designing ETR media trains 4C critical thinking, creativity, collaboration, and communication skills. Critical thinking is important when students design ETR media by making a series of lights and machines. Students are creative in making media design and makeup more attractive and free to explore and be creative in dressing up ETR media. The collaboration aspect is found when students work together to make ETR media. The communication aspect is found when students present the ETR media that has been made with their groupmates.	Designing Electrical Tandem Roller (ETR) products.
Rahayu & Maryani (2023)	Applying the PjBL STEM learning model uses the syntax of determining basic questions for students, designing project plans, developing schedules, monitoring project activities and progress, testing results, and evaluating learning processes and outcomes. From the results of observations and tests that have been carried out, there are significant differences in creativity after applying STEM-PJBL in grade IV elementary science learning.	Design and manufacture waterwheel products.
Irmayani et al. (2023)	STEM learning with mini projectors can potentially improve the quality of learning in primary schools and develop the 4C skills of critical thinking, communication, collaboration, and creativity.	Make a mini projector.
Suripto et al. (2023)	Using the "Bottle Boat" project, STEM learning can help students develop critical thinking skills. In addition, it was found that students still need to develop their critical thinking skills in discovery and building arguments.	Make a "Bottle Boat" project.
Oktavia & Ridlo (2020)	The STEM approach is the steps in making the project. Students in groups are asked to utilize recycled materials and then process them into a product related to the respiratory system as a learning medium, as well as a critical thinking test and communication skills questionnaire. Which can help develop critical thinking skills and communication skills.	Utilizing recycled materials into a respiratory system product, as well as critical thinking skills test questions based on communication skills with varying results.
Karimah & Wulandari (2023)	Project tasks are carried out in groups by conducting experiments using water purification devices. This	Make a simple project of a water

Author	STEM Approach to 4C Skills	Products
	water purifier is designed using various materials. students will try to connect the concepts learned in the material with the problems they want to solve in the project. students' problem-solving skills can be seen through how they describe the problems and solutions they provide.	purification device.
Siouli et al. (2018)	Students can construct meaning and explore the linkages between co-creative methods in STEM applications.	Creating a Mars Augmented Reality (AR) game development project.
Kurt & Benzer (2020)	Application of STEM to Grade 6 students' academic success, problem-solving skills, and attitudes toward STEM.	Electricity conduction experiment.
Ultay et al. (2020)	Improve skills in the development of communication and cooperation between individuals.	Make boat and raincoat skills.
Sasangbong & Huntula (2022)	A STEM approach that directs learners to understand content and integrate knowledge with electrical engineering design processes that can improve student creativity.	The electrical engineering design process includes city street switches and toys and tools made from waste.
Sahabudin et al. (2024)	Improving students' mathematical critical thinking skills using a STEM-based mathematics learning model shows that STEM-based mathematics learning was conducted in this study, where elementary school students were involved in designing and building tower frames using simple tools and materials.	Design and build the tower frame.
Yavuz & Duban (2021)	Light bulb ignition on Arduino uno with S4 A coding program trains students' creative and innovative thinking skills.	Light bulb lighting experiment.
Dilmen & Atalay (2021)	It was seen in the activities that students realized their misconceptions at the end of the implementation process, began to question the accuracy of the information they encountered and acquired critical thinking skills.	Augmented reality application experiments.
Guven & Alpaslan (2022)	Science activities organized with an interdisciplinary teaching approach improved students' creative problem-solving skills.	Design activities make satellites.
Winarni et al. (2022)	Students discuss science, technology, and engineering projects in the discovery stage. Students individually model the problem-solving of the animal life cycle project as a slogan of animal care for their environment, which is accommodated by elements of science, technology, and engineering in the application stage. The evaluation stage of the experience is done through student presentations and communication of the results of the diorama project.	Diorama group experiment (animal cycle concept).
Zengin et al. (2022)	STEM application to the problem-solving skills of grade 4 elementary school students and students' opinions about the application were analyzed. The students in the experimental group were offered STEM applications for eight weeks along with the science subject curriculum.	An experiment from "Energy from the Sun".
White (2022)	Significant and permanent improvement in creativity	Create a three-

Author	STEM Approach to 4C Skills	Products
	and problem-solving skills of the experimental group of students.	dimensional house.
Sulistia et al. (2019)	The development of STEM learning design with lakaraya media received a very positive response. This learning can help students collaborate according to the demands of the 21st century, and students must have 4C skills.	Lakaraya media experiment.
Togou et al. (2018)	Designed the pilot NEWTON Fab Lab STEM, supporting the concepts of "learning by doing" and "enjoying while learning" to enhance creativity and make students more interested in the possibility of integrating digital fabrication technology into the school curriculum.	Designed and fabricated a ceramic vase using a remote 3D printer and PLA filament with sandstone and a binder polymer that resulted in a ceramic surface finish.
Astuti et al. (2021)	Students design a dice with the concept of the cube and a pencil case with the concept of the unit cube. When implementing the engineering aspect of learning, students can indirectly construct their thoughts when designing a project related to their lives. They can also generate creativity and improve critical thinking skills.	Make a pencil box handicraft by applying the concept of building cubes and blocks.
Baker & Galanti (2017)	Train students to integrate concepts found in math learning in STEM. Enhance creativity, communication, and critical thinking.	Make a physical model of a watertight shelter.

From Table 2 of the results of the analysis of 21 articles on the implementation of the STEM approach on the 4C skills reviewed, it was found that the implementation of STEM at this level of basic education generally provides positive results and fosters student skills in the form of products, although there are some challenges. In the table, descriptions can include how each discipline (Science, Technology, Engineering, and mathematics) contributes to strengthening the 4C skills through an integrated STEM approach. The resulting products enable students to develop skills and a deep understanding of scientific and technological concepts and improve their critical thinking, communication, collaboration, and creativity skills. From the results of products produced by students, such as technology-based products or products derived from simple tools or materials, implementing some of these 4C skills can turn them into a product with both beauty and creative value.

STEM Approach to 4C Skills in Primary School

Previous research shows that STEM learning enhances 4C skills because it is highly relevant and promotes active engagement in the learning process. According to Binkley, as cited in Griffin and McGaw (2012), the 4C skills are crucial for students (Cahyana et al., 2020). Baber (2015) notes that STEM learning supports students in becoming critical thinkers, problem solvers, and creative individuals (Irmayani et al., 2023). Students who develop problem-solving skills can generate new information and improve their reasoning ability and creativity (Abdullah et al., 2014; Kurt & Benzer, 2020). The STEM approach aims to help individuals solve problems, think diversely, build confidence, integrate technology into learning, and develop creative and communication skills (Bybee, 2010; Morrison, 2006).

The learning outcomes influenced by the STEM approach are detailed in Table 3, particularly regarding students' critical thinking skills. According to Astuti et al. (2021), STEM learning

significantly enhances students' critical thinking abilities. The STEM approach encourages students to become aware of environmental events and conditions, and to acquire new knowledge through exploration, investigation, and problem-solving. However, an analysis of the STEM approach in relation to 4C skills indicates that most learning designs primarily focus on developing critical thinking skills. Therefore, the STEM approach is more effective when integrated with a technology-based approach, with learning outcomes including the measurement of critical thinking, communication, collaboration, and creativity.

Table 3. STEM Approach to 4C Skills (n=21 articles)

No	Category of STEM Approach to 4C Skills	Total
1	Critical thinking	14
2	Creativity	12
3	Collaboration	4
4	Communication	7

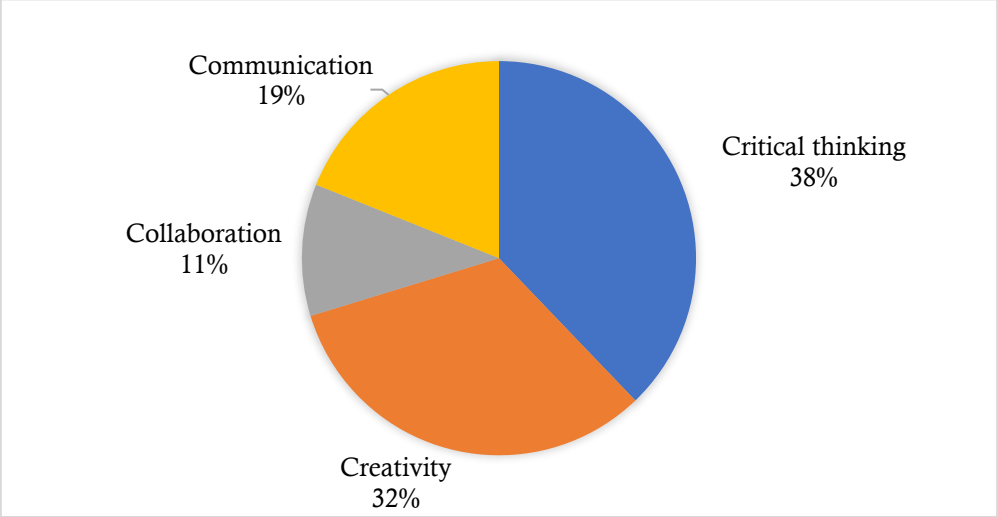


Figure 2. STEM approach to 4C skills (n=21 articles)

In Table 3, the analysis of 21 articles on the STEM approach addressing research question RQ1 shows that the STEM approach to 4C skills encompasses four aspects: critical thinking, creativity, collaboration, and communication. The results for the 4C skills are illustrated in Figure 2, which presents the following percentages: critical thinking (38%), creativity (32%), communication (19%), and collaboration (11%). Analysis of various articles on 4C skills indicates that critical thinking is the predominant skill within the STEM approach. This skill focuses on solving complex, real-world problems, as reflected by the 38% shown in Figure 2. Guven and Alpaslan (2022) highlight that designs incorporating the STEM approach to 4C skills demonstrate how critical thinking enables students to understand challenges, identify opportunities, explore data, formulate problems, generate ideas, plan actions, develop solutions, build acceptance, and strategically approach problems. Abdullah et al. (2014) note that students who develop critical thinking skills can generate new information and enhance their reasoning abilities (Kurt & Benzer, 2020). Ennis (2011) asserts that the main goal of STEM practice is to design learning experiences that develop students' critical thinking skills. According to Oktavia and Ridlo (2020), students can think critically if they meet several indicators, including analyzing arguments, focusing on questions, asking and answering questions, making and assessing judgments, providing explanations, inferring and examining similarities, and drawing conclusions.

Creativity skills, ranking second after critical thinking with a percentage of 32%, are emphasized in research by Yavuz and Duban (2021). Their study suggests that the STEM

approach provides opportunities to develop children's creative and innovative thinking skills. Additionally, the level of students' creative problem-solving skills was found to be 'high' following the implementation of interdisciplinary activities. When given the opportunity to enhance their creative problem-solving skills, students exhibited positive changes (Guven & Alpaslan, 2022). Pannels (2010) observed that students involved in creative problem-solving activities experienced increased creativity. Mariani et al. (2023) define creativity as the ability to generate new ideas, identify novel relationships between existing elements, solve problems, or create innovations that benefit individuals and society (Rahayu & Maryani, 2023). Creative problem-solving helps individuals manage everyday problems and long-term challenges (Treffinger et al., 2003; Guven & Alpaslan, 2022). Student creativity is more likely to develop if learning is not only conventional but also integrates skills that enhance creativity and technology. According to Togou et al. (2018), 'learning by doing' and 'enjoying while learning' can boost creativity and increase student interest in integrating digital fabrication technology into the school curriculum.

The results of the next skill analysis show that communication skills in the context of 4C within STEM education have a percentage of 19%. Oktavia and Ridlo (2020) state that if students' communication skills are high, their learning outcomes will improve (Guven & Alpaslan, 2022). Effective communication can enhance understanding, application skills, and investigative abilities and inform students about the studied subject. Eroğlu and Bektaş (2018) note that a lack of information regarding the products and target behaviors students design can hinder the effectiveness of STEM activities. Communication skills in STEM approaches are critical as they ensure students can clearly express their thoughts and discoveries, collaborate in teams to organize and deliver presentations, and write technical documentation. These skills ensure that students understand the material more deeply and share their knowledge with others, supporting problem-solving and innovation, which are key focuses of STEM education (Ultay et al., 2020). Bozkurt, Üçüncüoğlu, and Özek (2019) emphasize that students' success in delivering concise messages during STEM learning activities, especially when addressing scientific concepts, is very important (Winarni et al., 2022). Özkök (2004) asserts that creative problem-solving integrates creativity, critical thinking, and problem-solving abilities, which are essential for students to apply innovative solutions in everyday life (Yavuz & Duban, 2021).

Analysis of skills at the final level, namely collaboration, shows a percentage of 11%. Research by Irmayani et al. (2023) indicated that in Cycle 1, 81% of students found it easy to work together in groups, while in Cycle 2, 100% experienced no difficulties collaborating. The collaboration aspect is evident when students work together to create Electrical Tandem Roller (ETR) media, a tool used for compacting soil piles or leveling soil. ETR media is commonly employed in constructing dirt roads and roads with flexible or rigid pavement. The creation of ETR media is performed in groups of 4-5 students, necessitating collaboration to produce optimal results (Cahyana et al., 2020). According to Lou et al. (2017), collaboration offers several benefits, including encouraging students' courage and creativity as they develop ideas in an investigative environment. Students also assume responsibility for the outcomes of group tasks, fostering a dynamic learning environment that enhances their creative skills and ability to work effectively together (Hanif et al., 2019). Sulistia et al. (2019) note that collaboration can improve problem-solving skills, engage students in learning, and boost motivation, engagement, and a sense of responsibility. Collaboration skills in the 4Cs are often observed at lower percentages because, as Johnson (2019) points out, assessing individual contributions in teamwork is challenging and requires specialized methods.

Products Produced through STEM Approach to 4C Skills in Elementary School

The STEM approach to learning can develop 4C skills (Communication, Collaboration, Critical Thinking, and Creativity) essential for creating innovative products. Integrating science, technology, engineering, and mathematics provides students with opportunities to learn and apply their knowledge in real-world situations. As a result, students can enhance their critical thinking, collaboration, communication, and creativity skills. Consequently, the products created

reflect students' deep understanding of the material and ability to adapt and innovate. The STEM approach, emphasizing 4C skills, enriches students' learning experiences and prepares them to tackle challenges in complex environments.

The STEM approach produces several products that enhance 4C skills. According to Brown (2021), integrating 4C skills within the STEM approach equips students to think critically and creatively and to collaborate effectively, resulting in innovative products applicable in everyday life. This research demonstrates that incorporating 4C skills within the STEM framework can improve the quality and effectiveness of learning, leading to academically valuable and practically applicable products. Findings on products developed through the STEM approach, incorporating 4C skills, indicate that many projects and innovations can be achieved. These include the development of prototypes, technologies, creative solutions to real-world problems, software, applications, and complex scientific models.

Table 4. Products produced through STEM towards 4C skills (n=21 articles)

No	Product Categories	Description	Total
1	Prototype	The product is to be but not finalized	8
2	Ordinary simple technology	Products that can utilize relatively basic skills are not too complicated in how they work and are used.	10
3	Simple technology from scrap	Products made from used goods.	3

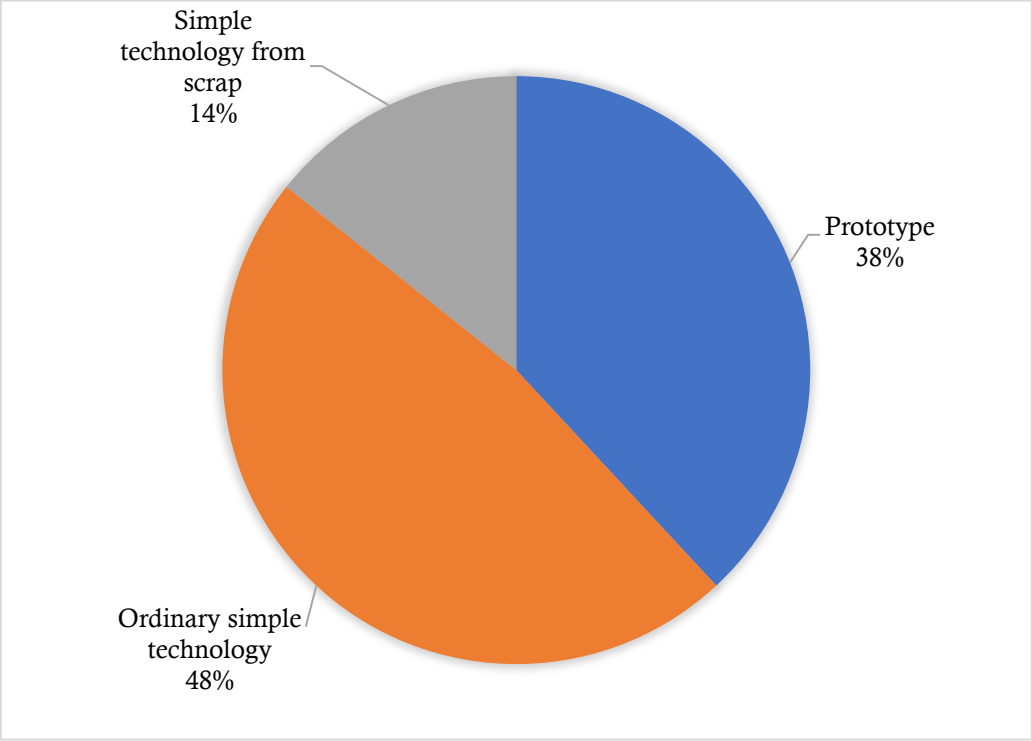
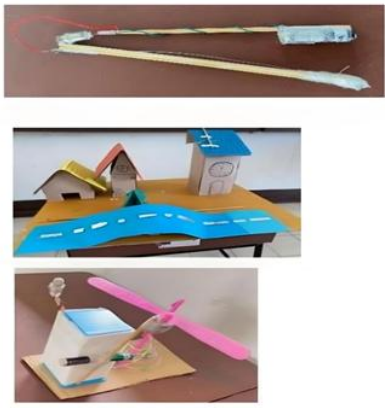


Figure 3. Percentage of Product Categories Produced Through the STEM Approach to 4C Skills (n = 21 articles)

Table 4 answers RQ2 by showing that the STEM approach is most valuable in producing products within the category of ordinary simple technology, with a percentage of 48%, as shown in Figure 3. Winarni et al. (2022) describe ordinary simple technology products as animal life cycle concepts, where students individually model animal life cycle project solutions with an environmental focus, supported by elements of science, technology, and engineering during the

application stage (White, 2022). Collaborative-based learning involves students working together in group activities within inquiry and problem-based learning contexts. Several articles, including Aranda, Lie et al. (2020), and Petrisino et al. (as cited in Winarni et al., 2022), show that simple technology products are typically teaching aids adapted to 4C characteristics, designed to engage students, stimulate creativity, and motivate problem-solving (Astuti et al., 2021). Kurt and Benzer (2020) describe an electrical conduction experiment as a product demonstrating STEM's impact on academic success, problem-solving skills, and attitudes toward STEM. Meanwhile, Ultay et al. (2020) focus on building boats and raincoats to improve student communication and cooperation. Sasangbong and Huntula (2022) discuss products such as city street switches, toys, and appliances made from waste, aiming to help students understand content and integrate knowledge with electrical engineering design to enhance creativity. Further STEM studies can explore these product skills and their success.



Electrical engineering design in the form of city street switches and toys and appliances from garbage. (Sasangbong, S., & Huntula, J. (2022))

Boat and Raincoat Skills. (Ultay, N., Zıvalı, A., Yılmaz, H., Bak, H. K., Yılmaz, K., Topatan, M., & Kara, P. G. (2020))

Figure 4. Product Results in the Ordinary Simple Technology Category (n=21 articles)

Figure 4 showcases various products from the simple technology category that illustrate applying basic techniques to create practical and innovative solutions. According to research by Sasangbong and Huntula (2022), products such as the City Street Switch, which is designed to control street lighting efficiently, and toys that employ basic electrical engineering principles reflect sustainability and creativity in simple technology. Waste equipment made from recycled materials also exemplifies the effective use of repurposed materials. Additionally, research by Ultay et al. (2020) highlights products like boats designed with basic techniques and raincoats intended as protective clothing against bad weather, showcasing skills in creating practical and protective tools. These examples highlight the diversity of innovation in simple technology, emphasizing how basic designs and techniques can solve everyday problems and enhance the quality of life in efficient and creative ways.

The analysis of product categories from various articles shows that the second most frequently improved product category in the STEM approach is prototyping, with a percentage of 38%, as shown in Figure 2. A prototype is an early version still under development, as Sulistia et al. (2019) described. Their study supports 'learning by doing' and 'enjoying while learning' to enhance students' creativity and increase their interest in integrating digital manufacturing technology into the school curriculum. One example is the ETR media designed for sixth-grade elementary students, which includes learning materials related to electrical components and functions, speed, and explanations of the text 'Electricity,' along with contextual discussions of 'The Changing Face of the World,' integrating scientific topics, mathematics, and Indonesian. The goal is for this ETR product to serve as a solution and alternative supporting thematic

learning within the STEM approach (Cahyana et al., 2020). Additionally, research by Dilmen and Atalay (2021) shows that the use of augmented reality applications effectively captures students' attention, increases their awareness of technology, and helps them visualize abstract concepts more efficiently, significantly boosting their creativity. Guven and Alpaslan (2022) highlight another category of products: satellite designs used in science activities organized with an interdisciplinary teaching approach. This method enhances students' creative problem-solving skills, with post-implementation evaluations indicating a 'high' level of these skills.

Lakaraya Media (Crocodile Lamp Carbon Battery)
(Sulistia *et al.*, 2019)

Media Electrical Tandem Roller
(Cahyana *et al.*, 2020)

Application of Augmented Reality
(Dilmen, I & Atalay,N., 2021)

Satellite Making Design
(Guven,I & Alpaslan, B., 2022)

Figure 5. Product Results in the Prototype Category (n=21 articles)

Figure 5 in the results and discussion section showcases various products from the prototype category, derived from 21 research articles. Among these products is the Lakaraya media, a carbon battery for crocodile lamps developed by Sulistia et al. (2019), which introduces innovations in energy storage and lighting. Additionally, the electric tandem roller media, described by Cahyana et al. (2020), demonstrates a mechanical device design that integrates electrical engineering principles to enhance operational efficiency. Another notable product is the application of augmented reality (AR) technology, discussed by Dilmen and Atalay (2021), which improves user interaction and experience across various applications. Lastly, the satellite design by Guven and Alpaslan (2022) underscores advancements in satellite technology, addressing both challenges and innovations in the field. Overall, this figure illustrates the diversity and progress in prototype development, emphasizing how different approaches and technologies can be integrated to create innovative and effective solutions across various domains.

The next product category is simple technology from reused items, with a percentage of 14%, as shown in Figure 2 of all articles analyzed. These products are from reusable items, primarily old bottles, ice cream sticks, and straws. For example, Rahayu and Maryani (2023) outline that creating waterwheels can produce simple products while enhancing students' creativity within an integrated model. White (2022) demonstrates how three-dimensional home projects apply STEM principles to improve problem-solving skills. The 'Bottle Boat' project, as described by Suripto et al. (2023), helps students develop critical thinking skills in STEM learning. Rati et al. (2018) found that imagination and courage significantly influence creativity, impacting responses to problems and collaborative project completion. This finding aligns with Lestari et al. (2023), who

assert that creative thinking can lead to developing unique products and teaching students to plan and overcome obstacles. Students are encouraged to plan, design, develop, and reflect on their projects, fostering imagination and interest in facing diverse challenges (Rahayu & Maryani, 2023).

Waterwheel Products
(Rahayu, A. S., & Maryani, I. (2023))

Three-Dimensional House
(White, M. (2022)

Building a Bottle Boat
(Suripto, S et al., (2023)

Figure 6. Product Results in the Simple Technology from Scrap Category (n=21 articles)

Figure 6 displays various products in the simple technology category, all made from used materials. This analysis is based on 21 articles that explore creative innovations. One featured product is the waterwheel, developed by Rahayu and Maryani (2023), which uses water flow as a simple alternative energy source. This product demonstrates how repurposed items can be transformed into useful tools for generating energy. Another example is the three-dimensional house created by White (2022). This innovative architectural model, constructed from recycled materials, reflects a creative approach to design and construction. Suripto et al. (2023) also designed a product for building bottle boats. In this project, bottles are used as the primary material for creating miniature boats, which function as works of art and as educational tools for understanding physics and engineering principles. Overall, Figure 6 illustrates how simple technology utilizing used goods can be applied in various creative and educational projects, highlighting the significant potential of this approach for developing sustainable and practical solutions.

4. Conclusion

Based on the results obtained, it is revealed that the STEM approach to 4C skills in elementary schools is found in the three categories of products it produces. However, most in the category of ordinary simple technology that contains critical thinking, creativity, communication, and collaboration are used in the STEM approach. The conclusion is that the STEM approach to students' 4C skills in elementary schools is more directed towards the products produced so that in implementing the products produced in this STEM approach requires effective and efficient products such as 4C skills-based to encourage further students who integrate with STEM and produce creative and innovative products. It is suggested that schools and teachers determine what steps can be taken to more effectively integrate STEM approaches and utilize technology to maximize STEM learning integrated with 4C skills. Furthermore, the implications that can be used from the results of this study are that it can be used as a reference, especially for schools and teachers to use the STEM approach to 4C skills in elementary school students. The strengths and weaknesses of this study can be used as a reference to produce a better quality for further research.

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