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STEM research trends in indonesia: A systematic literature review

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ABSTRACT

STEM can contribute to the achievement of Sustainable Development Goals (SDGs) through the development of 21st-century skills. It triggered a massive innovation in science education research on the STEM theme including Indonesia. This content analysis study aimed to systematically analyze STEM research trends in Indonesia based on articles published in national and international journals. Based on the inclusion criteria established, 50 articles were collected to be analyzed using the Paper Classification Form (PCF) instrument. The findings of the analysis indicated a dominance on the topic of learning strategies (54%) with the experimental method (46%). The most common integration pattern found is STEM-PjBL (34.48%). Learning outcomes (23.91%) and scientific literacy (21.74%) were the dependent variables that were dominantly associated with STEM learning. Thus, there needs to be a variety of STEM research on other potential issues to help the government accelerate the achievement of SDGs.

INTRODUCTION

The United Nations Development Program (UNDP) initiated the 2030 Sustainable Development Goals (SDGs) in 2016. It refers to the sustainable development agenda that contained 17 goals and 169 targets. These goals align the development needs with social, economic, and environmental aspects to improve marginalized communities' quality of life.

Education has a fundamental and transformative role in realizing the 2030 SDGs. This arises not because of the explicit and specific integration of education in the 4th goal of SDGs (Quality Education), but its urgency in raising literacy to support all SDGs goals (UNESCO, 2014). EAC (2016) explained that education directly contributes to poverty alleviation and inequality of human rights, health and nutrition, the environment, economic development, and labor productivity. These goals can be fulfilled if citizens have relevant 21st-century skills, particularly STEM literacy and skills.

STEM literacy and skills are obtained through the implementation of STEM education. It refers to learning that integrates disciplines and skills in science, technology, engineering, and mathematics to solve real-life problems (Wahono et al., 2020). This multidisciplinary integrative approach prepares students to become citizens and a workforce capable of making decisions on health, energy efficiency, environmental quality, resource use, and national security within the high-tech society (Bybee, 2010; Kang, 2019).

STEM learning has been proven empirically to improve various soft skills needed for work in the STEM field, such as higher-order thinking skills (HOTS), problem-solving, collaboration, critical and creative thinking, reasoning and decision making (Yusuf et al., 2018; Sarican & Akgunduz, 2018; Lin et al., 2019; Rahmawati et al., 2018; Altan et al., 2018). From the affective perspective, STEM learning can be used to develop self-efficacy, learning motivation, and attitudes (Sublett & Plasman, 2017; Ugras, 2018). It is not surprising that there has been an increase in STEM education awareness in several countries considering that workers who have STEM skills are a solution to the global economy (Knowles et al., 2018).

STEM is promoted as a national education reform project in many countries. The United States, through the Next Generation Science Standards (NGSS), establishes science and engineering practices as one of the main dimensions in the performance expectation of science learning and also implements engineering design as well as scientific inquiry (the NGSS Lead States, 2013). Meanwhile, the Irish Ministry of Education and Skills (2017), through the STEM education 2017-2026 policy, provides four pillars of STEM policy development to create a high-quality STEM education experience. Furthermore, the South Korean Ministry of Education inserted STEAM education into the national policy agenda in 2011 (Kang, 2019).

The Indonesian government has not issued an official policy regarding the establishment of STEM education in the curriculum. However, the reformation commitment can be observed from the relatively high engagement rate for STEM implementation as indicated by the emergence of numerous empirical studies on STEM over the last decade. This fact can be proven through a Google Scholar search with the keywords "STEM", "STEM Education", and "Indonesia" which yielded more than 100,000 findings.

STEM research, which is novel, innovative, and able to close the theoretical gap, can be conducted more easily if research trends in this area are already identified. Therefore, a systematic study is needed to examine these research trends in the Indonesian context. Systematic reviews that explore status and trends within specific themes have become commonplace in educational research, as the systematic literature review on STEM research trends in the International Journal of STEM Education (IJ-STEM) by Li et al. (2020), inquiry-based learning trends by Kızılaslan et al. (2012), trends in scientific literacy research in Indonesia by Ni'mah (2019), and a meta-analysis study of the STEM effect on learning achievement by Khoiri (2019).

A systematic literature review that aggregates STEM research in Indonesia holistically and comprehensively has not been carried out. Therefore, the present study aims to systematically analyze Indonesia's STEM research trends based on articles published in national and international journals. The details of the research questions guiding the analysis process are as follows: (1) what are the most explored topics in STEM research?; (2) what are the most used methods in STEM research?; (3) how are the STEM integration patterns in science learning?; (4) what are the dominant variables associated with STEM?; (5) what are the most potential research topics that can be developed in the future?

METHOD

The present qualitative study used a content analysis approach with a systematic literature review technique to analyze Indonesia's STEM research trends. A systematic literature review is a secondary research that combines findings from various primary studies to answer research questions (Newman & Gough, 2020). The present study adopted the review process by Sharif (2019), described as follows: (1) formulating the research questions; (2) establishing the inclusion criteria (Table 1); (3) searching for articles on various databases (Google Scholar, ERIC, DOAJ, journal websites) by typing the keywords “STEM” and “Indonesia”; (4) coding the articles using the Paper Classification Form (PCF); (5) identifying patterns throughout the articles; (6) synthesizing these patterns to answer the research questions. The filter stage resulted in 50 articles that met the inclusion criteria (Table 2).

The coding instrument resulted from the adaptation of the PCF was developed by Kızılaslan *et al.* (2012). The instrument has met the validity and reliability requirements. The collected data were analyzed using percentage calculation.

Table 1. The inclusion criteria

Category	Inclusion Criteria
Type of publication	Scientific articles published in journals
Journal specifications	National peer-reviewed journal accredited minimum grade 3 (Sinta 3); international peer-reviewed journal indexed minimum DOAJ
Publication year	2001-2020
Research setting	Indonesia
Researcher's nationality	Indonesian; the combination of Indonesian and foreigners
Independent variable	STEM and all kinds of integration patterns
Field	Science, physics, chemistry, biology
Type of study	Empirical and theoretical
Research subject	Students and teachers at all level (elementary, junior high school, senior high school, college)

Table 2. The distribution of articles based on the journals’ identity

Journal Type	Status	Journal Name	Quantity
National	Grade 1 (Sinta 1) accredited and Scopus Q2 indexed	Jurnal Pendidikan IPA Indonesia	3
	Grade 2 (Sinta 2) accredited	Jurnal Inovasi Pendidikan IPA	2
		Jurnal Ilmiah Pendidikan Fisika Al-Biruni	1
		Jurnal Penelitian dan Pengembangan Pendidikan Fisika	1
		Jurnal Kimia dan Pendidikan Kimia	1

Journal Type	Status	Journal Name	Quantity
		Jurnal Pendidikan Biologi Indonesia	1
		Jurnal Pendidikan Sains Indonesia	3
		Jurnal Penelitian dan Evaluasi Pendidikan	1
		Journal of Educational Science and Technology	1
		Kwangsan: Jurnal Teknologi Pendidikan	1
		Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan	8
		Al-Ibtida: Jurnal Pendidikan Guru MI	1
		Jurnal Pendidikan Indonesia	1
		Jurnal Prima Edukasia	3
	Grade 3 (Sinta 3) accredited	Berkala Ilmiah Pendidikan Fisika	1
		Jurnal Pendidikan Fisika	1
		Jurnal Inovasi Pendidikan Kimia	1
		Indonesian Journal of Science and Mathematics Education	1
		Scientiae Educatia: Jurnal Pendidikan Sains	2
		Jurnal Pendidikan Sains	2
		Premiere Educandum: Jurnal Pendidikan Dasar dan Pembelajaran	1
		UNNES *Science Education Journal*	1
		Journal of Science Learning	3
		Journal of Innovative Science Education	3
International	Scopus Q2 indexed	*International Journal of Instruction*	1
		Journal of Turkish Science education	2
	Scopus Q3 indexed	*Journal for the Education of Gifted Young Scientists*	1
	Scopus indexed (without Q)	*International Journal of Evaluation and Research in Education*	1
	DOAJ indexed	*Science Education International*	1
		Total	50

RESULT

STEM Research Topics

STEM research in Indonesia was conducted on a wide variety of topics. Table 3 shows that the learning strategies topic (54%) dominated STEM research, followed by teaching materials (20%), and learning media (12%). Learning evaluation and assessment (4%), teacher (4%) and students perceptions (4%), and learning instruments (2%) are the minor topics. These findings are generally in line with the science education research trends during 2013-2017 published in Science Education (SE), the Journal of Research in Science Teaching (JRST), and the International Journal of Science Education (IJSE), which focus primarily on the learning context topics (Lin *et al.*, 2019). Furthermore, Indonesia's present STEM research trend also aligns with international trends, especially in IJ-STEM, dominated by goals, policies, curriculum, evaluation, and assessment (Li *et al.*, 2020).

Table 3. The STEM research topics trends

Research Topics	Percentage (%)
Learning strategies	54
Teaching materials	20
Learning media	12
Learning evaluation and assessment	4
Teacher perceptions	4
Students perceptions	4
Learning instruments	2

Figure 1 indicates that STEM research attention increasingly began in 2015. STEM is indeed a new research theme in Indonesia compared to other research themes, such as scientific literacy initiated in 2009 (Ni'mah, 2019). As a result, Kızılaslan *et al.* (2012) stated that no wonder STEM research begins with a foundational topic in curriculum reform that focuses on learning strategies.

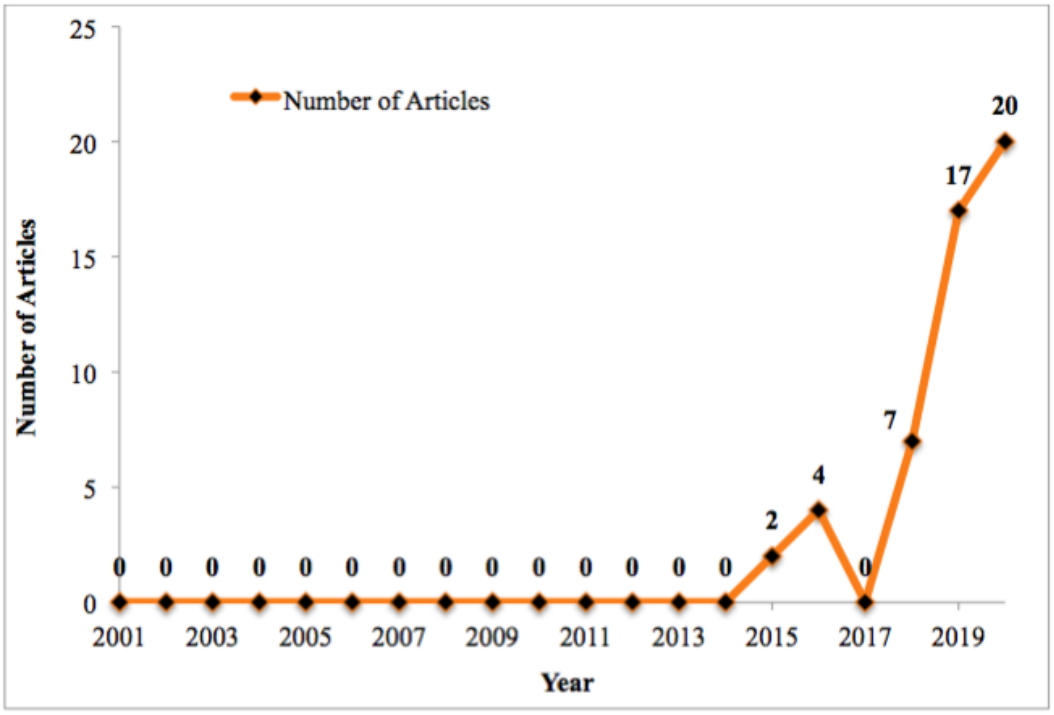

Figure 1. The distribution of STEM articles published annually.

STEM Research Methods

The present systematic literature review unveiled experimental methods (46%), research and development (26%), and survey (12%) as the trends in STEM education research in Indonesia (Table 4). The research method trends are following the topic trends. The effectiveness of STEM learning strategies (the most explored topic) are determined through experimental research (the most used method), which can be broken down into quasi-experimental (non-equivalent control group design, factorial design) and pre-experiment (one-group pretest-posttest design and one-shot case study).

Table 4. The STEM research methods trends

Approach	Research Methods	Percentage (%)
Quantitative	Experiment	46
	Survey	12
	Correlational	2
Qualitative	Literature review	4
	Phenomenology	2
	Narrative inquiry	2
The others	Research and development	26
	Mix method	4
	Classroom action research	2

Meanwhile, teaching materials and learning media are developed through research and development methods. The details of the STEM-based teaching materials and media are presented in Table 5.

Table 5. STEM-based teaching materials and media

Teaching Materials	Learning Media
Module; e-module; worksheet; video-assisted flipbook; book; e-book	Virtual laboratory; digital multimedia; encyclopedia; module-assisted CO_2 gas sensor; herbarium; mobile augmented reality

The trend of STEM research methods in Indonesia supports the international trends dominated by experimental methods, followed by qualitative research and mix methods (Li *et al*., 2020). This finding also implies that Indonesian researchers' interest in qualitative research is relatively low, such as phenomenological research and narrative inquiry.

STEM Integration Pattern

STEM learning strategies can be integrated with specific learning models, approaches, contexts, or competencies. Table 6 shows that project-based learning (STEM-PjBL) (34.48%), problem-based learning (STEM-PBL) (13.79%), and inquiry (STEM-inquiry) (13.79%) set the trends of STEM integration pattern in Indonesia. The official USA committee on STEM Education (2018) suggested the implementation of STEM-PjBL to accomplish meaningful and inspiring STEM learning that focuses on complex and challenging real-world problems. The dominance of STEM-PjBL in this finding aligns with Mustafa *et al.* (2016) analysis that PjBL is the most effective strategy for STEM learning in Asia, especially at the secondary education level. The STEM-PjBL learning environment provides students with opportunities to solve the complexity of concepts in the STEM field (Çevik, 2018).

Table 6. The STEM integration pattern trends

Integration Pattern	Percentage (%)
STEM-Project based learning	34.48
STEM-Problem based learning	13.79
STEM-Inquiry	13.79
STEM-Entrepreneurship	6.89
STEM-Scientific literacy	
STEM-Challenge based learning	
STEM-Contextual learning	
STEM-Religion-Culture	
STEM-Local wisdom	3.45
STEM-Critical thinking skills	
STEM-Flipped classroom	
STEM-Scientific approach	
STEM-HOTS	

STEM-PBL (Parno *et al*., 2020; Madyani *et al.*, 2019) and STEM-inquiry (Idawati *et al*., 2019; Nurbaya *et al*., 2019) have been empirically proven to be implemented in science learning and instruction though less prompted than STEM-PjBL. STEM learning helps students solve problems, conclude, and apply the knowledge obtained through science, technology, engineering, and mathematics (Lou *et al*., 2017). Therefore, it is rational to integrate STEM with the PBL learning model. Furthermore, the implementation of engineering design, which is in line with the scientific inquiry listed in the NGSS (NGSS Lead States, 2013) is the grounds for formulating the STEM-inquiry integration pattern.

STEM Associated Variables

STEM learning is always associated with specific variables in conducting STEM-based research. Table 7 shows that learning outcomes (concept mastery) (23.91%), scientific literacy (21.74%), and creative thinking skills/creativity (13.04%) are the most major STEM-associated variables. The other variables, i.e.: critical thinking skills (8.73%), learning motivation (4.35%), self-efficacy (4.35%), and problem-solving abilities (4.35%), also receive sufficient attention from researchers. This systematic literature review analysis indicates that there has been diversification in STEM research in Indonesia.

Indonesian researchers' preference for learning outcome is influenced by the Asian region's learning process conventional paradigm. According to Wahono *et al.* (2020), the philosophy of education in Asia and western countries is considerably different, where Asia's orientation remains in academic learning outcomes. However, a meta-analysis study conducted by Wahono *et al*. (2020), who examined the effect of STEM learning on learning outcomes and HOTS in Asia, showed that STEM on HOTS gives more significance than learning outcomes.

In Indonesia's STEM research, the scientific literacy trends indicate that education experts and practitioners try to achieve the 2030 SDGs. Emphasis on all forms of literacy, including scientific literacy, is UNDP's educational agenda (2019) to achieve SDGs goal 4 (Quality Education). STEM learning provides the critical knowledge needed to solve real-life problems, such as global warming, air and water pollutions, availability of clean water, and food safety (Reeve, 2015).

Creative thinking skills/creativity is present as the dependent variable associated with the STEM-PjBL and STEM-PBL. These findings imply that Indonesia's researchers have captured the urgency of creative thinking skills as one of the 21st-century skills. This trend aligns with the South Korea's STEAM program framework with the slogan "emotional touch with creative design" developed by the Korea Foundation for the Advancement and Creativity (KOFAC) in 2019. This framework uses the STEM-PBL integration pattern

and promotes STEAM's student interest by developing creative thinking skills and connecting the instruction with daily experiences (Kang, 2019).

Table 7. The STEM associated variables trends

Associated Variables	Percentage (%)
Learning outcomes (concept mastery)	23.91
Scientific literacy	21.74
Creative thinking skills/creativity	13.04
Critical thinking skills	8.73
Learning motivation	
Self-efficacy	4.35
Problem-solving abilities	
Communication skills	
Science process skills	
Multi-representation skills	
Scientific work skills	
Learning activity	2.17
Energy literacy	
Scientific attitude	
Misconception	
HOTS	

Hinojo-Lucena *et al*. (2020) found different associative variables trends through a systematic literature review. By tracing the transcendence of STEM education term in the Web of Science database from 2015-2019, computational thinking is established as a significant dependent variable. Shute *et al*. (2017) defined computational thinking as a term that covers design thinking and engineering (efficient solution design), systems thinking (understanding of systems and modeling), and mathematical thinking to be applied together in order to solve problems. Engineering and mathematics aspects in STEM are fully responsible for the development of computational thinking.

Future STEM Research Recommendations

Referring to the identified STEM research trends in Indonesia, several topics have not been optimally explored. Based on these findings, the following recommendations are proposed: (1) it is necessary to conduct quantitative and qualitative research to formulate a STEM teacher professional-development program under the 2013 Curriculum, which effectively increases teachers' readiness to implement STEM; (2) the development of ICT-based and robotics-based teaching materials and learning media needs to be initiated immediately to align Indonesia's STEM research trends with international trends; (3) the shift in research focus from conventional associative variables (learning outcomes, conceptual mastery, learning motivation) to engineering-based variables (computational thinking and other STEM skills) needs to be done immediately to prepare students to be the STEM workforce needed by the international labor market.

CONCLUSION

The STEM research trends in Indonesia are dominated by the learning strategies topics under experimental methods. The most common pattern of integration is STEM-PjBL. Learning outcomes and scientific literacy are the dominant dependent variables associated with STEM learning. Some issues have not been optimally explored, including the STEM teacher professional-development program, the development of ICT and robotics-based teaching materials and learning media, and the improvement of students' engineering-based skills (e.g. computational thinking).

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