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STEM Integration In Physics Education and Its Influence on Cognitive Skills: A Systematic-Literature Review (2014-2025)

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ABSTRACT

Integration of Science, Technology, Engineering, and Mathematics (STEM) in physics education has become a strategic approach to enhancing students' cognitive skills in response to the demands of the 21st century. This study aims to present a systematic literature review of 20 scientific articles that examine the implementation of STEM- based learning in physics education and its impact on students' cognitive skills. The method employed is a systematic literature review, involving stages of identification, selection, and thematic analysis of articles published between 2015 and 2024. The findings indicate that STEM integration consistently has a positive effect on students' cognitive skills, particularly in critical thinking, problem-solving, conceptual understanding, and higher-order thinking skills (HOTS). Furthermore, the STEM approach promotes learning that is more contextual, collaborative, and oriented toward real-world problem solving. Therefore, the integration of STEM in physics education is recommended as an effective instructional approach to improving the quality of students' cognitive learning outcomes.

Keywords: *STEM; physics education; cognitive skills*

ABSTRAK

Integrasi Science, Technology, Engineering, and Mathematics (STEM) dalam pendidikan fisika menjadi pendekatan strategis untuk meningkatkan keterampilan kognitif peserta didik dalam menghadapi tuntutan abad ke-21. Penelitian ini bertujuan menyajikan tinjauan pustaka sistematis terhadap 20 artikel ilmiah yang membahas penerapan pembelajaran berbasis STEM pada pendidikan fisika serta dampaknya terhadap keterampilan kognitif siswa. Metode yang digunakan adalah systematic literature review dengan tahapan identifikasi, seleksi, dan analisis tematik terhadap artikel yang dipublikasikan pada periode 2015–2024. Hasil kajian menunjukkan bahwa integrasi STEM secara konsisten memberikan pengaruh positif terhadap keterampilan kognitif siswa, khususnya pada kemampuan berpikir kritis, pemecahan masalah, pemahaman konsep, dan keterampilan berpikir tingkat tinggi (HOTS). Selain itu, pendekatan STEM juga mendorong pembelajaran yang lebih kontekstual, kolaboratif, dan berorientasi pada pemecahan masalah nyata. Dengan demikian, integrasi STEM dalam pendidikan fisika direkomendasikan sebagai pendekatan pembelajaran yang efektif untuk meningkatkan kualitas hasil belajar kognitif siswa.

Kata Kunci: STEM; physics education; cognitive skills

1. INTRODUCTION

Development knowledge knowledge and technology in the 21st century have bring implications significant to system education, including education physics (Baran et al., 2016)(Khalil et al., 2023). Global challenges such as Industrial Revolution 4.0, Society 5.0, and need will source Power adaptive, critical and innovative human beings demand learning that is not only mastery - oriented draft (Pendidikan et al., 2012)(Narul, 2024), but also on development skills cognitive level tall (Muyassarah et al., 2019)(Alaini et al., 2022)(Loof et al., 2022). Skills the covers ability think critical, solving problems, analysis, synthesis, and evaluation which are collective known as Higher Order Thinking Skills (HOTS) (Kusuma et al., 2017).

Physics education own role strategic in build skills cognitive Because its characteristics emphasize reasoning scientific, modeling mathematical, as well as implementation draft in phenomenon nature and technology (Loof et al., 2022). However, various study show that learning physics conventional (Aini, 2017)which is still teacher-centered tend emphasize memorization formula and solution routine matters, so that less than optimal in develop skills cognitive students . Conditions This push the need approach learning innovative and capable integrate draft physics with context real and cross discipline (Sunaryo et al., 2022).

One of many approaches studied and implemented in One decade final is integration of Science, Technology, Engineering, and Mathematics (STEM) (Mart & Naranjo-correa, 2022). The STEM approach emphasizes integration between scientific concepts, utilization technology, engineering processes, and modeling mathematical in finish problem authentic (Nagdi et al., 2018). In the context education physics, STEM integration allows student For understand draft physics in a way holistic through activity based projects, experiments, and solutions problem contextual (Fadil, 2004).

A number of study report that learning physics STEM- based capable increase understanding draft (Muyassarah et al., 2019)(Narul, 2024), skills think critical (Series, n.d.), and ability solution problem student (Sulistiani et al., 2024)(Series, 2019)(Saputri et al., 2025). In addition, STEM also encourages involvement active student in the learning process, improve motivation Study (Fadil, 2004), as well as grow skills collaboration and communication (Rahmayani & Asrizal, 2023)(Nilyani & Ratnawulan, 2023). Although Thus, the findings the Still spread in various publication with diverse focus and context.

This study is review literature systematic (SLR). Many have already do a number of studies about the use of STEM in learning physics For increase skills cognitive students ; however, application, methodology, population targets, and reported results vary widely Consequently, SLR is necessary For identify patterns and gaps research, as well as inspect diversity approach in incorporating STEM into in learning physics . In addition to mapping existing studies, review this also aims For give runway strong theoretical For STEM implementation in the future in increase skills cognitive student.

Therefore that, is necessary something review library systematic study in a way comprehensive results study related STEM integration in education physics as well as its influence to skills cognitive students . Review library systematic This aim to (1) identify forms STEM integration in learning physics, (2) analyzing influence STEM integration towards various aspect skills cognitive students, and (3) mapping trend as well as gap research that can become base for study furthermore.

2. METHOD

This study is review literature systematic review (SLR) which examines findings from study previously about the impact of STEM on cognitive students. This study follow Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria.

PRISMA is used For ensure that results review systematic can reliable, because PRISMA started review systematic through the process of identification, filtering or selection, testing eligibility, data inclusion, and finally data (Hikmah & Dkk, 2025)(Dhiya et al., 2025).

After identified, each relevant articles collected through search systematic use PICO elements (Population, Intervention, Comparison, Outcome) for break SLR's purpose is to be a keyword that can searched, so that facilitate the formulation process question research (Eriksen & Frandsen, 2018). Application of PICO in research is as following:

Table 1. Scope SLR research based on PICO

Element	Information
Population	Students in various level education follow STEM learning in schools .
Intervention	Use teaching materials or STEM integration in the learning process physics .
Comparison	Compare ability cognitive student without using STEM in learning physics .
Results	Identifying the impact of STEM on learning physics and progress ability cognitive student after the learning process.

Based on framework PICO work , keywords specific chosen For align the search process with The objectives of this SLR are “STEM”, “ cognitive ”, and “ learning” . physics ”. Search done use Publish or Perish application in various databases including Google Scholar, Semantic Scholar, Scopus, and ERIC. Boolean operators are applied For perfect results , using the search string the following : (“STEM”) AND (“cognitive”) AND (“learning”) (“physics ”) ; (“STEM”) AND (“ cognitive ”). This process produced a total of 250 articles at this stage identification before apply criteria inclusion and exclusion.

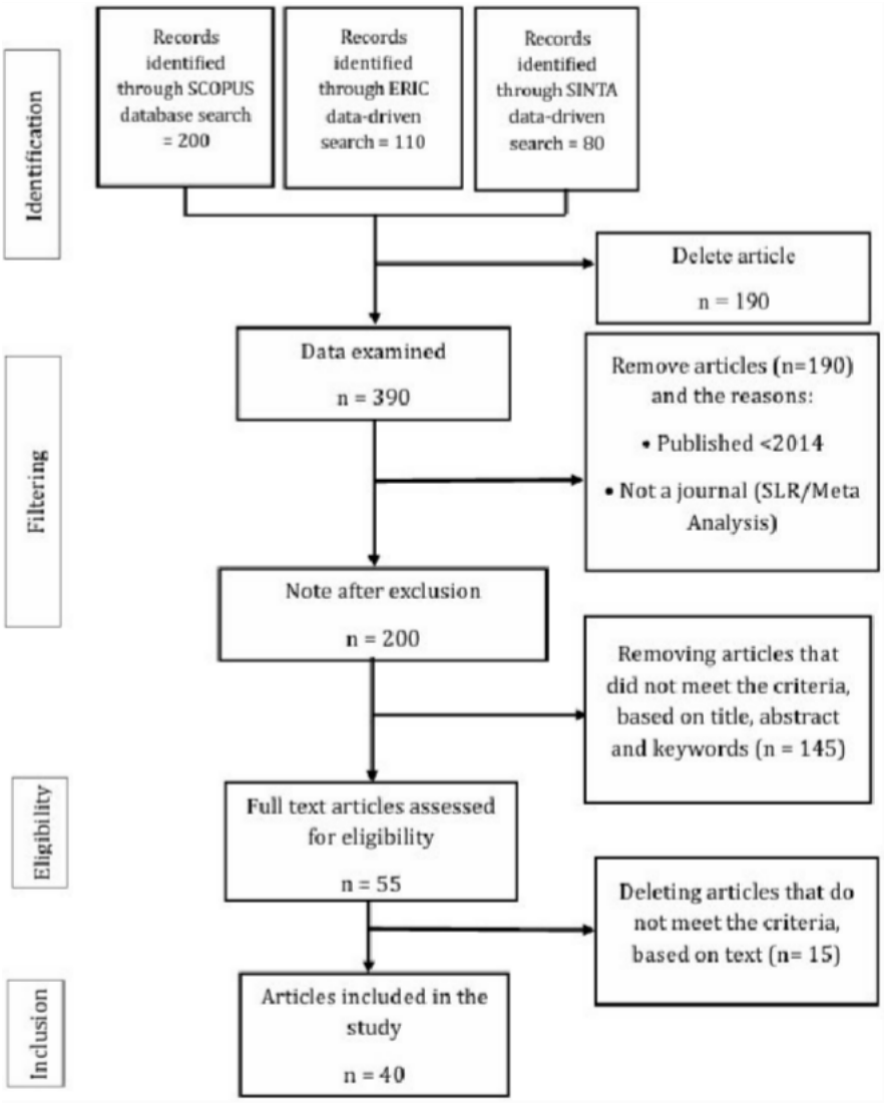

Figure 1. PRISMA Flowchart

After that , at the stage filtering , articles This will chosen more carry on with read abstract and its contents For ensure relevance and quality . This process started with selection . Year selected publications covers from 2014 to 2025 , with objective For ensure that articles found up-to-date and appropriate with development learning physics in schools . After the screening process , the next stage eligibility done For determine whether article the fulfil criteria research that has been set . Articles that don't fulfil criteria will deleted from the list.

Finally , at the stage inclusion , articles selected will analyzed more deep For get findings that can be contribute to development module electronics and flipbooks in learning physics. With approach this , it is hoped study This will produce analysis comprehensive about How the use of STEM in learning physics For increase skills cognitive student in framework education. It is hoped that findings study This will provide useful advice for educator For create material more learning creative. The article will be reviewed chosen using the PRISMA flowchart . The selection process articles that will be reviewed in study This done with follow PRISMA stages, as shown in the figure 1.

After obtained 40 articles that were reviewed and fulfilled criteria inclusion and exclusion , articles the analyzed . Until moment that , a report end prepared . Report end follow PRISMA guidelines in study This from the website, which consists of from the checklist following : (1) title , which in article This is the Integration of STEM in Physics Education and its Impact on Cognitive Skills : *A Systematic-Literature Review* (2014-2025); (2) abstract , which consists of from background background , methods , results , and conclusions from search literature analyzed ; (3) introduction , section This containing objective do review literature , namely For determine whether the use of STEM can increase skills cognitive students ; (4) methods , points This containing information about how the search process works literature conducted , sources and criteria what works as an article filter , and the number articles that will be analyzed . At this stage this, identification articles are also done

use application Integrated PoP with Google Scholar, Scopus, after That articles found filtered using keywords. (5) results , from selection relevant articles , 40 articles were obtained For analysis thematic For grouping findings study based on type skills cognitive studied as well as form STEM integration implemented in learning physics ; (6) discussion , stage This containing review from every articles analyzed , results search article research that has been done previously ; (7) conclusion , stage This is conclusion from article scientific that has analyzed and reviewed .

3. RESULTS AND DISCUSSION

3.1. Results

Review results library systematic This show that STEM integration in education physics give contribution significant to development skills cognitive student (Loof et al., 2022). Findings This consistent with theory constructivism which emphasizes that knowledge built in a way active through experience meaningful

learning . Learning STEM- based provides experience demanding learning student For linking draft physics with context real , so that push the occurrence of cognitive processes level tall (Nor et al., 2016).

Improvement ability think critical and problem solving reported issues in various study show that STEM is effective in shift paradigm learning from teacher- centered become student- centered (Series, 2019)(Evcİm & Arslan, 2021). Through activity based projects and engineering , students involved in a way active in the learning process , starting from planning , implementation , to evaluation . This is in line with objective education modern physics that does not only focused on results Study cognitive , but also on the thinking process scientific .

Although Thus , success STEM implementation is highly dependent on teacher readiness and support system education . Teachers are required For own adequate understanding about integration interdisciplinary as well as ability designing authentic and meaningful learning . Therefore that , training and development professional teachers become aspect crucial in support sustainability implementation of STEM in schools .

3.2. Discussion

3.2.1. Forms of STEM Integration in Physics Learning

STEM integration in education physics done with linking draft physics with problem relevant technology and engineering with life daily (Asrizal et al., 2025)(Asrizal & Ashel, 2023)(Syamra, 2025)(Burrows & Barber, n.d.). For example , the material waves and optics integrated with technology fiber optics , concept electricity and energy associated with generator electricity and energy renewable , as well as material mechanics applied in design tool simple . Approach This push student For No only understand concept , but also apply it in the design and problem solving process problem (Sulistiani et al., 2024)(Series, 2019)(Restanti et al., 2023).

3.2.2. The Impact of STEM Integration on Think Critical

Most of the articles analyzed show that learning physics STEM - based significant increase ability think critical student (W. R. Sari & Prayitno, 2024)(Novia & Dwi, 2023). Activities demanding learning student For identify problems , analyzing data, formulating hypothesis , and evaluate solution push development ability think critical . Improvement This seen on the indicator ability analysis , evaluation , and reasoning logical .

3.2.3. Influence to Understanding Concepts and HOTS

STEM integration is also evident increase understanding draft physics and skills think level high (HOTS) (Restanti et al., 2023)(S. Sari et al., 2021)(Buar & Obiedo, n.d.). Learning based projects and experiments allows student build draft through experience directly , so that draft physics No only understood in a way abstract , but also contextual . Some study report improvement significant on ability analysis , synthesis , and evaluation after implementation STEM (Series, n.d.)(Series, 2023).

3.2.4. Influence to Ability Solution to problem

Ability solution problem is one of the aspect skills the most cognitive investigated in STEM context . Review results show that learning physics effective STEM- based in increase ability student in formulate problem , designing solutions , and testing results in a way systematic . Engineering process in STEM provides framework clear work for student in finish problem complex (Pendidikan et al., 2012)(Restanti et al., 2023)(Nor et al., 2016).

3.2.5. Supporting Factors and Obstacles STEM Implementation

Apart from the impact positive , some The article also identifies factor supporters and obstacles in STEM implementation . Supporting factors covering teacher readiness , availability of media and teaching materials , and support curriculum . Meanwhile that , the obstacles that often reported is limitations means infrastructure , time limited learning , as well as lack of teacher training in designing learning STEM- based [6]

4. CONCLUSION AND RECOMMENDATION

Based on results review library systematic against 40 articles research, can concluded that STEM integration in education physics influential positive to skills cognitive students. Approach This proven effective in increase ability think critical , understanding concepts , HOTS, and skills solution problem . With Thus , learning physics STEM- based worthy For implemented in a way more wide as a learning strategy innovative in increase quality education physics . Research furthermore recommended For study effectiveness STEM integration in quantitative through meta- analysis as well as explore application of STEM in various fields level education and topics different physics.

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