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Systematic literature review: Implementation of STEM-based learning approach on students' interest in biology

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Abstract

Student interest in STEM-based biology learning is essential to support the development of science and technology, yet the trends and dynamics of this interest over seven decades have not been mapped in depth. This study analyzes students' interest in biology learning through the STEM approach over seven decades using Scopus data, offering valuable insights for biology education at all educational levels. The study utilizes a systematic literature review (SLR) method, adapted from the PRISMA model. The SLR findings reveal that interest and persistence in STEM learning peaked in 2022, particularly in Indonesia and the United States. In Indonesia, biology education faces challenges such as outdated curricula, lack of resources, and insufficient teacher training, which decrease student motivation. The STEM approach can address these issues by integrating biology with technology, engineering, and mathematics, allowing students to see real-world applications and enhancing engagement in learning. The study suggests aligning biology education with the STEM approach, which can be applied across all science subjects, making learning more meaningful and boosting students' interest. STEM is included in this SLR due to its importance in education, as it helps engage students in science education and provides supportive conditions for their interests to grow. The ultimate goal is to make science education accessible to all learners in the 21st century, fostering an environment that encourages curiosity, creativity, and critical thinking.

Abstrak. *Minat siswa dalam pembelajaran biologi berbasis STEM sangat penting untuk mendukung perkembangan sains dan teknologi, namun tren dan dinamika minat ini selama tujuh dekade belum dipetakan secara mendalam. Penelitian ini bertujuan untuk menganalisis minat siswa dalam pembelajaran biologi dengan pendekatan STEM selama tujuh dekade, menggunakan data dari Scopus, yang akan memberikan wawasan berharga bagi pendidikan biologi di semua tingkat pendidikan. Penelitian ini menggunakan metode tinjauan literatur sistematis (SLR) yang diadaptasi dari model PRISMA. Hasil SLR ini mengungkapkan beberapa temuan menarik, termasuk fakta bahwa minat dan ketekunan dalam pembelajaran STEM mencapai puncaknya pada tahun 2022, khususnya di Indonesia dan Amerika Serikat. Di Indonesia, pendidikan biologi menghadapi tantangan seperti kurikulum yang sudah ketinggalan zaman, kurangnya sumber daya, dan pelatihan guru yang tidak memadai, yang menurunkan motivasi siswa. Pendekatan STEM dapat mengatasi masalah ini dengan mengintegrasikan biologi dengan teknologi, teknik, dan matematika, sehingga siswa dapat melihat aplikasi di dunia nyata dan meningkatkan keterlibatan dalam pembelajaran. Penelitian ini menyarankan untuk menyelaraskan pendidikan biologi dengan pendekatan STEM, yang dapat diterapkan di semua mata pelajaran sains, membuat pembelajaran lebih bermakna dan meningkatkan minat siswa. STEM dimasukkan dalam SLR ini karena pentingnya STEM dalam pendidikan, karena STEM membantu melibatkan siswa dalam pendidikan sains dan menyediakan kondisi yang mendukung agar minat mereka tumbuh. Tujuan utamanya adalah membuat pendidikan sains dapat diakses oleh semua siswa di abad ke-21, menumbuhkan lingkungan yang mendorong keingintahuan, kreativitas, dan pemikiran kritis.*

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A. Introduction

The emphasis on enhancing the quality of education and equipping youth to tackle upcoming challenges has led to a growing emphasis on science, technology, engineering, and mathematics (STEM) education. Biology, a key discipline within STEM, is pivotal in comprehending natural phenomena and driving practical applications that influence health and the environment. According to Thisgaard & Makransky (2017) STEM education can improve students' analytical and critical skills, which are essential for solving complex problems. Other researchers also added that an integrated learning for help them understand scientific concepts more deeply (Johnson & Elliott, 2020).

Student interest in learning is an important factor that influences success in STEM learning, including biology. According to Goff et al. (2020) showed that students who have a high interest in STEM material tend to be more involved and achieve better results. Curiosity and interest in learning are the main focus of educators in attracting students' attention to learning. STEM consists of 3D involving students and teachers in the learning process, of course this will emphasize that students' interest in biology can improve learning persistence and academic outcomes (Tomperi et al., 2022). Kulshreshtha et al. (2022) highlighted the importance of creating an engaging learning environment to develop students' interests, while Rafanan et al. (2020) showed that innovative teaching strategies can increase students' motivation to learn in STEM fields, Nation & Hansen (2021) and Mikhailova et al. (2022) It was mentioned that creating a curriculum that is pertinent and appropriate can foster students' engagement in the study of biology. Generally, employing the STEM method can significantly influence students' enthusiasm for learning, particularly in the field of biology.

In the study of biology in the context of STEM, research shows that the right approach can improve students' understanding of the material. Nordqvist & Aronsson (2019) It has been determined that implementing project-based learning approaches in the field of biology has the potential to heighten student involvement. Kokkonen & Schalk (2021) and Hiatt et al. (2021) emphasized that the use of technology in biology learning can create a more interactive learning experience. Porter (2017) and Owolabi et al. (2021) showed that integrating biological concepts with real-world issues can increase the relevance of learning for students. In addition, Bernstein et al. (2022) and Christopoulos et al. (2023) also highlighted the significance of cooperation between educators and pupils in establishing a conducive educational atmosphere.

Numerous research projects have been carried out regarding the academic engagement of students in the STEM field. (Hazari et al., 2017) showed that students' interest in science and technology can be influenced by their early experiences that develop into knowledge and skills. Laine et al. (2020) It was also noted that students who participate in extracurricular STEM activities demonstrate an increased level of interest. The research indicated that the correlation between students' personal interest in science and math and academic performance fluctuates. This suggests the need to carefully consider the timing and nature of feedback provided to students with varying levels of interest. Favorable encounters with STEM education can result in heightened student interest in undertaking careers within this field (Balta et al., 2023; Seidelin et al., 2019).

This systematic review of literature aims to investigate the correlation between students' interest in learning and their uptake of biology in the context of STEM education. By analyzing various existing studies, it is expected to provide deeper insights into the interest in learning biology using the STEM approach. Serhan & Almeqdadi (2021) showed that teaching strategies that focus on students' interests can increase their engagement and learning outcomes. The results of this research are anticipated to make a contribution towards the creation of improved and captivating instructional approaches, as well as aid teachers in crafting educational experiences that can enhance student engagement and determination in the field of biology (Seth et al., 2017)

There is a scarcity of SLR on the topics of biology, STEM, and student interest. Only ten review articles pertaining to this research can be found in the Scopus database. These articles have been authored by experts who specialize in this particular area of study. Consequently, the goal of this study is to examine the patterns and extent of STEM enhancement. This SLR is anticipated to make three significant contributions. Firstly, it will aid in identifying and summarizing existing research findings from Scopus journals, thus providing researchers with an insight into the development of trends and study directions. Secondly, the findings of this SLR can serve as a credible resource for educators, policymakers, and academics to develop curricula and programs that integrate the STEM approach with biology education in order to positively influence student interest.

This SLR not only adds to theoretical knowledge, but also has important practical implications for enhancing the quality of education and literacy in the field of biology. Differences in curriculum in various countries, including Indonesia, have an impact on how students are interested in learning. Related to this, as a response to existing developments and policies, there have been many studies with various types of approaches, focuses, and topics, so it is necessary to study the impact, which aspects are strong and which aspects are still weak, so that this can be a consideration (Artika et al., 2021). The author conducted a literature review to

investigate the impact of the STEM approach on students' interest in studying biology. This is done to find out whether the STEM approach has the implementation for students' interest in learning biology.

B. Material and method

This study entails an SLR with the purpose of methodically identifying, evaluating, and analyzing particular research inquiries, subjects, or domains (Chigbu et al., 2023; Newman & Gough, 2020). The focus of the study is on the analysis or identification of STEM approaches to Interest in Biology subjects of students. The data collected came from databases in the last seven years (2017-2024).

There were 96 articles reviewed which were obtained using the keywords STEM approaches, student interests, and biology learning. The selection criteria for the articles reviewed were based on: (1) the focus of the discussion on the analysis of STEM approaches, Student interests and biology learning; (2) publication of articles in the last 7 years (2017-2024), and (3) Scopus indexed journals (Q1-Q4). Systematic literature review includes three stages according to Wahono (2015): planning, conducting and reporting.

1) Planning

Research Question (RQ) is the initial part and the basis for running SLR. RQ is used to guide the search and extraction process from existing literature. A good RQ is one that is useful, measurable, and directed towards understanding the research of a research topic. This study uses Publish or Perish to determine the research topic from the journal found.

2) Conducting

The conducting stage involves carrying out the SLR, following the established SLR Protocol. It begins with selecting the appropriate literature search keywords (search string). Understanding word synonyms is crucial for the accuracy of the search, as is choosing the source (digital library) for the literature search. Since the volume of collected literature can be extensive, it is recommended to use Mendeley to facilitate the management of the literature. Researchers synthesize the data using descriptive narratives.

3) Reporting

Reporting is the stage where the results of the SLR are documented, which will eventually be printed or submitted to a scientific journal. The end goal of this process is to produce a written publication that follows a specific format set by professionals in the field.

C. Results and discussion

This research investigates 96 publications on the STEM method and its impact on students' interest in biology education from 2017 to 2024. The analysis was conducted using the Publish or Perish 8 software database, specifically focusing on Scopus journals. The selected keywords were utilized to gather a comprehensive. The article selection process using in SLR using the PRISMA model can be seen in Figure, and the findings are presented in Table 1, showing an overview of research studies.

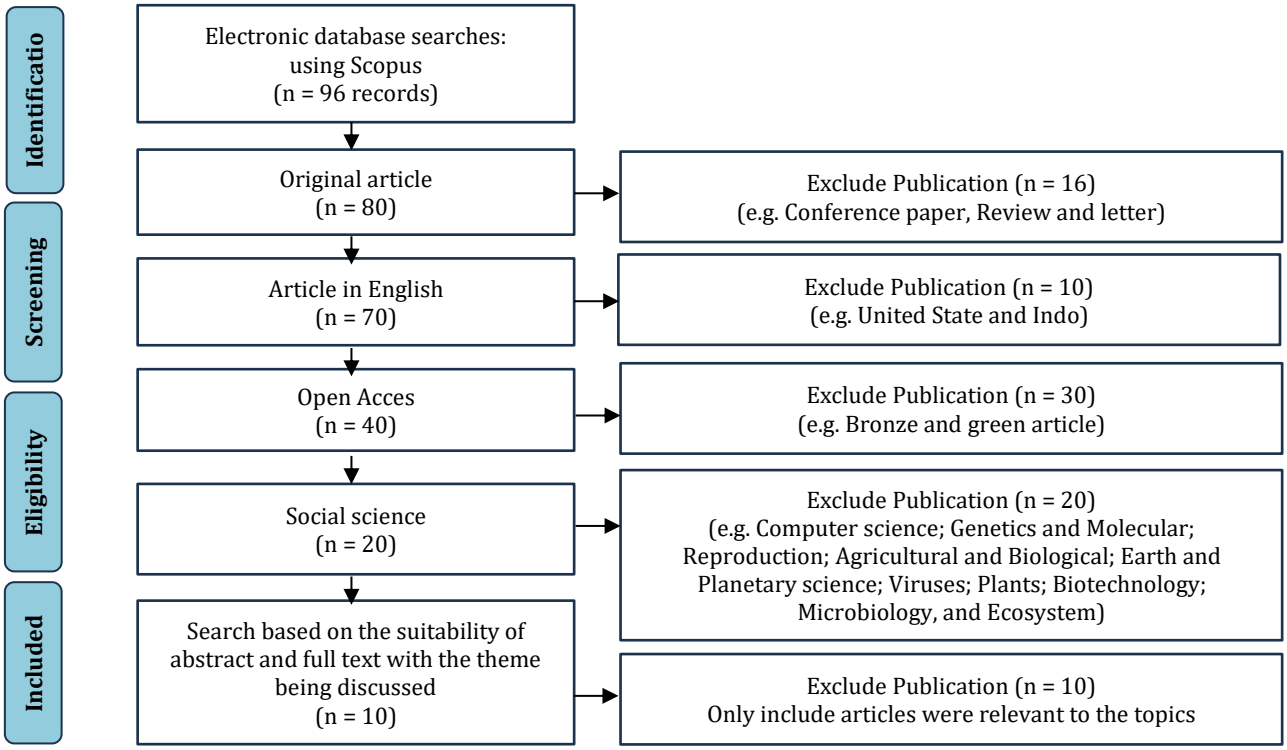

Figure 1 Article selection used in SLR using PRISMA model (Source: Result of PRISMA process)

Table 1 Analyzing an article on the implementation of the STEM approach on students' interest in learning biology

No	Writer	Title and Year	Results
1	Zahra Azhari, Geoff Potwin, Jennifer D. Cribbs, Allison Godwin, Tyler D. Scott & Leidy Klotz	Interest in STEM is Ontagious for Students in Biology, Chemistry, and Physics classes (2017)	The findings showed a significant positive impact of student learning interests on STEM career intentions ($F_{4,2087}$ = 28.2, P < 0.0001) and course performance. Group 4 had the highest likelihood of pursuing STEM careers, with effect sizes ranging from small (Cohen's d = 0.22) to large (Cohen's d = 0.98). Significant differences were also observed in GPA for biology (P < 0.01), chemistry (P < 0.0001), and physics (P < 0.0001). These results emphasize the role of peer interest in improving educational outcomes.
2	Erkka Laine, Marjaana Veermans, Andreas Gegenfurtner & Koen Veermans	Individual Interest and Learning in Secondary school STEM Education (2020)	This study shows that individual student interest in STEM enhances engagement. Interest predicted mid-year grades (β=0.42,p<0.01 β=0.42,p<0.01 in mathematics, β=0.26, p<0.01β=0.26,p<0.01 in biology), while grades influenced end-of-year interest. Learning technology supports teachers in tracking interest and personalizing learning pathways.
3	Derar Serhan & Farouq Almeqdadi	Exploring Middle School Students' Interest and Their Perceptions of the Effect of STEM Education on Their Future Careers (2021)	The study revealed that 68.8% of students were interested in mathematics, while 71.5% favored biology, making it the most popular STEM subject. Additionally, 97.4% agreed that strong scientific knowledge is crucial for career success. This highlights their enthusiasm for STEM and recognition of its importance in enhancing their knowledge and securing better opportunities in the future
4	Deeksha Seth, James Tangorra, Mike Kaczmarczik & Mariah Romaninsky	Comparing High-school Students' Interest and Understanding in Individual versus Integrated Biology and Engineering Topics (2017)	The study revealed that students were highly interested in integrated topics, such as how bees utilize electrostatic forces to gather pollen (mean interest = 2.0) and the gear-like structures that enable planthoppers to jump (mean interest = 1.8). They also demonstrated a strong understanding of natural science concepts, including the process of bees collecting pollen (mean understanding = 2.3), emphasizing the importance of interdisciplinary learning approaches
5	Wiwit Artika, Hendra Yulisman, Mailizar & Cut Intan Evtia Nurina	Analysing students' Feedback: Their Motivations and Interests in STEM-Based Learning (2021)	The study highlights that STEM-based learning successfully engages students by promoting critical thinking and linking concepts to real-life applications. Among 54 students, 85% found STEM beneficial for understanding biological systems, and 78% felt it made lessons more interesting. These findings offer valuable guidance for educators in developing effective STEM-based programs
6	Nuri Balta, Nursultan Japashov , Ainur Karimova, Shakhrizat Agaidarova, Sholpan Abisheva & Patrice Potvin	Middle and High School Girls' Attitude to Science, Technology, Engineering, and Mathematics career Interest across grade levels and school types (2023)	This study highlights the impact of the STEM approach on female students. NIS students showed greater interest in technology (M=3.50) and engineering (M=3.01) compared to public school students (M=3.23 and M=2.78). Additionally, 7th graders exhibited the highest interest in math (M=3.68), outperforming 8th (M=3.37) and 9th graders (M=3.11). Positive correlations were found between STEM grades and career aspirations.

No	Writer	Title and Year	Results
7	Eva Knekta, Ashley A. Rowland, Lisa A. Corwin & Sarah Eddy	Measuring University students' Interest in Biology: Evaluation of an Instrument Targeting Hidi and Renninger's Individual Interest (2020)	This study shows biology majors scored higher than non-biology students on positive feelings (1.10), perceived value (1.13), and re-engagement (0.68) in biology-related activities. These findings highlight the potential of tailored instruments to deepen understanding of student interests in STEM and suggest expanding their use across disciplines
8	Hadi Suwono, Rifka Fachrunnisa, Chokchai Yuenyong & Linda Hapsari	Indonesian Students' Attitude and Interest in STEM: An Out- look on The Gender Stereotypes in The STEM Field Hadi (2019)	This study concludes that focused STEM education development can minimize the influence of factors like family support, finances, friends, teachers, and hobbies. Males showed higher attitudes toward engineering (M=207.44) and technology (M=194.96), while females excelled in science (M=194.11) and showed interest in biology (M=2.74) and social fields (M=3.18). These findings underscore the need for tailored interventions to enhance STEM engagement and graduation rates in Indonesia
9	Pavi Tomperi, Stig Uteng & Saeed Manshadi	Investigation of STEM Subject and Career Aspirations of Lower Secondary School Students in the North Calotte Region of Finland, Norway, and Russia (2022)	In this study, the adapted STEM approach demonstrated satisfactory reliability (Cronbach's alpha = 0.86–0.89). Among 700 students (108 from Finland, 273 from Norway, and 319 from Russia), Finnish students showed the highest interest in chemistry (mean rank = 419.93), while Russian students excelled in technology (mean rank = 400.22). Gender differences were notable, with males scoring higher in physics (mean = 3.28) and technology (mean = 3.57), while females scored higher in biology (mean = 3.01). This instrument provides valuable data for schools to understand students' STEM interests.
10	Elena A. Mikhailova, Grayson Younts & Christoper Post	Connecting Students' Interests to a Learning Context: The Case of Ecosystem Services in STEM Education (2022)	This research emphasizes the significance of connecting students' interests with the learning environment. Through an online quiz (average score: 7.0/9), students demonstrated substantial growth in their understanding of ecosystem services (+39.4%) and soil inorganic carbon (+44.7%). The laboratory activities successfully deepened students' comprehension of soil pH and its ecosystem benefits, offering valuable insights for both their personal growth and future careers.

This research conduct collection and analysis ten articles about the effects of STEM-based learning approaches on students' interest in biology. These analyses show that many groups of primary and secondary education levels vary in curriculum design, discipline, sample characteristics, duration and intensity of treatment implementation, and different control groups. Activities can be used that are part of the modules and are included in the biology study.

Callaghan et al. (2020), the results of our analyses found that STEM-based learning approaches can influence the interest and learning outcomes of primary and secondary education students. These results have implications for the use of STEM-based pedagogy and inquiry-based modules (Caliskan & Pehlivan, 2024). Donowarti (2024) The new curriculum currently used in schools refers to 21st century ideals, and STEM is an effort to equip students to be smarter and more interested in STEAM. In addition to imparting many concepts, STEM can also instill an attitude of learning with a product-oriented approach, thus creating a positive character in the field of science, especially biology. However, in practice, the collection of STEM-based curricula and their impact must be known, and to date, there are many barriers between schools and policymakers, and there are not yet many supports in the school itself, such as from instruments and teachers (Costello et al., 2020).

The importance of STEM in the 21st century must be equated with supporting STEM learning in schools. Some subjects related to the importance of STEM are engineering and biology. Therefore, teaching

activities must carry out the principles of STEM distributions correctly. The method in STEM learning also affects the interest in learning and how students understand learning (Ardianti et al., 2020). Given that STEM has a different concept from the existing curriculum, a review of the revision reveals a different view, such as the provision of detailed research material and a review of the development process of the STEM program itself (Knekta et al., 2020). Our SLR to date have not found reviews similar to the researchers mentioned above, in all of the databases already owned. The results of the review are indeed in favor of the effectiveness of STEM in a module or learning approach to student interest, especially in biology, as shown by the regression coefficient between the pre-and post-evaluation scores in integrated climatology and ecosystem questioning modules, and low-inference concept tests in the same field, which have a model of coefficient of determination. Therefore, it is better if the studies reviewed or further resignations are tested between studies with subjects that are not managed by the same research team, although the sample is in one city, but the personality is different so that the basis for inference is not the same as the inferential tests available (Annweiler et al., 2020).

Implications for Practice

The findings indicate several implications for educational practice. This review recommends providing students with the opportunity to make links with real-world biological applications, creating a focus on practical as well as theoretical work in science, thereby creating experiential learning (Weng et al., 2020). To conduct these practical activities out of school, permission is needed from these organizations, and it is therefore important that these collaborators also see the benefit of working with students. Further support from their governing body to link with schools also supports ethical considerations with regard to these potential issues. In addition, students who feel included and see the relevance of what they are learning are more likely to participate, be engaged, and successful. This calls for teachers to have access to training, resources, and supportive ongoing communication, networking, and reflection opportunities to investigate the value of developing new interdisciplinary practice (Affouneh et al., 2020).

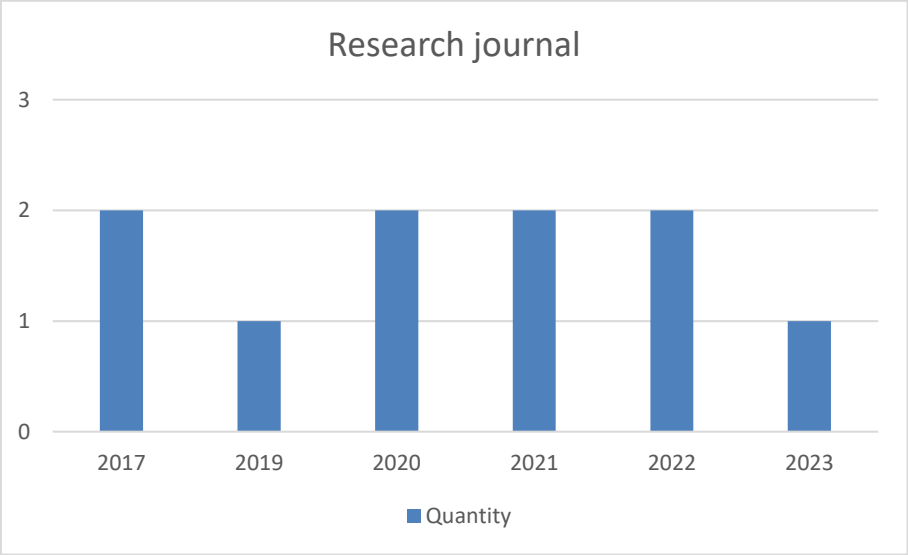

Figure 2 Article selection with graphics

Figure 2 shows a selection of articles published each year that measure student interest in biology lessons. To ensure that STEM-based strategies can be adopted effectively, however, it requires that both staff and researchers produce evidence of the impact of such interventions (Cohn et al., 2024). There is the potential loss of motivation and trust of participants if professional development and training are not valued and indeed require ongoing validation. Furthermore, it is necessary that school science will primarily be linked to the development of future potential scientists, and therefore we need to be culturally inclusive, make it practical and fun, but also attend to equity issues if the strategies and focus are not to be seen by students as elitist. To do this requires effective initial and ongoing assessment with an understanding of the students from diverse backgrounds and how their learning needs may differ. Cross-curriculum collaboration requires ongoing reflection and adjustments, supporting teachers as well as external professionals in developing good, flexible evidence-based practice (Attard et al., 2021). This recommends a synergy of both approaches for value, meaning, and reproducibility. Collaboration for data and sharing with other schools is also recommended to assist validation and create access for all rather than just those with the necessary contacts.

Future Research Directions

The SLR revealed a lack of longitudinal studies that assess the lasting effects of STEM interventions on students' interest in biology. Therefore, it is essential for future research to focus on understanding the long term impact of these initiatives. Additionally, there is a gap in research comparing the effectiveness of different STEM approaches. Conducting comparative studies would be valuable in determining whether a specific STEM method leads to higher or varied levels of student engagement (Callaghan et al., 2020). Furthermore, it would be beneficial to examine differences across socio-demographically diverse populations. The geographical scope of existing research has been predominantly centered on schools and colleges in Western countries, making it difficult to generalize these findings to non-Western contexts. Further studies should aim to involve educators from these regions, such as Indonesia, to validate and diversify the findings (Slayi et al., 2023).

In addition, the use of digital tools in supporting STEM methods has not been thoroughly explored. Investigating how digital technologies can facilitate the implementation of STEM in biology education could offer a valuable perspective on the current review (Bybee, 2013). In Indonesia, while the use of digital tools in education is growing, there remains limited research on their specific impact within STEM-based biology teaching. Research should look into how tools like virtual laboratories, simulations, and educational apps can engage students and improve their understanding of biological concepts, especially considering the varying levels of access to technology across different regions, including rural areas. The influence of parental and community involvement on students' attitudes and interests is also significant, and future studies should use mixed-methods approaches to assess how this support shapes students' interest in biology. Many STEM-biology interventions have involved direct connections between teachers and industry, aiming to engage parents and families in the educational process (Miller & Downey, 2020).

The role of parents is critical, particularly in terms of their socio-demographic and educational background as well as their employment status. In the Indonesian context, parental support significantly impacts students' academic interests, especially in regions where educational resources may be limited. Understanding the experiences and interests of parents in biology is an important aspect of this research. Acknowledging the involvement of both parents and the broader community is better achieved through mixed-methods approaches, which allow for the inclusion of diverse perspectives from multiple cohorts. Collaborative research between education experts and biology educators can enhance the quality of education, fostering innovative solutions. Additionally, research on how STEM education influences interest in biology should involve cross-disciplinary collaborations between researchers, educators, and industry professionals. For instance, studies in Indonesia could investigate how partnerships between schools, industry stakeholders, and families are integrated into biology education, providing students with real-world applications of biological knowledge (Lee & Clinedinst, 2020).

D. Conclusion

The current study systematically reviewed previous research to uncover the influence of a STEM-based learning approach on students' interest in learning biology. The findings have uncovered the significance of developing learning strategies, especially in biology, that engage students and develop their interest in the subject. Results have shown that the implementation of STEM in education significantly increases students' interest in learning biology. Specifically, it was found that the STEM-based approach with a duration of longer than 6 hours provided stronger effects. The collaboration of an inclusive and social learning approach was also found to further enhance students' intrinsic motivation and enjoyment in learning, the method to illustrate the impact of certain teaching strategies on students' interest in subjects. In light of these observations, educators are recommended to integrate a teaching approach that encourages active participation while also facilitating an inclusive classroom culture. This foundational work raises important questions and draws attention to the differences that exist in the targets of these sorts of impacts. Subsequent research should be conducted into developing methods that deepen understanding in this space. This underlines the need for identification of what is helping develop this interest in learning, in this case through biology. STEM can support young people to enjoy science learning, providing strong conditions that support their opportunities to flourish. In order for science education to be accessible to all 21st-century learners, systemic changes need to be made to ensure that all students can gain benefits from learning.

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F. References

Affouneh, S., Salha, S., Burgos, D., Khlaif, Z. N., Saifi, A. G., Mater, N., & Odeh, A. (2020). Factors that foster and deter STEM professional development among teachers. *Science Education*, *104*(5), 857–872. DOI:

https://doi.org/10.1002/sce.21591

Annweiler, C., Beaudenon, M., Gautier, J., Simon, R., Dubée, V., Gonsard, J., Parot-Schinkel, E., Aidoud, A., Albaret, G., Annweiler, C., Audemard-Verger, A., Asfar, M., Barré, J., Berteau, F., Bertoletti, G., Beuscart, J. B., Bigot, A., Boucher, S., Botelho-Nevers, E., … Vandamme, Y. M. (2020). Covid-19 and high-dose vitamin D supplementation TRIAL in high-risk older patients (COVIT-TRIAL): study protocol for a randomized controlled trial. *Trials*, *21*(1), 1–10. DOI: https://doi.org/10.1186/s13063-020-04928-5

Ardianti, S., Sulisworo, D., Pramudya, Y., & Raharjo, W. (2020). The impact of the use of STEM education approach on the blended learning to improve student's critical thinking skills. *Universal Journal of Educational Research*, *8*(3B), 24–32. DOI: https://doi.org/10.13189/ujer.2020.081503

Artika, W., Mailizar, M. Handayani, D., Yulisman, H., & Nurina, C. I. E. (2021, May). Analysing students' feedback: Their motivations and interests in STEM-based learning. In *Journal of Physics: Conference Series* (Vol. 1882, No. 1, p. 012149). IOP Publishing. DOI: https://doi.org/10.1088/1742-6596/1882/1/012149

Attard, C., Berger, N., & Mackenzie, E. (2021). The positive influence of inquiry-based learning teacher professional learning and industry partnerships on student engagement with STEM. *Frontiers in Education*, *6*(August), 1–14. DOI: https://doi.org/10.3389/feduc.2021.693221

Balta, N., Japashov, N., Karimova, A., Agaidarova, S., Abisheva, S., & Potvin, P. (2023). Middle and high school girls' attitude to science, technology, engineering, and mathematics career interest across grade levels and school types. *Frontiers in Education*, *8*(May), 1–13. DOI: https://doi.org/10.3389/feduc.2023.1158041

Bernstein, D., Puttick, G., Wendell, K., Shaw, F., Danahy, E., & Cassidy, M. (2022). Designing biomimetic robots: iterative development of an integrated technology design curriculum. *Educational Technology Research and Development*, *70*(1), 119–147. DOI: https://doi.org/10.1007/s11423-021-10061-0

Bybee, R. W. (2013). The case for education: STEM challenges and opportunities. *NSTA (National Science Teachers Assocation)*, 33–40. Retrieved from www.nsta.org/permissions.

Çalışkan, C., & Şenler, B. (2024). Enhancing 21st-century skills, STEM attitudes, and career interests through stem-based teaching: A primary school intervention study. *International Primary Education Research Journal*, *8*(2), 221-232. DOI: https://doi.org/10.38089/iperj.2024.177

Callaghan, N. I., Jose, M., Cadavid, L., Huntley, M., Chang, H., Ivanov, M. N., Rubianto, M. J., & Davenport Huyer, L. (2020). *Discovery: Differential student impact is evident within an inquiry-focused secondary/post-secondary collaborative STEM program (Evaluation) PhD student in biomedical engineering working on tissue engineered immune-oncology models*.

Chigbu, U. E., Atiku, S. O., & Du Plessis, C. C. (2023). The science of literature reviews: Searching, identifying, selecting, and synthesising. *Publications*, *11*(1), 1-16. DOI: https://doi.org/10.3390/publications11010002

Christopoulos, A., Pellas, N., Bin Qushem, U., & Laakso, M. J. (2023). Comparing the effectiveness of video and stereoscopic 360° virtual reality-supported instruction in high school biology courses. *British Journal of Educational Technology*, *54*(4), 987–1005. DOI: https://doi.org/10.1111/bjet.13306

Cohn, C., Snyder, C., Fonteles, J. H., Ashwin, T. S., Montenegro, J., & Biswas, G. (2024). A multimodal approach to support teacher, researcher and AI collaboration in STEM+C learning environments. *British Journal of Educational Technology*, *May*, 1–26. DOI: https://doi.org/10.1111/bjet.13518

Costello, E., Girme, P., McKnight, M., Brown, M., & ... (2020). *Government responses to the challenge of STEM education: case studies from Europe*. Retrieved from http://doras.dcu.ie/25150/1/STEM Education Policy Europe.pdf

Donowarti, I. (2024). Research trends related to Beluntas (Pluchea indica L.) in Indonesia during and post covid-19 based on scopus database. *Jurnal Biolokus: Jurnal Penelitian Pendidikan Biologi dan Biologi*, *7*(1), 1–18. DOI: http://dx.doi.org/10.30821/biolokus.v7i1.3599

Goff, E. E., Mulvey, K. L., Irvin, M. J., & Hartstone-Rose, A. (2020). The effects of prior informal science and math experiences on undergraduate STEM identity. *Research in Science and Technological Education*, *38*(3), 272–288. DOI: https://doi.org/10.1080/02635143.2019.1627307

Hazari, Z., Potvin, G., Cribbs, J. D., Godwin, A., Scott, T. D., & Klotz, L. (2017). Interest in STEM is contagious for students in biology, chemistry, and physics classes. *Science Advances*, *3*(8), 1–8. DOI: https://doi.org/10.1126/sciadv.1700046

Hiatt, A. C., Hove, A. A., Ward, J. R., Ventura, L., Neufeld, H. S., Boyd, A. E., Clarke, H. D., Horton, J. L., & Murrell, Z. E. (2021). Authentic research in the classroom increases appreciation for plants in undergraduate biology students. *Integrative and Comparative Biology*, *61*(3), 969–980. DOI: https://doi.org/10.1093/icb/icab089

Johnson, A., & Elliott, S. (2020). Culturally relevant pedagogy: A model to guide cultural transformation in STEM departments. *Journal of Microbiology & Biology Education*, *21*(1), 1–12. DOI: https://doi.org/10.1128/jmbe.v21i1.2097

Knekta, E., Rowland, A. A., Corwin, L. A., & Eddy, S. (2020). Measuring university students' interest in biology: evaluation of an instrument targeting Hidi and Renninger's individual interest. *International*

Journal of STEM Education, *7*(1), 1-16. DOI: https://doi.org/10.1186/s40594-020-00217-4

Kokkonen, T., & Schalk, L. (2021). One instructional sequence fits all? A conceptual analysis of the applicability of concreteness fading in mathematics, physics, chemistry, and biology education. *Educational Psychology Review*, *33*(3), 797–821. DOI: https://doi.org/10.1007/s10648-020-09581-7

Kulshreshtha, P., Gupta, S., Shaikh, R., Aggarwal, D., Sharma, D., & Rahi, P. (2022). Foldscope embedded pedagogy in stem education: A case study of SDG4 promotion in India. *Sustainability (Switzerland)*, *14*(20), 13427. DOI: https://doi.org/10.3390/su142013427

Laine, E., Veermans, M., Gegenfurtner, A., & Veermans, K. (2020). Individual interest and learning in secondary school stem education. *Frontline Learning Research*, *8*(2), 90–108. DOI: https://doi.org/10.14786/FLR.V8I2.461

Lee, S., & Clinedinst, L. S. (2020). Mathematical biology: expand, expose, and educate! *Bulletin of Mathematical Biology*, *82*(9), 1–15. DOI: https://doi.org/10.1007/s11538-020-00796-x

Mikhailova, E. A., Post, C. J., Younts, G. L., & Schlautman, M. A. (2022). Connecting students' interests to a learning context: The case of ecosystem services in STEM education. *Education Sciences*, *12*(5), 318. DOI: https://doi.org/10.3390/educsci12050318

Miller, R. A., & Downey, M. (2020). Examining the STEM climate for queer students with disabilities. *Journal of Postsecondary Education and Disability*, *33*(2), 169–181. Retrieved from https://eric.ed.gov/?id=EJ1273676

Nation, J. M. B., & Hansen, A. K. (2021). Perspectives on community STEM: Learning from partnerships between scientists, researchers, and youth. *Integrative and Comparative Biology*, *61*(3), 1055–1065. DOI: https://doi.org/10.1093/icb/icab092

Newman, M., & Gough, D. (2020). Systematic Reviews in Educational Research. In *Systematic Reviews in Educational Research*. DOI: https://doi.org/10.1007/978-3-658-27602-7

Nordqvist, O., & Aronsson, H. (2019). It is time for a new direction in biotechnology education research. *Biochemistry and Molecular Biology Education*, *47*(2), 189–200. DOI: https://doi.org/10.1002/bmb.21214

Owolabi, O. A., Ladeji-Osias, J., Shokouhian, M., Alamu, O. S., Lee, S. W., Oguntimein, G. B., Ariyibi, A., Lee, H. J., Bista, K., Dugda, M. T., Ikiriko, S., & Chavis, C. (2021, July). Best practices for the implementation of home-based, hands-on lab activities to effectively engage STEM students during a pandemic. In *2021 ASEE Virtual Annual Conference*. DOI: https://doi.org/10.18260/1-2--36744

Porter, A. (2017). Biopatterning of keratinocytes in aqueous two-phase systems as a potential tool for skin tissue engineering. *MRS Advances*, *357*(May), 1–8. DOI: https://doi.org/10.1557/adv.201

Rafanan, R. J. L., De Guzman, C. Y., & Rogayan, D. V. (2020). Pursuing stem careers: Perspectives of senior high school students. *Participatory Educational Research*, *7*(3), 38–58. DOI: https://doi.org/10.17275/per.20.34.7.3

Seidelin, L., Albrechtsen, T. R. S., Schöps, K., Holmer, M., & Wahlberg, M. (2019). Does teaching about artificial reefs trigger students' situational interest in marine biology? *Journal of Biological Education*, *55*(3), 264–275. DOI: https://doi.org/10.1080/00219266.2019.1679659

Serhan, D., & Almeqdadi, F. (2021). Exploring middle school students' interest and their perceptions of the effect of STEM education on their future careers. *International Society for Technology, Education, and Science*, *7*(1), 1–10. Retrieved from https://eric.ed.gov/?id=ED623629

Seth, D., Tangorra, J., Kaczmarczik, M., & Romaninsky, M. (2017). Comparing high-school students' interest and understanding in individual versus integrated biology and engineering topics. *ISEC 2017 - Proceedings of the 7th IEEE Integrated STEM Education Conference*, *October*, (pp. 113–120). DOI: https://doi.org/10.1109/ISECon.2017.7910225

Slayi, M., Zhou, L., & Jaja, I. F. (2023). Exploring farmers' perceptions and willingness to tackle drought-related issues in small-holder cattle production systems: a case of rural communities in the eastern cape, South Africa. *Applied Sciences*, *13*(13), 7524. DOI: https://doi.org/10.3390/app13137524

Thisgaard, M., & Makransky, G. (2017). Virtual learning simulations in high school: Effects on cognitive and non-cognitive outcomes and implications on the development of STEM academic and career choice. *Frontiers in Psychology*, *8*(MAY), 1–13. DOI: https://doi.org/10.3389/fpsyg.2017.00805

Tomperi, P., Kvivesen, M., Manshadi, S., Uteng, S., Shestova, Y., Lyash, O., Lazareva, I., & Lyash, A. (2022). Investigation of STEM Subject and career aspirations of lower secondary school students in the North Calotte Region of Finland, Norway, and Russia. *Education Sciences*, *12*(3), 192. DOI: https://doi.org/10.3390/educsci12030192

Wahono, R. S. (2015). A systematic literature review of software defect prediction: Research trends, datasets, methods and frameworks. *Journal of Software Engineering*, *1*(1), 1–16. Retrived from http://journal.ilmukomputer.org/index.php/jse/article/view/47

Weng, C., Otanga, S., Christianto, S. M., & Chu, R. J. C. (2020). Enhancing students' biology learning by using augmented reality as a learning supplement. *Journal of Educational Computing Research*, *58*(4), 747–770. DOI: https://doi.org/10.1177/0735633119884213