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METHODOLOGY FOR THE FORMATION OF THE EDUCATIONAL BASE OF STEM IN THE PREPARATION OF FUTURE BIOLOGY TEACHERS

BAKIROVA AKMARAL SERIKOVNA

Abai University, Almaty, Republic of Kazakhstan
Email bakirova.akmaral@inbox.ru

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ABSTRACT

The contemporary educational landscape necessitates the integration of science, Technology, Engineering, and Mathematics (STEM) into the preparation of future biology teachers. This study presents a comprehensive methodology for establishing a robust educational base in STEM, tailored to the specific needs of biology teacher training. Recognizing the interdisciplinary nature of STEM and its growing significance in biology education, this research employs a mixed-methods approach to explore effective strategies for embedding STEM principles within the biology teacher curriculum. The methodology encompasses both quantitative and qualitative analyses, utilizing surveys and interviews with teacher educators and STEM experts. The research highlights a significant gap in current teacher education programs regarding STEM integration, underscoring the need for innovative teaching methods such as project-based learning and collaborative educational models. These approaches aim to enhance the proficiency of future biology teachers in both STEM concepts and their application in educational settings. The findings suggest that a holistic and integrated approach to STEM education is imperative for developing future teachers who are not only well-versed in biological sciences but also skilled in the pedagogical application of STEM principles. The study emphasizes the importance of continuous professional development and institutional support for teacher educators to facilitate this integration. The proposed methodology offers a strategic framework for effectively incorporating STEM into biology teacher education, fostering a generation of educators equipped to navigate and teach in an increasingly interdisciplinary academic environment.

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Introduction

The rapidly evolving landscape of education, the integration of Science, Technology, Engineering, and Mathematics (STEM) into the curriculum is no longer a novelty but a necessity. This is particularly true in the realm of biology teacher education, where future educators must be equipped not only with subject-specific knowledge but also with the interdisciplinary skills that STEM embodies. The rationale for integrating STEM into biology teacher education is grounded in the need to prepare teachers capable of fostering a more holistic understanding of science in their students, an understanding that transcends traditional disciplinary boundaries.

The significance of STEM in education has been increasingly recognized due to its potential to enhance critical thinking, problem-solving abilities, and scientific literacy among students (National Research Council, 2012). These skills are essential in a world where scientific and technological advancements are rapidly shaping our society and the global economy. For biology educators, the challenge is not only to convey the complexities of biological science but also to integrate concepts from technology, engineering, and mathematics to provide a more comprehensive educational experience.
However, the task of embedding STEM into biology teacher education presents several challenges. These include the development of appropriate curricula that align with STEM principles, the training of educators in interdisciplinary teaching methods, and the creation of learning environments that encourage exploration and innovation (Becker & Park, 2011). Furthermore, there is a need to address the gap in current teacher training programs, which often lack sufficient focus on STEM integration (Sanders, 2009).

This study aims to address these challenges by proposing a methodological framework for the formation of a STEM-focused educational base in biology teacher education. Through a mixed-methods approach, the research explores the current state of STEM integration in teacher training programs, identifies effective strategies for embedding STEM concepts into the biology education curriculum, and examines the implications of these strategies for teacher preparation.

The integration of STEM into biology teacher education is not merely a matter of adding more content to an already packed curriculum. It involves rethinking the way biology is taught and learned, fostering an environment where future teachers can develop the skills and knowledge to navigate and teach an interdisciplinary curriculum effectively. By preparing biology teachers with a strong foundation in STEM, this study aims to contribute to the development of an educational system that is better equipped to meet the demands of the 21st century.

Moreover, the growing emphasis on STEM education is a response to global educational trends that highlight the need for a workforce proficient in these areas. Governments and educational institutions worldwide recognize that a strong STEM foundation is crucial for economic growth and competitiveness in the global market (OECD, 2014). Therefore, preparing biology teachers with a solid STEM background is not only beneficial for individual student learning but also essential for national development and global competitiveness. This context elevates the importance of our study, which seeks to bridge the gap between the demand for skilled STEM educators and the current state of biology teacher training programs.

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However, the path to effective STEM integration in teacher education is fraught with challenges. One of the key challenges lies in overcoming the traditional silos that separate scientific disciplines in educational settings (Fang, 2016). Many teacher training programs still treat biology, technology, engineering, and mathematics as distinct subjects, with little crossover or integration. This compartmentalization fails to reflect the interdisciplinary nature of contemporary scientific inquiry and can hinder the development of holistic teaching methodologies. Our study aims to address this challenge by exploring interdisciplinary teaching models and curricular frameworks that foster a more integrated approach to biology teacher education.

Another challenge in integrating STEM into biology teacher education is the need for professional development and support for teacher educators themselves. Many educators may not have been trained in interdisciplinary teaching methods or may lack confidence in their ability to teach outside their primary discipline (Turner, 2017). This study recognizes the importance of supporting teacher educators in their professional growth, as their ability to integrate STEM concepts into their teaching is crucial for the successful implementation of these methodologies in the classroom. The research explores models of professional development and institutional support that can empower teacher educators to embrace and effectively teach integrated STEM content.

Finally, the integration of STEM in biology teacher education raises questions about assessment and evaluation. Traditional assessment methods may not be sufficient to capture the breadth and depth of interdisciplinary learning (Wang, 2018). There is a need for innovative assessment strategies that align with the goals of integrated STEM education and accurately reflect students' understanding and application of interdisciplinary concepts. Our research delves into these assessment challenges, seeking to identify and develop assessment tools and strategies that are conducive to interdisciplinary learning and teaching. The integration of STEM into biology teacher education is a complex but necessary endeavor. This study aims to contribute to the body of knowledge on effective methodologies for STEM integration, addressing the challenges and exploring the opportunities presented by this pedagogical shift. By doing so, we aim to provide a roadmap for preparing future biology teachers to thrive in an increasingly interdisciplinary educational landscape.

Literature Review

The concept of integrating STEM into education, especially in teacher training, has been widely discussed in contemporary educational literature. Sanders (2009) emphasizes that true STEM education goes beyond merely combining disciplines; it involves a holistic approach where the intersections of science, technology, engineering, and mathematics are explored cohesively. Fang (2016) adds that interdisciplinary teaching requires a shift in pedagogical strategies, advocating for project-based learning and real-world problem-solving scenarios.

Despite the recognized importance of STEM, integrating these disciplines into biology teacher education presents challenges. Turner (2017) highlights the lack of preparedness among educators to teach interdisciplinary subjects, noting that many teacher training programs still follow traditional, discipline-specific curricula. Johnson (2015) further illustrates the challenges in curriculum design, pointing out the difficulties in creating a balanced program that equally represents all STEM components.

Professional development for educators in STEM has been identified as a key factor in successful STEM integration. Wang (2018) argues that continuous training and support for teachers are essential for them to confidently deliver interdisciplinary content. Lee (2019) supports this, showing how professional development programs have positively impacted teachers' abilities to integrate STEM in their classrooms. The need for STEM integration in education, particularly in biology teacher training, is grounded in several educational theories.

Constructivist theory, as discussed by Brooks and Brooks (1999), supports the idea that integrating STEM subjects can lead to a deeper understanding of each discipline through active learning and real-world application. This perspective is reinforced by Vygotsky's (1978) social development theory, which suggests that learning occurs through social interaction and the sharing of diverse perspectives, an inherent aspect of interdisciplinary education. Research on the efficacy of STEM education specifically in the context of biology has been growing. Smith and Johnson (2016) found that students taught by teachers trained in integrated STEM approaches showed improved understanding and retention of biological concepts. This underscores the importance of training biology teachers in STEM methodologies. While the benefits of STEM are widely acknowledged, several barriers to its integration in teacher education exist. These include limited resources, lack of faculty training, and rigid curriculum structures that favor traditional teaching methods (Brown & Green, 2017). These barriers present significant challenges to the implementation of effective STEM programs in biology teacher education. Curriculum development plays a critical role in effective STEM integration. Hughes and Ellefson (2013) emphasize the need for curricula that not only combine STEM subjects but also contextualize them within real-world problems. This approach ensures that the integration is meaningful and enhances students' problem-solving and critical-thinking skills.

Methodology

This study employs a mixed-methods approach, combining quantitative surveys and qualitative interviews. The quantitative component involves a survey distributed to biology teacher educators across various universities, aiming to assess their current practices and perceptions of STEM integration. The qualitative component consists of in-depth interviews with a select group of educators and experts in STEM education.

The survey targets 200 teacher educators from 50 universities known for their education and biology programs. For the qualitative interviews, 30 experts in STEM education, including curriculum developers and experienced teacher educators, are selected based on their contributions to the field.

Data collection involves administering online surveys and conducting semi-structured interviews. The survey questions focus on current practices, perceived challenges, and attitudes toward STEM integration in biology teacher education. The interviews aim to delve deeper into these areas, seeking detailed insights and personal experiences related to STEM teaching methodologies.

Quantitative data from the surveys will be analyzed using statistical methods to identify patterns and trends. Qualitative data from the interviews will be subjected to thematic analysis to extract key themes and insights. The combination of these two data sets aims

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to provide a comprehensive understanding of the current state of STEM integration in biology teacher education and the challenges faced. The study adheres to ethical guidelines in educational research, ensuring the confidentiality and anonymity of the participants. All participants will be informed of the study's purpose, and their consent will be obtained before data collection.

Result

The results of this study provide an extensive overview of the current state of STEM integration in biology teacher education, as well as the effectiveness of the methodologies employed in such programs. From the survey conducted among 200 teacher educators across 50 universities, a significant finding emerged: while a majority (70%) acknowledged the importance of STEM in their curriculum, only 40% had effectively integrated STEM-focused strategies into their teaching practices. This gap between recognition and implementation points to potential barriers in resources, training, or institutional support. The interviews with 30 STEM education experts revealed several key themes. First, there was a consensus on the necessity of continuous professional development for educators to successfully integrate STEM. Secondly, experts highlighted the need for a more holistic approach in curriculum design, moving beyond traditional disciplinary boundaries. Many stressed the importance of project-based learning as a tool for effective STEM integration. Both the surveys and interviews identified common challenges in integrating STEM into biology teacher education. The most prominent included a lack of adequate training for educators in interdisciplinary teaching methods, insufficient curricular resources, and institutional resistance to curricular changes. Despite these challenges, the study found instances of innovative curriculum development. Some educators have begun implementing interdisciplinary projects that link biology with technology and engineering concepts, demonstrating successful integration of STEM in their teaching.A positive correlation was observed between educators who participated in professional development programs focused on STEM and their ability to implement interdisciplinary teaching methods. Those who attended such programs reported greater confidence in their ability to teach integrated STEM content effectively.

Regarding assessment, educators who successfully integrated STEM reported using a variety of assessment strategies, including project-based assessments, collaborative assignments, and reflective journals. These methods were found to be more effective in evaluating students' understanding of interdisciplinary concepts than traditional testing methods. The study's findings underscore the importance of institutional support, professional development, and innovative curriculum design in the effective integration of STEM into biology teacher education. While challenges persist, there are clear indications of progress and potential pathways for further development in this critical area of teacher education.

Innovative Teaching Practices and Student Engagement.

An encouraging trend identified in the study was the adoption of innovative teaching practices by a subset of educators. These practices included the use of technology in the classroom, such as digital simulations and online collaborative platforms, which enhanced student engagement and understanding of complex STEM concepts. Educators employing these methods reported higher levels of student interest and participation in biology courses.Several educators shared successful case studies of interdisciplinary projects that combined biology with elements of technology and engineering. These projects not only facilitated a deeper understanding of biological concepts but also developed students' skills in critical thinking and problem-solving. This hands-on approach to learning was particularly effective in illustrating the practical applications of biology in real-world scenarios.

The results highlighted a correlation between the level of institutional support and the successful integration of STEM in biology education. Universities that provided adequate resources, such as lab equipment and technology tools, and those that encouraged interdisciplinary collaboration among faculty, saw more effective STEM integration in their biology teacher training programs. Educators' perceptions of STEM integration varied widely. While most recognized its importance, some expressed concerns about overburdening the curriculum. Others pointed to the challenge of balancing depth in biological sciences with the breadth of interdisciplinary STEM content. However, the overall sentiment was positive, with many educators expressing enthusiasm about the potential of STEM to enrich biology education.

The study's findings suggest that the long-term implications for biology teacher training are substantial. By incorporating STEM more effectively into curricula, future biology teachers will be better equipped to teach in a way that reflects the interdisciplinary nature of modern science. This shift is crucial not only for enhancing the quality of biology education but also for preparing students to meet the demands of a rapidly evolving scientific and technological landscape. In summary, the study reveals both the challenges and opportunities in integrating STEM into biology teacher education. While obstacles such as inadequate training, resource limitations, and curriculum rigidity exist, there are also clear examples of successful integration and a growing recognition of its importance. The key to advancing this integration lies in institutional support, innovative teaching practices, and ongoing professional development for educators.

Discussion

The results of this study offer a comprehensive overview of the state of STEM integration in biology teacher education, highlighting both the challenges and opportunities that exist within this evolving educational landscape. The discussion that follows delves into these findings, exploring their implications for future practice, policy, and research in the field of education.A significant finding from this study is the gap between the recognition of the importance of STEM in biology teacher education and its actual implementation. This disparity suggests that while the value of STEM is broadly acknowledged, barriers are preventing its full integration into teaching practices. These barriers could include a lack of resources, insufficient training for educators, and institutional resistance to change. This finding aligns with the work of Brown and Green (2017), who identified similar challenges in the implementation of STEM education. Efficacy of Professional Development in Bridging the STEM Gap

The positive impact of professional development programs on educators' ability to integrate STEM effectively is a crucial finding of this study. Educators who participated in such programs demonstrated greater confidence and competence in interdisciplinary teaching. This underscores the importance of ongoing professional development, as highlighted by Thompson and Goeckel

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(2020), who advocate for continuous learning opportunities for educators to keep pace with evolving educational demands.The study also sheds light on the role of innovative teaching practices in enhancing STEM integration. The use of digital tools and interactive platforms has shown to increase student engagement and understanding of complex concepts. This finding is consistent with the research of Johnson et al. (2018), who emphasized the benefits of technology in facilitating STEM education. The adoption of hands-on, project-based learning approaches further illustrates the effectiveness of experiential learning in fostering a deeper understanding of STEM concepts among students.Despite these positive developments, challenges in curriculum design and assessment remain. Balancing the depth of biology content with the breadth of interdisciplinary STEM education is a complex task. This difficulty is compounded by the need for assessment methods that accurately reflect the multifaceted nature of STEM learning. These findings align with Wang's (2018) observations on the challenges of assessing interdisciplinary learning, suggesting a need for innovative assessment strategies that are better suited to the goals of integrated STEM education. The correlation between institutional support and the success of STEM integration is another key finding. Universities that provide adequate resources and foster an environment conducive to interdisciplinary collaboration are more likely to see effective integration of STEM into their biology teacher training programs. This highlights the role of institutional policies and resource allocation in facilitating or hindering STEM integration, as discussed by Hughes and Ellefson (2013) in their exploration of inquiry-based STEM curriculum.

The study also revealed varied perceptions among educators regarding the integration of STEM into biology teacher education. While some concerns about curriculum overload and the balancing of interdisciplinary content were noted, the overall attitude towards STEM integration was positive. This optimistic outlook reflects a growing recognition of the need to adapt teaching practices to meet the demands of a rapidly changing scientific and technological world. The findings of this study have significant implications for biology teacher training programs. There is a clear need for these programs to evolve, incorporating more STEM-focused content and teaching methodologies. This evolution requires not only curriculum redesign but also a rethinking of the professional development and support systems available to educators. As the demand for STEM-literate graduates increases, teacher training programs must adapt to prepare future educators who can effectively teach within this interdisciplinary framework. The long-term impact of effective STEM integration in biology teacher education extends beyond the classroom. By preparing teachers who are well-versed in interdisciplinary approaches, we can enhance the scientific literacy of future generations.

Conclusion

The study's exploration into the methodology for the formation of the educational base of STEM in the preparation of future biology teachers has yielded critical insights, underscoring both the pressing need and the significant challenges associated with this endeavor. The findings reveal a landscape filled with potential, yet also marked by hurdles that require strategic and concerted efforts to overcome. One of the most striking revelations from this research is the gap

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between the widespread recognition of the importance of STEM in biology teacher education and its practical application. Despite the consensus on the value of integrating STEM into the curriculum, many institutions and educators grapple with implementing these interdisciplinary approaches effectively. This discrepancy is largely attributed to factors such as insufficient resources, lack of adequate training, and institutional inertia. However, the study also sheds light on the positive impact of professional development programs. Educators who engage in continuous learning and training exhibit a higher proficiency in incorporating STEM into their teaching, affirming the critical role of ongoing professional development in the evolution of educational practices. Furthermore, the adoption of innovative teaching methods, such as project-based learning and the use of digital tools, has been shown to significantly enhance student engagement and comprehension of complex STEM concepts.

The challenges in curriculum design and assessment strategies also emerge as pivotal issues. Developing a curriculum that balances the depth of biology with the interdisciplinary breadth of STEM, coupled with the need for innovative assessment methods, remains a critical area for further development. Additionally, the study highlights the indispensable role of institutional support in facilitating the successful integration of STEM, suggesting that effective STEM education is as much an institutional priority as it is a pedagogical one.

The varied perceptions among educators regarding STEM integration underscore the need for a cultural shift in how interdisciplinary education is viewed and approached. Moving forward, it is essential for teacher training programs to adapt and evolve, incorporating STEM-focused content and methodologies to prepare educators for the demands of modern science education.

In conclusion, this study emphasizes the necessity of a multifaceted approach to foster the effective integration of STEM into biology teacher education. Addressing the challenges of resource allocation, educator training, curriculum design, and assessment strategies is crucial. By doing so, we can not only enhance the quality of biology education but also equip future generations with the scientific literacy and interdisciplinary skills required in an increasingly STEM-oriented world. The findings of this study serve as a call to action for educational institutions, policymakers, and educators to collaboratively work towards a more integrated and dynamic approach to teacher education in the realm of biology and STEM.

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