A Computational Modelling in Secondary Physics Teaching as an Example of the Implementation of the Concept of STEM Education

Oktawia KOC

University of Wrocław, Max Born Square 9, 50-204 Wrocław, Poland

Abstract. STEM education is a learning management approach in which students acquire the ability to integrate scientific knowledge, technology, mathematics and engineering processes. Particular attention is paid to the development of so-called "twenty-first century skills", among which ICT skills play significant role. For the needs of research, innovative classes will have been conducted, during which secondary students will meet the examples of computer-aided mathematical modelling in physics. The main purpose of the research is to prove that computational modelling based on the use of programming in Wolfram Mathematica language facilitates integrated learning and develops ICT skills.

Introduction and Theoretical framework

A review of the literature underscores the emphasis in STEM education on developing 21st-century skills, enabling the application of scientific knowledge to real-world problems [1]. An integrated approach in teaching STEM subjects prioritizes the cultivation of ICT skills for information handling and presentation, acknowledging their relevance beyond academic settings [2,3]. However, guidance on the integration of mathematics and science knowledge in STEM education lacks clarity [1]. Emphasis lies on meaningful learning through rich tasks and real-life scenarios, with integration across at least two STEM disciplines being sufficient [4]. Mathematical modelling serves as a valuable tool for integrating multiple STEM domains to address complex real-world problems [5]. Computational modelling, supported by advanced software, facilitates the study and simulation of complex systems, making it accessible not only to scientists and engineers but also to educators and school teachers for interdisciplinary STEM projects..

Project Assumptions and Methods

The project, aimed at secondary students with a focus on science or engineering, involves a computer laboratory introducing Wolfram Mathematica and Wolfram Cloud. Students will explore the usage of Wolfram Mathematica for physical modelling, learning about differential equations and modelling systems enriched with additional factors. This approach, supported by intuitive tools, enables students to understand complex calculations. The project's primary goal is to demonstrate the integration of physics, mathematics, and programming, deepening interest in physics and encouraging advanced mathematical skills. Student attitudes will be assessed using surveys.

The project includes two four-hour meetings, with potential additional sessions. Preliminary classes with a four-person group in May refined the methodology for larger groups. Final classes in June 2024 will involve at least three groups of 10-12 students. Students will learn the basics of Wolfram Language, tackling tasks in mathematical modelling of physical phenomena, focusing on mechanics. They will solve problems involving the meeting of two bodies and compare projections with different resistances, encountering numerical methods for problems lacking analytical solutions. Exercises will include visualizing results through graphs and animations.

A detailed educational script has been prepared to guide teachers in replicating the classes. This script includes step-by-step instructions, objectives, and materials, enabling effective introduction to Wolfram Mathematica and mathematical modelling principles, even for teachers with basic experience. This ensures broader dissemination and impact, contributing to STEM education advancement.

To evaluate the effectiveness of the project, a mixed-methods approach will be used. Students' attitudes and skill development will be assessed through post-project surveys, which will measure changes in their interest in STEM subjects, self-efficacy in computational tasks, and perceived improvement in 21st-century skills such as critical thinking, problem-solving, and ICT proficiency. Additionally, performance assessments will be conducted to evaluate students' practical understanding and application of the concepts taught. Observational data and qualitative feedback will be collected during the sessions to ensure that students are engaging deeply with the content rather than focusing solely on outcomes.

Preliminary Findings and Conclusion

Preliminary results from the initial trial sessions indicate that students show increased engagement and interest in STEM subjects when exposed to computational modelling. There is evidence of improved understanding of the connection between mathematical models and physical phenomena. These initial findings suggest that the project has the potential to significantly enhance students' ICT skills and their ability to apply scientific knowledge in practical contexts.

During the oral presentation, I will share detailed conclusions based on the full project evaluation. Drawing from my experiences as the project author and instructor, as well as the survey results, I will verify hypotheses regarding the potential benefits of integrating computational modelling laboratories into regular physics classes. My presentation will clarify which 21st-century skills were most significantly fostered by the project and how the project adheres to the integrated STEM education concept. I will also discuss the measures taken to ensure that students engage deeply with the content and reflect on the mathematical models they construct.

References

[1] M. Mohr-Schroeder, M. Cavalcanti, K. Blyman, Stem Education: Understanding the Changing Landscape. In: S. Alpaslan (Eds.), *A Practice-based Model of STEM Teaching: STEM Students on the Stage of the (SOS)^{TM}* (pp. 3-14). Houston: SensePublishers, 2015.

[2] S. Changpetch, T. Seechaliao, The propose of an instructional model based on stem education approach for enhancing the information and communication technology skills for elementary students in Thailand, *International Education Studies* **13**(1) (2019) 69-75.

[3] S. Marginson, R. Tytler, B. Freeman, K. Roberts, *STEM: Country comparisons*, Melbourne: Australian Council of Learned Academies, 2013.

[4] M. F. Doğan, R. Gürbüz, Z. Çavuş-Erdem, S. Şahin, Using mathematical modelling for integrating STEM disciplines: A theoretical framework, *Turkish Journal of Computer and Mathematics Education* **10**(3) (2019) 628-653.

[5] M. Tezer, *The Role of Mathematical Modelling in STEM Integration and Education*. In: Theorizing STEM Education in the 21st Century (pp.1-14). Rijeka: IntechOpen, 2019. http://dx.doi.org/10.5772/intechopen.88615