The potential of mathematical contributions to scientific models

Mathilde Kjær Pedersen[1], Maria Kirstine Østergaard[2], Morten Misfeldt[1], Uffe Thomas Jankvist[2]

[1]University of Copenhagen, Department of Science Education, Copenhagen, Denmark; mkpedersen@ind.ku.dk

[2]Aarhus University, Danish School of Education, Copenhagen, Denmark

This proposal will be presented in person at the MACAS symposium, Moncton University, August 2025. It communicates ongoing research as well as practical examples of interdisciplinary teaching and learning from Danish upper secondary science education.

Models and modelling are essential concepts in the STEM disciplines, both in research and in the teaching and learning of STEM. Yet, there are significant differences between the interpretations and applications of models and modelling across different STEM subjects. For instance, mathematical models are often a tool to investigate phenomena outside the mathematical domain (e.g., from the natural sciences). A mathematical model comes from 'mathematising' a real phenomenon by idealising the phenomenon and carefully selecting and formalising relevant variables into mathematical formulas (Niss & Blum, 2020). Whereas, in physics some models are about translating natural phenomena into calculations (Jensen et al., 2017). In chemistry and biology, models often visualise and describe complex phenomena (Gilbert & Treagust, 2009; Treagust & Tsui, 2013).

The different perceptions of models may cause challenges when learning the subjects of physics, chemistry, biology, and mathematics parallelly as it is the case for many science students in Danish upper secondary school. The aim of our research is to contribute with new didactical knowledge on how to tackle these challenges and on what opportunities there are to exploit the potentials that exist in overlaps between the subjects' different conceptualisations of models.

Through design research (e.g., Bakker, 2018), we investigate the similarities and differences between the concepts of models and modelling in upper secondary science education. Interdisciplinary teaching activities dealing with models and modelling in biology, physics and chemistry are designed, tested and adjusted iteratively with respect to new content. The purpose of this iterative process is twofold: (1) to elaborate on and refine the understanding of models and modelling and their differences in the three subjects, applying mathematics as an auxiliary subject, and (2) to support and increase the students' understanding of models and modelling.

In general, a model can be defined as a simplified representation of a real-world phenomenon which aims at explaining the phenomenon for instance by producing adequate predictions of the behaviour of the phenomenon under certain conditions (Gilbert & Treagust, 2009). Some models serve to simplify complex objects and concepts, stimulate learning and conceptualisation by explaining scientific phenomena (Coll & Lajium, 2011). Hence, models enable students to study natural phenomena that may otherwise be difficult to observe and experiment with directly. From this perspective, a laboratory exercise can be considered as a model with the educational purpose of understanding a given scientific phenomenon.

In mathematics, models are often presented algebraically to illustrate covariant relationships between variables that describe a simplified natural phenomenon and can be tested empirically using statistical methods (Jensen et al., 2017). This may involve datafication, meaning the translation from the real-world phenomenon to data, that is the ability to collect and analyse data of the phenomena in a quantitative manner (Weintrop et al., 2016). Related to science, mathematics can be applied at different levels, for instance, in terms of symbolic representations based on mathematical rules, such as balancing chemical equations and describing physical reactions. On the other hand, mathematics can be applied to set up mathematical models in forms of algebraic equations or equation systems based on covariant variables, as for instance radioactivity over time. However, in our research we have observed several examples where the mathematical post-processing of data from laboratory exercises merely consists of calculations without any form of generalisation or algebraic treatment. Instead of offering a mathematical perspective on the scientific phenomenon, the mathematical contribution thus resembles a superficial appendix to the exercise. We find that this kind of application of mathematics leaves an unfulfilled potential. Instead, if the data and the mathematical post-processing were applied in further detail to create a mathematical model based on the data, mathematics may contribute to a more nuanced understanding of the phenomenon. In addition, having both the laboratory exercise and the mathematical model may support the students' metacognitive perspective on the nature of models.

Furthermore, an increased attention to the potential of the mathematical contribution to students understanding scientific phenomena as well as the nature of models, offers an opportunity for the students to work with mathematical modelling based on real scientific data while simultaneously achieving a deeper understanding of the natural phenomena of interest. In this way, science supports the students' mathematics learning, and mathematics supports the students' learning of science.

This proposal is thus connected to several of the MACAS conference topics, including investigations of the relations between mathematics and science, as well as the potential of integrating mathematics and science through interdisciplinarity and mathematical modelling.

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References

Bakker, A. (2019). Design Research in Education. A Practical Guide for Early Career Researchers. Routledge. https://doi.org/10.4324/9780203701010

Coll, R. K., & Lajium, D. (2011). Modeling and the future of Science Education. In M. Khine & I. Saleh (Eds.), Models and Modeling (pp. 3-21). Springer. https://doi.org/10.1007/978-94-007-0449-7_1

Gilbert, J. K., & Treagust, D. (Eds.) (2009). Multiple Representations in Chemical Education. Springer.

Jensen, J. H., Niss, Ma., & Jankvist, U. T. (2017). Problem solving in the borderland between mathematics and physics. Int. Jour. of Math. Ed. in Sci. and Tech., 48(1), 1–15. https://doi.org/10.1080/0020739X.2016.1206979

Niss, M., & Blum, W. (2020). The Learning and Teaching of Mathematical Modelling. Routledge. https://doi.org/10.4324/9781315189314

Treagust, D. F., & Tsui, C. Y. (Eds.). (2013). *Multiple representations in biological education*. Springer. https://doi.org/10.1007/978-94-007-4192-8

Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining computational thinking for mathematics and science classrooms. Jour. of Sci. Ed. and Tech., 25, 127–147. https://doi.org/10.1007/s10956-015-9581-5