

Towards a methodology for developing implementable techno-critical mathematics education innovations

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Problem addressed

With this proposal, we seek to introduce a methodology that supports the design of techno-critical mathematics education innovations that are implementable in Danish lower secondary education. During the past years, we have witnessed a growing need to prepare students for a world full of pervasive digital technologies. This need has manifested in increased attention directed towards integrating computational thinking and mathematics education in both research and curriculum policy. Many innovations developed to achieve this goal rely on disciplinary knowledge from computer science. This approach has been shown to create substantial difficulties, mainly since mathematics teachers do not feel sufficiently qualified to teach computational thinking (e.g., Børne- og Undervisningsministeriet [BUVM], 2021). According to the European Commission (2022), international recommendations increasingly stress students' capabilities to relate critically to digital technology as a needed focus in education. A central question is thus how to develop implementable innovations in mathematics education that can support students to achieve this.

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The approach referred to as technocritical mathematics education (TCME) (Jankvist et al., 2023) provides a promising path to mitigate this problem. With reference to critical mathematics education, Jankvist et al. (2023) illustrate that we might view technology as mathematics-in-action. They show how mathematics education can enable students to unpack the mathematics behind technologies such as cryptography. This approach allows addressing technology through mathematical investigations without needing to incorporate domains of knowledge from e.g., computer science. As acknowledged by the authors, the mathematical foundations of most technologies, however, far exceed the level of difficulty that is applicable in mathematics education curricula. To address this problem, we rely on the modelling cycle (Niss, 2015) and Gagliardi et al.'s (2011) implementability framework. A key feature of our innovations is that they take an outset in computer science research, which we convert into TCME teaching sequences that are independent of content knowledge outside mathematics.

How is it addressed theoretically and methodologically?

Our proposal illustrates a methodology through an innovation that takes the outset in a study from computer science research conducted by Moreau et al. (2024). This study performs an audit of a machine learning model used in a Danish project that sought to provide decision support for social workers in childcare. Our methodology consists of an approach to convert parts of this original research into teaching sequences that are implementable in lower secondary mathematics education in Denmark. Implementability refers to “*how realistic and feasible it is for practitioners to implement an innovation*” (Koichu et al., 2024, p. 163). To support our design of implementable TCME innovations, we rely on Gagliardi et al.'s (2011) conceptual implementability framework. This framework consists of 22 elements organized in eight domains (Gagliardi et al., 2011). For this paper, we limit our perspective on implementability to concern a single, yet critical, domain, namely *applicability*. This domain involves nine elements, which we list and briefly exemplify here in the context of our innovation. The *objective* of an innovation is whether it has a clear purpose. The purpose of our innovation is guided by TCME and concerns enabling students to unpack mathematics related to their own technological surroundings. *User needs/values* include the extent to which the purpose addresses an adapter need and/or aligns with the adapters' values. In our case, evaluations of a previous large-scale national development project suggest that Danish teachers find it important to teach students to relate critically to digital technology (BUVM, 2021). The *technical* element concerns whether the innovation involves technology that is available and with which adapters are acquainted. Consequently, our innovations are

developed to exclusively include technology that mathematics teachers have access to and are accustomed to. The *regulatory* element concerns policy regarding the use of an innovation. In our case, whether the innovation aligns with the curricular guidelines. A central focus in our methodology is thus to ensure applicability to legislative guidelines. *Human resources* regard needs for additional staff to implement an innovation and the *professional* element concerns needs for training of adapters. To maximize implementability, our methodology strives to develop innovations that do not require training nor additional staffing to be implemented.

The audit conducted by Moreau et al. (2024), which our innovation takes an outset in, studies the methodological correctness of a model and its limitations through counterfactual simulations. This study is guided by a broad aim of critically relating to digital technology, among other things through statistical simulations. In this sense, this study constitutes an obvious starting point for developing a TCME innovation. To convert this study into an implementable TCME innovation, it must be processed into a format recognizable by adapters. To achieve this, we opted to describe the study as an example of mathematical modelling using the modelling cycle (Niss, 2015). Modelling is mandatory in the Danish lower secondary curriculum and part of the teacher training education. Despite this format, the original work still included *technology* foreign to most Danish teachers (Python) and analyses of the composition of proxy variables that exceed *regulatory* guidelines. The counterfactual simulations in the original study were carried out via a Python script (Moreau et al., 2024). This however involves *technology* that is rarely used in lower secondary school and thereby is not implementable. To address this, we integrated the algorithm in GeoGebra with sliders¹. This allows students to reproduce the counterfactual simulations using technology that is already part of mathematics education. Consequently, students can relate critically to the limitations of powerful technology in their surroundings through mathematical content depicted in the curriculum.

What is implemented/replicated?

Our innovations are teaching sequences consisting of four lessons of 45 minutes each. The innovations are guided by objectives aligned with TCME and are designed to be as implementable as possible while preserving fidelity to their initial source of inspiration. We are currently implementing the innovations and studying the adapters' perspectives on their implementability.

¹ <https://www.geogebra.org/classic/w68uybxf>

What is the potential importance/significance?

If successful, our methodology holds the potential to expand our applications of mathematical modelling in education in a direction that allows mathematics teachers to activate their professional knowledge in ways that meet new demands for civic competencies. Our preliminary findings from classroom interventions and interviews with teachers strongly indicate that our innovations are implementable from the perspective of adapters; they are found to be applicable to the national curriculum, require no additional preparation compared to other available teaching materials, and align with their views of what values to prioritize in mathematics education. Going forward, our work will focus on reporting a more elaborate account of our methodology and systematically studying adapters' views on the implementability of our TCME innovations.

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