

Implementing interdisciplinarity in monodisciplinary school structures: From design to teacher ownership

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Problem addressed

In Danish upper secondary schools, the natural sciences—biology, chemistry, and physics—are traditionally taught as distinct subjects. Teachers typically have expertise in one or at most two of these disciplines, and in the latter case their training is often compartmentalized, thus limiting opportunities for fostering interdisciplinarity in practice. Yet, interdisciplinarity is valued politically (e.g., Michelsen, 2005) and from a learning perspective (Jensen & Jankvist, 2018). Designing and implementing interdisciplinary activities remains challenging, not only because school structures and teaching cultures provide limited support for such work, but also because meaningful and sustainable implementation re-

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Pedersen, M. K., Østergaard, M. K., Misfeldt, M., & Jankvist, U. T. (2026). Implementing interdisciplinarity in monodisciplinary school structures: From design to teacher ownership. In M. S. Aguilar & M. Misfeldt (Eds.), *Proceedings of the First Implementation and Replication Studies in Mathematics Education Conference: IRMEC 2025* (pp. 143–147). Editorial SOMIDEM. <https://doi.org/10.24844/SOMIDEM/S3/2026/03-19>

quires a shift in ownership (Coburn, 2003). For interdisciplinary practices to take root, teachers must find the innovations meaningful to their own teaching and thereby adapt and appropriate the researcher-designed ideas to fit their pedagogical purposes and classroom contexts. Understanding how such a shift occurs—or fails to occur—is therefore central to the problem of implementing interdisciplinarity in Danish upper secondary school. This leads us to the tentative research question: *What conditions support or constrain science teachers' development of ownership of interdisciplinary teaching activities that engage students with discipline-specific models?*

How is the problem addressed?

Our project, in which this study takes place, draws on principles of design research (e.g., Bakker, 2018), carried out through close collaboration between researchers and practicing science teachers—one from each of the three disciplines. Each interdisciplinary activity combines two of the subjects (biology–chemistry, chemistry–physics, or biology–physics). While the design work provides theoretically informed activity structures, the challenge lies in implementing these designs in everyday classroom practice. For this reason, we conceptualize the subsequent work as design implementation (Bach et al., 2025), where designs developed through design research in authentic school contexts are elaborated on to formulate implementation principles. Our implementation approach is guided by a theory of change (ToC) (Jankvist et al., 2021) that articulates both the intended mechanisms of learning (e.g., students comparing models across disciplines) and the assumptions about teachers' roles, school structures, and contextual constraints. This theory-driven perspective enables us to study systematically how the innovation interacts with and is shaped by the classroom ecology (Century & Cassata, 2016).

Our ToC is a combination of Coburn's (2003) shift in ownership and theoretical constructs related to interdisciplinary teaching (Jensen & Jankvist, 2018; Michelsen, 2005) to consider the conditions and constraints of implementing interdisciplinary activities in Danish upper secondary school. To analyze how teachers come to take responsibility for and continue using the interdisciplinary activities, we apply Coburn's (2003) four dimensions of scale, with particular emphasis on the shift in ownership. The conceptualization of scale as a matter of depth, sustainability, spread, and ownership is productive for understanding small-scale, early-stage implementations. In our project, "scaling" does not refer to dissemination across many schools but to local, in-depth processes through which teachers engage with, reinterpret, and adapt the interdisciplinary activities in their own classrooms. Ownership thus emerges through mutual

adaptation, as teachers internalize the innovation, transform it in light of their disciplinary identities and classroom constraints, and gradually integrate it into their instructional repertoires. Using Coburn's framework allows us to examine what supports or constrains this emerging ownership, and to assess whether and how these interdisciplinary practices may develop into durable components of science teaching despite the structural and cultural barriers of the school system.

The teachers' approach to interdisciplinary collaboration has been to identify exemplary phenomena that can be investigated from the perspectives of both involved disciplines. In this way, each subject contributes with its disciplinary framing of the phenomenon and its related models. Such an approach to interdisciplinarity can be seen as fostering students' "understanding and overview across disciplines" (Jensen & Jankvist, 2018), enabling them to become familiar with disciplinary perspectives while also recognizing their distinct boundaries. To address this type of interdisciplinarity in science classrooms we apply the two-phase framework of *horizontal linkage* and *vertical structuring* (Michelsen, 2005), where phenomena are first explored through thematic integration across disciplines and subsequently anchored within the conceptual and symbolic systems of the individual subjects, in an iterative process of moving between interdisciplinary and subject-specific instruction.

What is implemented?

At the core of the project is the implementation of teaching designs in which two science subjects jointly address a phenomenon, using their respective models to highlight both complementarities and differences. The approach emphasizes how disciplinary perspectives play together in constructing a richer understanding of a given phenomenon, while at the same time making visible the distinct epistemic commitments embedded in the models of each subject.

One case of such a teaching design is a teaching activity in chemistry and biology on female hormones and the menstrual cycle. First, the students studied the chemical structure of hormones, e.g., estradiol and progesterone. Second, they drew their own models of the menstrual cycle with markers and paper. Lastly, they were asked to connect the influence of the chemical process of a hormone binding to a receptor with the biological processes of the changing levels of hormones and how that affects the body. However, only one group managed to actualize the last part of connecting the two subjects in relation to the phenomenon of the menstrual cycle on their own initiative—not on the teachers'. Most other groups focused on the two subjects in parallel, first focusing on the chemical processes, asking

the chemistry teacher for guidance when needed, and afterwards focusing on the menstrual cycle, asking the biology teacher for guidance when needed.

This case illustrates the challenges of merging the two subjects due to the school structures and teaching cultures of compartmentalized subjects, such that it rather becomes a double-disciplinary activity with the two subjects in parallel, which does not necessarily give rise to richer understanding of the given phenomena at issue. Thus, this work continues seeking to implement a framework for interdisciplinary teaching that is adaptable across different combinations of science subjects and phenomena, while being aware of the changes in structure and culture that this requires.

Potential importance and significance

The project contributes to research and practice by offering a framework for implementing interdisciplinary activities in upper secondary science education that foregrounds the role of phenomena as potential common ground for interdisciplinary teaching activities. This approach should not only facilitate interdisciplinary connections but also provide a lens through which students and teachers can recognize and reflect upon the differences between the subjects and their respective types and use of models. However, the phenomenon itself is not enough to make the activity interdisciplinary, as the phenomenon can simply be studied in each of the subjects alone. To facilitate interdisciplinary connections and reflections, explicit tasks across the subjects need to be formulated. In doing so, it holds promise for enriching students' scientific literacy by deepening their understanding of both scientific content and the nature of disciplinary knowledge.

Acknowledgments

The paper was written in the frame of project NNF23OC0086786 under the Novo Nordisk Foundation.

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