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NATIONAL REPORT ON TEACHERS' NEEDS AND CURRENT TEACHING PRACTICES FOR MODELING-BASED LEARNING GERMANY

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Empowering Teachers for Science Learning Through Modelling-Based Approaches

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Erasmus+ Project EMPOWER

EMPOWERING TEACHERS FOR SCIENCE LEARNING THROUGH MODELLING-BASED APPROACHES

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1 Introduction

This report is situated within the context of secondary science education in northern Germany. The German school system is decentralized, with each federal state differing in key aspects of education, such as school types and curricular structures. This decentralization has a significant influence on curriculum design and, consequently, on the implementation of model-based learning (MbL) (Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany [KMK], 2025).

In most federal states, students leave primary school after Year 4 (around age 10) and proceed to either academically oriented or comprehensive secondary schools. However, the exact school types and the timing of transition vary somewhat across federal states. The present report draws on interviews with stakeholders from the federal state of Schleswig-Holstein and teachers from the federal state of Hamburg. Model-based learning (MbL) is embedded both in national educational frameworks and in the individual curricula of the federal states, and it is represented in various forms within science and biology classrooms.

However, despite its inclusion in curricula, the implementation of modelling and MbL as components of scientific reasoning remains limited. In many cases, school-level curricula place greater emphasis on content knowledge than on the development of scientific reasoning and inquiry competencies. This highlights the importance of examining how MbL is conceptualized and enacted in practice in order to identify both its potential and the areas in which further support is needed.

2 Educational Context

The German education system is characterised by a strong federal structure, which has a significant impact on the implementation of model-based learning (MbL) (Standing conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany [KMK], 2025). The 16 federal states are responsible for education and exercise significant autonomy within the concept of “cultural sovereignty” to determine key aspects of their education systems independently. These include the organisation of the school system (including the types of secondary schools), the development of curricula, school supervision, and the recruitment and remuneration of teachers (KMK, 2025).

The Standing Conference of the Ministers of Education and Cultural Affairs (Kultusministerkonferenz, KMK) is a joint body of education ministers from all 16 federal states (KMK, 2025). It adopts cross-state agreements and binding educational standards, which are then enacted into state law by the individual federal states (Eurydice, n.d.).

It is therefore important to consider the diversity among the federal states and the locality of the report.

Mostly, in German secondary schools science is separated in three subjects: biology, chemistry, and physics. This is an individual characteristic of the German school system. However, in some federal states, the subject “integrated science” becomes more important especially for lower secondary schools. In this report, we have focused on biology education as an example for science education in Germany for the stakeholder and teacher interviews. This matches the reported curriculum analysis in the EMPOWER project, which also took into account the German biology curricula.

3 Method

This study employed a qualitative research design based on focus group discussions. Each focus group lasted 60–90 minutes and followed a shared structure that ensured consistency across countries while still allowing moderators to adapt the conversation when relevant topics emerged naturally. Sessions opened with a brief introduction in which the moderator explained the purpose of the study, referred to the information letter, and reminded participants of their rights; consent was confirmed through continued participation. Two parallel sets of guiding questions were used: one for teachers, focusing on their knowledge and views on models and modelling, their classroom experiences, connections to the national curriculum, and their perceived support needs; and one for stakeholders, addressing their understandings of modelling, its position in the curriculum, available resources and system-level support, and the kinds of development needed to strengthen modelling-based science education. Data were collected through two focus groups conducted in Germany with the objective of exploring perceptions, experiences, and needs related to MbL in secondary biology education (students ages 10–18).

3.1 Participants

A total of seven participants took part in the study, organized into two focus groups: three participants in the stakeholder group and four participants in the teacher group. The composition of the groups was intentional, aiming to capture complementary perspectives from both system-level stakeholders and classroom practitioners with varying degrees of experience in MbL.

Focus Group 1: Stakeholders in teacher education and system support

The first focus group comprised three stakeholders closely linked to initial teacher education, in-service professional development, curriculum implementation, and institutional support for science education in Germany. Within this group, stakeholder SH01 works at the ministry and in school as biology teacher as well. The other two stakeholders (SH02 and SH03) hold a full-time position within the ministry-led federal teacher education institute. All stakeholders

worked for several years in different schools (compulsory and/or comprehensive) as biology teachers.

This focus group provided a system-level perspective on MbL, addressing issues related to teacher education, curriculum interpretation, assessment practices, and institutional support structures. However, as the interviewed stakeholders all do have experiences as teachers as well, they provide a linked understanding between system- and institutional-level.

Focus Group 2: Secondary school teachers

The second focus group comprised four secondary school teachers with diverse subject profiles, professional trajectories, and levels of teaching experience. All participants were currently teaching at academically oriented secondary schools ("Gymnasium"). T01 specialized in biology and chemistry and had entered the teaching profession through a non-traditional route after originally training and working as a pharmacist; she had recently completed her teacher training. T02 taught biology, chemistry, and mathematics, completed teacher training ten years ago, gained experience in different educational settings, including one year of teaching in Mexico, and had been working permanently at their recent school since almost five years. T03 specialized in biology and English and had completed teacher training two years ago, after which she began teaching at her recent school. T04 taught biology and chemistry and had been working as a teacher at his recent school since nearly 20 years, thus contributing the perspective of a more experienced practitioner.

This focus group was intended to capture classroom-based perspectives reflecting different stages of familiarity and engagement with MbL within secondary science education.

3.2 Data collection

Both focus groups were conducted online via Zoom during April and May 2026. A semi-structured interview format was used in both sessions, following a common interview protocol developed within the EMPOWER project. The questions addressed participants' understanding of models, modelling, and MbL; classroom practices in science education; curriculum integration; assessment; and perceived challenges and support needs.

In each focus group, two researchers from the project team were present in addition to the participants. One researcher acted as moderator, guiding the discussion and posing the interview questions, while the other researcher asked follow-up questions and took note if the answers were sufficient. Participation was voluntary, and ethical considerations were ensured through informed consent, confidentiality, and anonymization of all collected data.

3.3 Data analysis

All focus group sessions were recorded in Zoom. The recordings were transcribed verbatim. The transcripts were analyzed using a thematic analysis approach, focusing on the

identification of recurring themes, patterns, and contrasts across and within the two focus groups. Particular attention was paid to differences between stakeholder perspectives and teacher perspectives, as well as to variations associated with participants' levels of experience in Modeling-Based Learning.

4 Findings

4.1 Knowledge

Within both interviews, stakeholders and teachers, the participants indicate a broadly shared view that the central aim of science education is the development of students' scientific literacy. According to the stakeholders and teachers, science education should enable students to participate in society as reflective and informed individuals who understand how science works and who are able to critically evaluate scientific information. In this context, the stakeholders emphasized that science education should foster students' interest and enthusiasm, particularly in the earlier years of schooling. As SH02 stated, "enthusiasm is a very important part of biology" (German original: "Begeisterung [ist] ein ganz wesentlicher Teil in der Biologie", pos. 28), while SH01 highlighted that, depending on the school type, it may be more important that students "have taken something away for life" (German original: "was fürs Leben mitgenommen haben", pos. 29) than that they are prepared for future academic study. Across the interviews, stakeholders consistently pointed to motivating learning environments, including "real-life contexts," "a great deal of cognitive activation," "engaging openings," and "lots of hands-on activities," as important conditions for engaging students in science learning. In addition, the teachers emphasized the importance of helping students recognize the interconnectedness of biological phenomena. As T04 noted, what matters most is not that students know every detail, but rather "that everything is connected" (German original: "dass alles zusammenhängt"; T04, pos. 23). The teachers also suggested – similarly to the stakeholders – that biology education should enable students to act responsibly in relation to themselves and their environment and should therefore foster evaluative, communicative, and inquiry-oriented competencies.

With regard to the definition of the term *model*, stakeholders described models as simplified and intentionally selective representations that help make complex aspects of reality more accessible. SH02, for example, characterized a model as something that "makes complex reality more tangible" (German original: "die komplexe Realität greifbarer machen", pos. 44) while necessarily focusing on specific aspects and never capturing reality in its entirety. Similarly, the teachers described models as purposeful and selective representations that highlight particular aspects of a phenomenon while omitting others. However, their accounts suggest that models are understood primarily as explanatory tools that need to be aligned with the respective instructional goal. Several teachers also emphasized that models should

not only serve as illustrations, but also as means through which students actively construct understanding. In this context, T01 stressed that students should learn to develop and evaluate models themselves. In contrast to these accounts, a recurrent theme across the stakeholder answers was that the limitations of models are often insufficiently addressed in classroom practice. The stakeholders argued that this creates the risk that students may conflate models with reality unless these distinctions are made explicit. SH03, in particular, noted that scientific work itself is conducted within a "model framework" (German original: "Modellrahmen"), yet this aspect is actually never explicitly addressed in school teaching.

The stakeholders' accounts of modelling and MbL suggest a comparatively nuanced understanding of these concepts with each other. Modelling was not described as the mere use of a given model, but rather as a process that includes developing, testing, revising, and reflecting on models. SH03 suggested that students often construct mental models, yet this cognitive step is rarely made explicit or framed as a competence in its own right. Similarly, SH02 described modelling as involving the observation of how a model is used, the identification of where it reaches its limits, and, where appropriate, its subsequent revision. The stakeholders also drew a distinction between learning with models and learning about models: In their accounts, MbL was primarily associated with the use of models as supports for understanding scientific content, whereas modelling competence was linked more specifically to scientific inquiry and to students' explicit understanding of how models function. The teachers' statements on modelling and MbL suggest that modelling was understood mainly as students' active construction of models. At the same time, modelling was associated with trial and error, revision, and persistence. Across the interviews, MbL was described as a central feature of biology teaching. As T04 put it, one cannot "jump into a cell with the kids" (German original: "mit den Kids in eine Zelle hüpfen", pos. 111) in order to observe processes directly; rather, scientific understanding in the classroom depends on work with models. Overall, the interviews suggest that teachers regard models, modelling, and MbL as indispensable for biology education.
Regarding their own knowledge of models, modelling, and MbL the stakeholders and teachers reported, that it derives largely from their own teacher education, the preparatory service phase, practical classroom experience, and – for the stakeholders – their involvement in the development of training modules. In conclusion, the interviews suggest that stakeholders regard the explicit teaching of model use, model critique, and modelling practices as an important component of science education, while the teachers focus more on model use, and model critique.

4.2 Teaching experience

During the interview, the stakeholders suggest that modelling-based approaches are considered educationally valuable in classroom practice, but also challenging to implement in a sustained and meaningful way. According to the stakeholders, teachers should not restrict

themselves to presenting models as illustrative tools; rather, they should support students in understanding what models represent, how they function, and where their limitations lie. The stakeholder accounts further imply that students should, where possible, be involved in a range of modelling-related activities, including constructing, using, critiquing, and revising models. Such engagement was described as particularly important if students are to move beyond the descriptive use of models towards a deeper conceptual understanding.

The teachers suggest that models are addressed explicitly in classroom practice, although the extent of this explicitness varies. Teachers reported that they often identify representations as models and draw students' attention to their affordances and limitations. T01, for example, stated that they repeatedly emphasize "that models have limitations and do not necessarily depict reality" (German original: "dass Modelle Grenzen haben und nicht unbedingt die Realität abbilden"; T01, pos. 141). According to the teachers, reflection on models is also often initiated by students themselves, particularly when comparing different models or contrasting models with real objects.
The interviews further indicate that teachers see their role in modelling-based instruction as both structuring and facilitative. They described themselves as selecting models, defining tasks, and establishing criteria, while at the same time creating space for students' independent engagement. As T03 explained, teachers should "accompany, guide, and support" (German original: "begleiten, anleiten, unterstützen"; T03, pos. 156) students' work with models, but not intervene too strongly. Teachers also reported using scaffolding strategies, for example by reducing complexity or limiting the materials available for modelling, depending on students' age and experience. This aspect was not mentioned by the stakeholders as essential for MbL.

With regard to modelling practices, the teachers reported that students are regularly involved in creating and using models, whereas systematic revision of models appears less common. T03 noted that model construction can be pedagogically valuable, but also demanding, and therefore requires "a healthy balance" between educational ambitions and classroom realities (T03, pos. 171). The teachers identified several challenges in this area, including the selection of suitable models, the definition of criteria for modelling, limited time, and the cognitive demands of modelling tasks. In terms of intended outcomes, the interviews suggest that models and MbL are used primarily to support explanation, prediction, and process understanding, and that both modelling products and modelling processes may be assessed.

4.3 Curriculum integration

The stakeholder interviews suggest that models and modelling have become more strongly embedded in the German national curriculum, particularly in lower and upper secondary education, and that they are primarily located within the competency area of scientific inquiry. Stakeholders described the German national curriculum as conceptually coherent, especially in relation to the cumulative structuring of sub-competencies. SH02, for instance,

emphasized that the curriculum offers a useful basis for teaching because these competencies are described in a progressive and interconnected manner. At the same time, stakeholders argued that MbL cannot be reduced to a single competency area. Rather, as SH02 observed, it could be placed "across many other sub-competencies and competency areas, or perhaps even across all of them" (German original: "über viele andere Teilkompetenzen und Kompetenzbereiche oder vielleicht sogar über alle drüber", pos. 112), reflecting the fact that competencies in science education are closely interwoven.

However, the stakeholder accounts also point to limitations in the practical uptake of curriculum intentions. While the national curriculum was generally described as logically structured, some stakeholders indicated that its content often remains too abstract to be directly actionable in classroom practice. In their view, this creates a need for further interpretation and concretization in the context of teacher education, the preparatory service phase, and professional development. Moreover, the stakeholders expressed the view that many teachers may no longer consult the national curriculum on a regular basis after completing their formal training. Instead, they are perceived to rely primarily on school-internal curricula, which, according to the stakeholders, tend to emphasize topics and content coverage rather than competency-oriented aspects such as modelling.

In contrast, the teachers provide only limited evidence regarding the influence of the national curriculum on the use of models and modelling in classroom practice. Some teachers indicated that they rarely consult the curriculum directly. Instead, school-internal curricula appear to play a more immediate role. T02, for example, reported that specific models are explicitly mentioned there for particular topics such as osmosis and diffusion.

In terms of available resources, stakeholders and teachers identified both material supports, and social supports for the implementation of MbL. Regarding material support, the stakeholders referred to preparatory service modules, opportunities to construct models, accompanying instructional materials, and the use of everyday objects as relevant material resources; the teachers referred to textbooks, workbooks, school collections, and online materials. Textbooks were mentioned as useful because they contain models and, in some cases, instructions for model construction. At the same time, the interviews suggest that many teachers have to compile materials independently. T03, for instance, reported having gathered many resources personally and noted that, unlike in general science, biology offers fewer shared "experiment and modelling kits" (German original: "Experimentier- und Modellierkästen"; T03, pos. 217). For the stakeholders, textbooks, by contrast, were regarded as only partially useful after intervention of the interviewer. Stakeholders argued that they typically address models only selectively and do not provide systematic support for the development of modelling competence.

As social support, the stakeholder and teachers mentioned collegial exchange within subject departments repeatedly as an important source of support.

In conclusion, the stakeholders' accounts suggest that the curriculum provides an important conceptual framework for MbL, but that its enactment depends heavily on how it is

interpreted, supported, and translated into concrete teaching practice, as supported by the teachers' accounts.

4.4 Teacher support and needs

The stakeholders pointed out a clear need for sustained support for teachers in relation to the use of models and modelling in science classrooms. Stakeholders described their own contribution primarily in terms of teacher education and professional development, where they aim to foreground competency-oriented teaching and to raise awareness of the need for an explicit and reflective approach to models. As SH02 explained, the support provided involves emphasizing "that precisely such an explicit and conscious approach to working with models is helpful" (German original: "dass gerade so ein expliziter und bewusster Zugang zum Arbeiten mit Modellen hilfreich ist", pos. 122), particularly in helping teachers understand what models do, how they can be used, and why they should be integrated purposefully into instruction. The stakeholders' responses therefore suggest that modelling competence is not assumed to develop automatically, but requires systematic attention in both initial and continuing teacher education.

The interviews also indicate that stakeholders frequently observe difficulties in classroom practice when models are used without sufficient conceptual clarity. In particular, stakeholders reported that teachers and students may conflate models with reality if the representational character and limitations of models are not addressed explicitly. SH02 described this as a recurring issue in professional conversations with teachers, especially in cases where a model is simply "thrown into the room" (German original: "in den Raum geworfen", pos. 127) without adequate linguistic and conceptual differentiation. Such observations appear to reinforce stakeholders' perception that teachers would benefit from structured opportunities to reflect on classroom examples, analyse problematic uses of models, and discuss alternative instructional approaches.

Contrarily, the teacher interview indicates a clear need for stronger support in the use of models and modelling in biology classrooms. In particular, the teachers called for high-quality, well-developed teaching materials that are centrally provided and aligned with curriculum requirements. T04 argued that what would be especially helpful would be "well-developed materials" (German original: "gut ausgearbeitete Materialien"; T04, pos. 225) made available through official platforms and endorsed at the state level. Similarly, T02 and T04 emphasized the need for materials that are adapted to the respective federal state while also reflecting current scientific knowledge.

In addition to material support, the teachers also referred to the importance of teacher professional development. More broadly, their statements suggest dissatisfaction with the extent to which individual teachers are expected to develop and evaluate materials on their own. In this context, T04 explicitly stressed that meaningful improvement requires input "of course through science" (German original: "Natürlich mit Wissenschaft"; T04, pos. 235) rather

than relying solely on individual teachers' efforts. Overall, the interviews suggest that teachers perceive support needs not only at the level of classroom resources and training, but also at the systemic level.

5 Conclusions

Overall, the findings show that both stakeholders and teachers regard models, modelling, and MbL as central to science education and to the development of students' scientific literacy. Across both groups, science education is understood as fostering reflective, informed, and responsible participation in society, while also supporting students' motivation and engagement.

At the same time, differences emerge in how MbL is conceptualized. Stakeholders expressed a more process-oriented understanding of modelling, emphasizing the development, critique, and revision of models as well as the distinction between learning with and learning about models. Teachers, in contrast, focused more strongly on the use of models for explanation and understanding in classroom practice. This suggests that the epistemic and competency-oriented dimensions of modelling are articulated more explicitly by stakeholders than by teachers.

The findings further indicate that MbL is valued in practice, but its implementation is constrained by limited time, the complexity of modelling tasks, challenges in selecting suitable models, and insufficient attention to the distinction between models and reality. Although the curriculum provides a general framework for MbL, its practical uptake appears limited, with teachers relying more strongly on school-internal curricula and self-developed or individually collected materials.

Overall, the interviews point to a clear need for stronger systemic support. While stakeholders emphasized teacher education and professional development, teachers particularly highlighted the need for high-quality, research-informed, and centrally provided materials. In sum, MbL is widely recognized for its educational potential, but its implementation currently depends more on individual teacher capacity than on coherent structural support.

6 References

Eurydice. (n.d.). Verwaltung und Steuerung auf nationaler und/oder regionaler Ebene. European Commission: Brussels. https://eurydice.eacea.ec.europa.eu/de/eurypedia/germany/verwaltung-und-steuerung-auf-nationaler-undoder-regionaler-ebene

Standing Conference of the Ministers of Education and Cultural Affairs of the Länder in the Federal Republic of Germany [KMK]. (2025). The education system in the Federal Republic of Germany 2023/2024: A description of the responsibilities, structures and developments in education policy for the exchange of information in Europe. Secretariat of the KMK: Bonn. https://www.kmk.org/fileadmin/Dateien/pdf/Eurydice/EN/dossier_en_ebook.pdf

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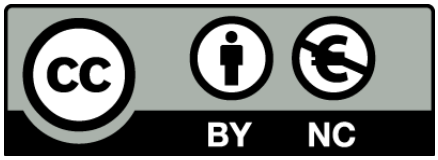

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