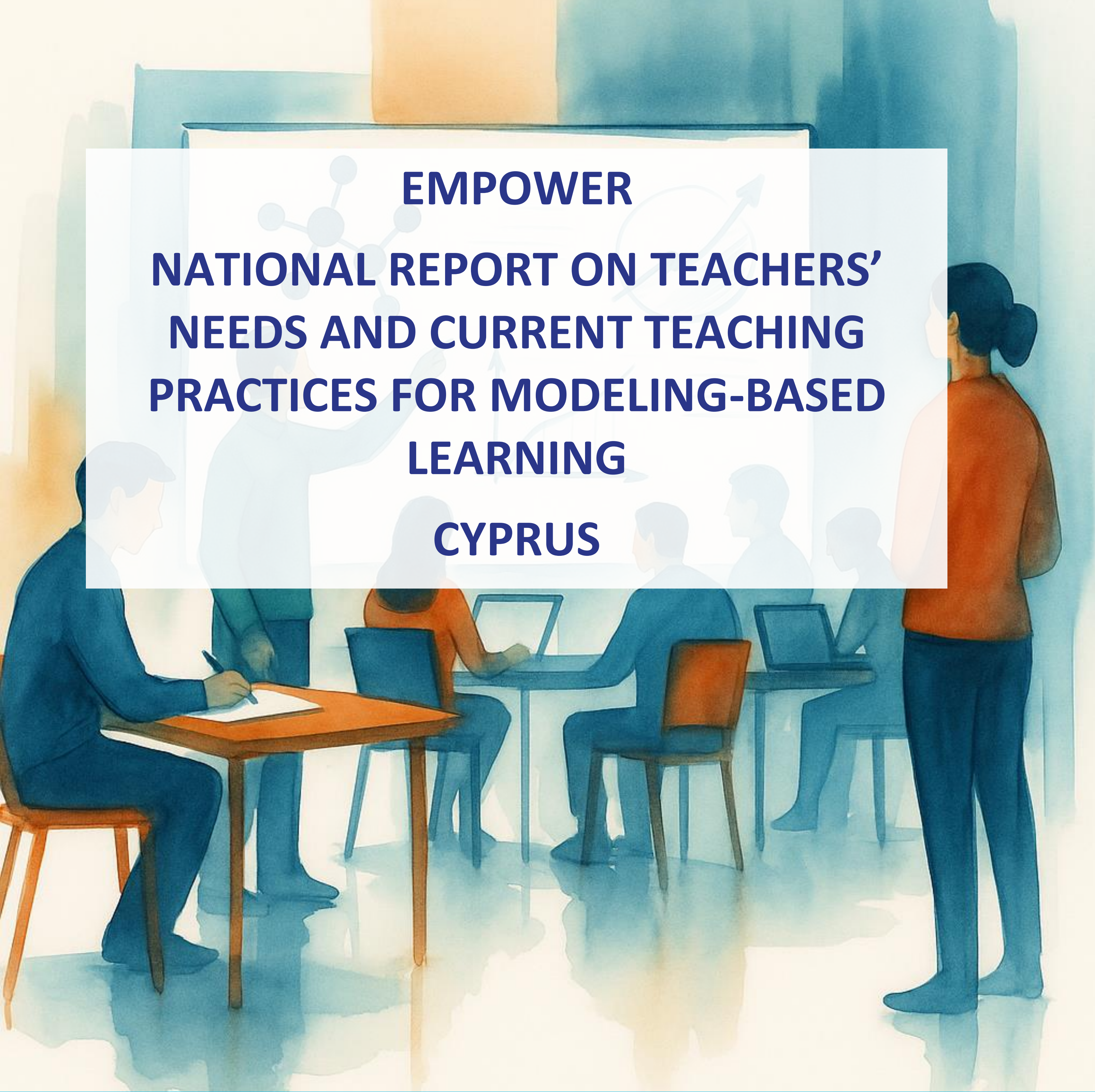

EMPOWER

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

CYPRUS

2026

EMPOWER

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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General introduction

This report presents two complementary national studies conducted in Cyprus as part of the Erasmus+ EMPOWER project, focusing on how teachers and stakeholders understand, experience, and support the use of models, modelling, and modelling based learning (MbL) in science education.

Part A focuses on early childhood education, drawing on focus group discussions with kindergarten teachers. It provides insight into how MbL is interpreted and enacted in the context of young learners, where science is taught once a week and modelling has been part of the curriculum for more than a decade.

Part B focuses on primary education and institutional stakeholders, including inspectors and consultants. It highlights how MbL is positioned within the broader Cypriot curriculum, how teachers and stakeholders conceptualise modelling, and what systemic supports or constraints shape its implementation.

Part A: Early Childhood Education

1 Introduction

This report is situated within the context of early childhood science education in Cyprus, specifically focusing on kindergarten teachers. In this setting, the Natural Sciences are integrated into the national curriculum and are typically taught once a week. The curriculum also incorporates some elements related to modeling, providing a general framework for its integration into teaching.

Modeling-based Learning (MbL) is particularly relevant in this context, as it aligns with current educational priorities that emphasize inquiry, active participation, and the development of scientific thinking from an early age. As reflected in the findings of this study, MbL supports children in understanding scientific phenomena through exploration, experimentation, and the construction of knowledge.

However, despite its inclusion in the curriculum, the practical implementation of modeling remains challenging, possibly related to the fact that it was introduced in the national curriculum about 11 years ago. The focus interview findings indicate that teachers often rely on their own experience and professional development, as the curriculum provides limited guidance for classroom application. This highlights the importance of examining how MbL is conceptualized and enacted in practice, in order to identify both its potential and the areas where further support is required.

2 Educational Context

In Cyprus, the Natural Sciences are institutionalized within early childhood education and are taught in kindergartens on a weekly basis, typically once per week. The national curriculum provides a general framework for science education, incorporating some references to modeling and modeling-based approaches as integral components of inquiry-oriented learning.

Approximately 11 years ago, professional development initiatives were introduced to support teachers in science instruction and the classroom implementation of inquiry-based teaching and learning. These training programs aimed to familiarize kindergarten teachers with inquiry-based approaches and to provide concrete guidance on integrating such practices into everyday teaching. During the past 4 years, these efforts also included support for modeling-based learning.

Despite these efforts, the curriculum primarily offers high-level guidelines rather than detailed, practical instructions for classroom application. Consequently, teachers' ability to implement MbL often depends on their participation in professional development, years of experience, and collaboration with colleagues.

Overall, the Cypriot educational context reflects a system where MbL is recognized at a conceptual level, while its practical execution continues to evolve through professional learning and individual teacher initiative.

3 Method

This study employed a qualitative research design, utilizing data collected through 2 focus group interviews with 5 kindergarten teachers each. The participants were educators active in early childhood education, with varying levels of experience in Modeling-based Learning (MbL). To ensure ethical standards, no identifiable personal information was collected.

Participants were recruited through professional networks and on a voluntary basis. The focus group discussions were conducted in March in an online format. Each session was moderated to facilitate dialogue and ensure that all participants had the opportunity to share their perspectives.

The discussions were guided by a semi-structured interview protocol focusing on participants' understanding and application of models, modeling, and Modeling-based Learning in science education. The duration of each session allowed for in-depth discussion and a meaningful exchange of experiences among participants.

All sessions were audio-recorded and subsequently transcribed. The data were anonymized to maintain strict confidentiality. Data analysis focused on identifying recurring themes, patterns, and divergences, with particular attention to variations between teachers with greater and less experience in modeling.

4 Findings

4.1 Knowledge

[Q1-Q6] Describe how participants talk about and understand models, modelling, and Modelling-based Learning (MbL). What meanings do they attach to these concepts? What role do they see MbL playing in science education? You may also reflect on where their knowledge appears to stem from (e.g. professional experience, teacher education, curriculum documents, policy discussions). Differences or similarities between teachers and stakeholders can be addressed where relevant.

Q1: What do you think are the most important goals for students to learn in science education? Why?

Participants with more experience in Modeling-based Learning (MbL) highlight the development of scientific and cognitive skills – such as inquiry, observation, data collection and classification, as well as the design and execution of experiments – as a fundamental objective of teaching Natural Sciences. At the same time, the importance of children's mental empowerment and the cultivation of communication skills within the context of Natural Sciences is emphasized. Particular emphasis is placed on shaping positive attitudes toward science so that students develop interest and a positive disposition toward learning. Simultaneously, the importance of cultivating scientific reasoning is highlighted through processes such as formulating hypotheses, investigating phenomena, and revising initial perceptions. Through classroom examples, it is shown that children are encouraged to seek alternative explanations, challenge obvious interpretations, and reach conclusions through investigation and the manipulation of variables. Overall, the responses converge on the view that the teaching of Natural Sciences aims not only at the acquisition of knowledge but primarily at the development of a way of thinking based on inquiry and understanding.

Participants with less experience in modeling emphasize the importance of developing basic skills in Natural Sciences, such as critical thinking and observation, focusing on children's ability to think autonomously, describe, explain, and compare. At the same time, the significance of understanding concepts, such as operational definitions, and the use of modeling is highlighted. Furthermore, all participants underscore the importance of learning through experience, discovery, and exploration, as well as the need to cultivate attitudes toward nature and the environment. Overall, the responses show a common direction, without significant variations, focusing on children's active engagement in the learning process.

Q2: What does the term models mean to you in the context of science education?

Participants with more experience in MbL perceive the 'model' as a representation of a physical phenomenon, which can be rendered in various ways and media. It is noted that the model constitutes the final result of a process, which can take different forms, such as drawings, theatrical representations, or three-dimensional constructions. At the same time, it is emphasized that this representation is not uniform but can be implemented with different materials and approaches, depending on the context and the goal of the instruction. Overall, the participants converge on the view that the model functions as a tangible and visible result, through which a phenomenon is represented and understood.

Q3: What does the term modelling mean to you in the context of science education?

Participants with more experience in MbL perceive modeling as a process through which a model is constructed and evolves. It is emphasized that this is a trajectory not limited solely to the creation of the model, but one that includes its use, evaluation, and continuous improvement. At the same time, it is noted that through this process, children are guided toward understanding and explaining phenomena, as modeling functions as a means of inquiry and of making sense of knowledge. Particular emphasis is placed on the evolutionary nature of the process, where the model is gradually modified – through additions or subtractions – until it represents the phenomenon in a more comprehensive way. Overall, the participants converge on the view that modeling constitutes a learning path leading from inquiry to the gradual construction and refinement of knowledge.

Q4: What does the term Modelling-based Learning mean to you in the context of science education?

Participants with more experience in MbL perceive learning through modeling as a process of knowledge construction, through which children understand and explain phenomena by creating, using, and improving models. It is emphasized that children's engagement in this process leads to deeper understanding, in contrast to more theoretical approaches, as knowledge emerges experientially through inquiry and active participation. At the same time, it is noted that different models for the same phenomenon can coexist; these are not necessarily rejected but are utilized according to the purpose and criteria, highlighting different aspects of the phenomenon. This process helps children depict and organize their thinking (e.g., through drawing), facilitating understanding. Furthermore, it is highlighted that through modeling, children learn not only the content of a phenomenon but also the process of scientific inquiry, such as the need for testing, evaluation, and documentation. Overall, learning through modeling is presented as a substantial and comprehensive approach that enhances both understanding and the development of a scientific way of thinking.

Q2 – Q4:

Participants with less experience in MbL perceive the model as a representation of reality that helps children better understand phenomena, processes, and concepts. It is emphasized that models can take various forms (e.g., drawings, three-dimensional constructions) and evolve to represent not only the parts but also their role and function. At the same time, it is noted that modeling contributes significantly to understanding, allowing children to move beyond simple knowledge through experiential examples and active participation. It is also mentioned that children are actively involved in the process, constructing and investigating for themselves. Finally, a distinction is made between the model as a final product and modeling as a process with steps leading to the construction of the model, while it is highlighted that it constitutes a practice frequently used in daily teaching and is considered particularly important.

Q5: Where does this knowledge you have about models, modelling and MbL come from?

Participants with more experience in MbL report that their knowledge of models and modeling stems primarily from professional development programs, seminars, and collaboration with colleagues, as well as from the exchange of experiences within the educational community. Particular emphasis is placed on school-based professional training that was offered for several years by the Ministry of Education, which is considered more effective as it offers a more direct, personal, and experiential experience. At the same time, it is noted that familiarity with modeling is not yet universal, as many educators either lack sufficient information or feel insecure regarding this teaching approach of Science Education. Furthermore, the need for further and more substantial professional development is highlighted – one that combines theoretical understanding with practical application, such as observing demonstration lessons and utilizing appropriate instructional materials. Finally, participants point out that although the curriculum includes references to modeling, it does not provide adequate guidance for its practical implementation. Overall, it appears that the development of knowledge in modeling is based mainly on a combination of training, collaboration, and personal experience, while there remains a need for a more systematic and supportive approach.

Participants with less experience in MbL report that their first contact with modeling primarily emerged through the curriculum, professional development seminars, and professional experiences. At the same time, collaborations with colleagues, as well as participation in programs and actions (national or European), appear to play a significant role. Furthermore, the contribution of studies and university education – even through online forms of instruction – to the shaping of their understanding of modeling is highlighted. Overall, the participants' experiences show that familiarity with modeling develops gradually, through a combination of professional development, personal experience, and practical application in the classroom.

Q6: What is the role of models, modelling and MbL in Science Education?

Participants with more experience in MbL report that models and modeling constitute a fundamental tool for teaching Natural Sciences, as they allow for a deep understanding of phenomena through children's active engagement. Modeling is utilized in units where it is feasible, such as shadows, and freezing and melting, with participants stating that in these specific cases, it was applied throughout the duration of the units. At the same time, it is noted that although systematic application is considered important, its implementation is affected by practical constraints, such as available time and classroom obligations.

Participants with less experience in MbL emphasize that the use of models helps children explore and understand the functioning of systems and phenomena through the study and gradual improvement of models. It is noted that the process may involve the creation of multiple models to achieve a better understanding of the phenomenon under study. At the same time, the importance of experiential engagement is highlighted, where children actively participate and even 'become part' of the phenomenon, which helps them understand processes that are not directly visible. Furthermore, it is emphasized that through modeling, children engage in processes such as making predictions, experimentation, and investigating factors, leading to conclusions through their own thinking without being given ready-made answers. Finally, all participants agree that knowledge is acquired more effectively when children experience, test, fail, and retry through experiences that reinforce understanding.

4.2 Teaching experience

[Q7-Q11] Describe how MbL is experienced in practice. How do teachers report using models and modelling in their teaching? What roles do they see for themselves and for students? What learning goals are associated with MbL, and how are these approached or assessed? You may also include examples of challenges, uncertainties, or promising practices that emerged during the discussions.

Q7: Do you explicitly address models in your teaching? If yes, how (example!)? If not, why not? [(why) do you think it (explicitly addressing models) is useful for your students?]

Participants with more experience in MbL report that explicit reference to the term 'model' is not a common practice in their teaching, particularly in the initial stages of the learning process. Instead, they prefer to introduce the activity using simpler and more familiar terms, such as 'draw' or 'represent,' and only after children become familiar with the process of creating and using models do they gradually move toward using the relevant terminology. In some cases, the term 'model' is introduced indirectly through discussion or at later stages, without being a central teaching objective. At the same time, it is noted that children often recognize and recall the modeling process even without explicit reference to the term, as they are able to connect it with their previous experiences. Indeed, it is mentioned that in subsequent activities, children themselves may spontaneously use the term, showing that they have understood the process.

Is this useful?

Participants with more experience in MbL consider that knowledge of terminology is not a primary learning criterion. Instead, greater importance is given to children's participation in the process and their understanding of the phenomenon. It is emphasized that even if children do not immediately retain the term 'modeling,' they are likely to understand it at a later stage by connecting it with experiences they have already acquired. Overall, it appears that emphasis is placed more on the process and understanding rather than on the memorization of terminology.

Participants with less experience in MbL report that, although they implement modeling practices in their teaching, they do not explicitly use the term 'model' or 'modeling' in the classroom. All agree that they do not consider it necessary to introduce this specific terminology to the students, choosing instead to focus on other concepts and vocabulary of the Natural Sciences. Overall, a common practice is observed where modeling is utilized at the activity level, without, however, being highlighted as a term within the instructional process.

Q8: What is your role as a teacher in supporting students' understanding of models and modelling? And what is your role in supporting their learning of science using models and modelling?

Participants with more experience in MbL report that the role of the kindergarten teacher is primarily supportive and guiding, with an emphasis on creating opportunities for children to repeatedly come into contact with the modeling process. It is emphasized that through the systematic involvement of children in relevant activities—such as using modeling in different units throughout the year—children gradually understand the process as they experience it again and again. At the same time, the teacher supports learning by creating appropriate conditions for inquiry, encouraging children to participate actively, express their ideas, and engage in the process of constructing and processing models. Overall, it appears that the role of the kindergarten teacher is to facilitate the learning process, emphasizing experiential involvement and the gradual construction of understanding through repeated experience.

Participants with less experience in MbL describe the teacher's role in modeling primarily as guiding and supportive. It is emphasized that the teacher directs the process, helping children to think, articulate ideas, and move toward understanding, without, however, providing them with ready-made answers. At the same time, it is mentioned that learning is intended to emerge through questions and discovery by the children themselves, with the teacher reinforcing, encouraging, and supporting their thinking. Furthermore, it is noted that the degree of guidance may vary depending on the activity and the children's level, while in some cases (especially at the beginning), the approach may be less directive and more open-ended. Overall, the participants agree on the view that the teacher's role is to guide and support the process while maintaining the children's active engagement in learning.

Q9: Do you actively involve your students with modelling practices such as creating, using, or revising models? If so, with which ones and how? If not, why?

Participants with more experience in MbL report that children are actively involved in all fundamental modeling practices. Specifically, they participate in investigating phenomena, express ideas and questions, and proceed to create models through drawing or dramatization. At the same time, they use models to explain phenomena, testing, evaluating, and improving them through an iterative process. Overall, children's engagement is active and covers all stages of modeling.

Participants with less experience in MbL describe that children are actively involved in the modeling process, aiming to understand, describe, and present what they are learning. The process usually begins with discussion, where children suggest ideas and select materials, and continues with the construction of models, explaining how they were created, and their evaluation and revision. At the same time, it is mentioned that discussion constitutes a central element, as it helps children develop their thinking and leads to deeper understanding. Furthermore, in several cases, experimentation is integrated, through which children observe, record, and utilize data to create their models. However, it is noted that the implementation of the different phases of modeling (creation, use, evaluation, revision) depends on the theme and the lesson, while these stages often function in an interrelated manner. Although the existence of all phases is recognized, it appears that the creation of models is the most frequent practice, while the revision or use of ready-made models are used less. Finally, it is mentioned that the learning process can also start from the children's own experiences, which are utilized as a starting point for further inquiry and model development.

Q10: What are the main challenges you and your students face in using/applying models and modelling in your classes?

Participants with more experience in MbL report that the challenges associated with the implementation of modeling are multi-level and involve both external and internal factors. At the educational framework level, a lack of understanding of MbL and support from authorities – such as the inspectorate, school administration, and the educational system in general – is highlighted, which hinders the meaningful implementation of MbL. At the same time, the limited time and the multiple responsibilities of the classroom teacher are emphasized, affecting the ability to systematically utilize this approach, especially given that modeling is more time-consuming. Furthermore, challenges related to classroom conditions are mentioned, such as student heterogeneity, the availability of materials and media, as well as practical difficulties arising from the physical space and the organization of instruction. It is also stressed that many educators do not implement modeling due to a lack of professional development, self-confidence, and support, while the need for guidance – such as the presence of a mentor and appropriate instructional materials – is highlighted. Overall, it appears that the effective implementation of modeling requires systematic support, sufficient time, and appropriate teacher preparation.

Q11: What are your target learning outcomes when using MbL? And how do you evaluate them?

Participants with more experience in MbL report that MbL aims to achieve the learning objectives set from the beginning, as the modeling process contributes substantially to the understanding of phenomena and the construction of knowledge. It is emphasized that through children's active engagement in the process, most, if not all, of the intended learning outcomes are achieved. Assessment is carried out primarily through the products themselves and the learning process. Specifically, participants report that they utilize children's recordings, the models they create, and the solutions or explanations they propose. Particular emphasis is placed on children's ability to describe and explain their model, as well as to analyze the process they followed for its construction. At the same time, children's line of reasoning – both before and after the creation of the model – is taken into account, along with their ability to formulate conclusions. Finally, it is noted that assessment also has an individualized character, adapted to the capabilities and progress of each child.

Q10-Q11:

Participants with less experience in MbL recognize that, although modeling is implemented in the classroom, it is accompanied by certain challenges and difficulties. Key issues mentioned include the lack of suitable materials, limited time, and large class sizes, which hinder the management of the process and the active engagement of all children. At the same time, difficulties related to the construction of models and the differentiation of activities according to the needs of the class are highlighted. Furthermore, it is reported that challenges arise when children lead to incorrect conclusions, as it is difficult for them to revise their ideas, as well as instances where different groups reach different results. Particular emphasis is also placed on the teacher's need for support, either through collaboration with colleagues or through more specialized guidance, especially on more complex topics. This is also linked to the need for ready-made instructional materials and designs that can be implemented in the classroom. Finally, issues regarding children's characteristics (e.g., learning difficulties, safety concerns) are noted, which affect the manner and selection of activities. Overall, the participants believe that most difficulties can be addressed; however, they require adaptation, support, and appropriate planning.

4.3 Curriculum integration

[Teachers Q12-Q13] Describe how teachers perceive the role of the national curriculum in relation to models, modelling, and MbL. How do teachers experience curriculum expectations in their daily practice? Do they feel supported, constrained, or guided by current curriculum frameworks?

Q12: How does the national curriculum influence the use of models and modelling in your teaching practices?

Q13: What are the main tools, manuals, teaching materials available in your country that help you in applying MbL?

Q12 – Q13:

Participants with more experience in MbL report that the curriculum does not provide substantial guidance for the implementation of modeling; although it includes relevant references, it does not practically support the design and execution of classroom activities. As shown in previous reports, the utilization of modeling is based primarily on personal experience, professional development, and collaboration among educators, rather than on clear curriculum instructions.

At the same time, participants state that the available support in terms of tools and instructional materials is limited and does not adequately meet the needs of modeling. It is emphasized that while they themselves do not face significant difficulties due to their training, experience, and peer feedback, the lack of organized and reliable material remains a challenge. Furthermore, it is noted that materials available in schools are often insufficient or unsuitable for the effective application of modeling—for instance, equipment that does not function properly or does not cover the requirements of the activities. The need for more specialized and appropriate materials that substantially support the teaching of Natural Sciences through modeling is highlighted. Additionally, it is mentioned that in some cases, there is uncertainty as to whether specific units are suitable for modeling, a fact that reinforces the need for clearer guidance and support.

Participants with less experience in MbL report that the curriculum offers limited support, primarily at the level of goals and objectives, without substantially assisting in practical implementation. Conversely, it is highlighted that professional development and seminars constitute the main source of support, as they offer guidance, structure, and practical tools that can be utilized in the classroom. At the same time, the importance of collaboration with colleagues is emphasized, as well as the teacher's personal effort through preparation, and seeking assistance. Furthermore, the need for more practical and applicable material is highlighted, along with more organized forms of professional development that substantially support the teacher in instruction. Overall, participants consider that the effective implementation of modeling requires continuous professional development, support, and personal involvement, beyond the existing curriculum.

4.4 Teacher support and needs

[Teachers Q14-Q15, stakeholders Q11-13] Describe the kinds of support participants consider important for strengthening MbL. This may include professional development, teaching materials, structural conditions, collaboration opportunities, or system-level changes.

Q14: What would help you in (further) using models and modelling in your classes?

Participants with more experience in MbL report that reinforcing the use of modeling in teaching primarily requires more and better-targeted support at multiple levels, as has already been highlighted in previous responses. Specifically, the need for more substantial professional development – combining theoretical understanding with practical application – is noted, alongside the need for continuous guidance and feedback. At the same time, the importance of having appropriate and reliable instructional materials is emphasized, as well as the need for more available time so that modeling can be implemented comprehensively. Furthermore, the value of collaboration among colleagues and the exchange of experiences is highlighted, functioning as a support to teaching practice.

What kind of support would you like?

Participants with more experience in MbL express the need for more organized and practical forms of support, such as school-based training, guidance from more experienced educators or mentors, and access to clear instructions and application examples. It is emphasized that support should be experiential and applied, so as to facilitate immediate utilization in the classroom.

Q15: Do you think there is a need for teachers to receive more support in using models and modelling in science classrooms? Please explain why or why not.

Participants with more experience in MbL consider that kindergarten teachers need more support for the use of modeling, as – according to previous responses – its implementation depends heavily on the educator's professional development, experience, and personal initiative. It is emphasized that many teachers do not possess sufficient familiarity or self-confidence to implement modeling, which necessitates the provision of systematic guidance, appropriate materials, and supportive structures. Overall, it is highlighted that reinforcing support can contribute substantially to a more effective and wider utilization of modeling in the teaching of Natural Sciences.

Q14 – Q15:

Participants with less experience in MbL report that, beyond what has already been discussed, key support needs relate to the existence of a clear lesson structure, ensuring a smooth and natural flow in teaching. At the same time, particular emphasis is placed on the importance of guided lesson planning, as well as the presence of a person acting in a supportive role, providing feedback and guidance during the process. Furthermore, participants underline that the most effective form of learning for them is active participation in the design and implementation of lessons. It is emphasized that practical application leads to deeper understanding and knowledge retention, in contrast to a theoretical approach that is not accompanied by application. Overall, participants consider that support should focus on practical, experiential forms of professional development that combine design, implementation, and guidance.

5 Conclusions

Overall, the findings indicate that Modeling-based Learning (MbL) is perceived as a valuable approach to science education, fostering inquiry, active student engagement, and the development of scientific thinking. Participants from both groups emphasize that children learn more effectively through exploration, experimentation, and the construction of knowledge, highlighting MbL as a meaningful and experiential learning process.

Distinct differences emerge between participants with greater and less experience in modeling. More experienced participants demonstrate a deeper, process-oriented understanding, emphasizing the full cycle of creating, using, evaluating, and refining models. In contrast, less experienced participants tend to focus more on the construction of models and hands-on activities, placing less emphasis on systematic evaluation and revision. This suggests that professional experience and targeted development play a key role in shaping how MbL is conceptualized and implemented.

A significant strength of the national context lies in the emphasis on experiential, student-centered learning, as well as the role of collaboration and professional development in supporting teaching practices. However, substantial challenges remain, including limited time, insufficient or unsuitable materials, classroom constraints, and a lack of systematic support. The curriculum is perceived as providing general direction but lacking practical guidance, leading teachers to rely largely on personal initiative and experience.

Based on these findings, key development priorities include the need for more structured and practice-oriented professional development, clearer instructional guidance, appropriate teaching materials, and robust support systems, such as mentoring and collaborative networks. Enhancing the alignment between curriculum expectations and classroom practice is also essential.

In conclusion, while MbL is highly valued and widely recognized for its pedagogical potential, its implementation depends heavily on individual teacher capacity rather than systemic support. This combination of high educational value and structural limitations represents a defining feature of the current national context.

Part B: Primary Education & Institutional Stakeholders

1 Introduction

This report is situated within the Cypriot educational context, with a primary focus on primary science education and, where relevant, reference to secondary science education. In Cyprus, the Natural Sciences are taught as part of the national curriculum and are connected to broader educational aims such as inquiry, explanation, problem solving, critical thinking, collaboration, and scientific literacy. Within this context, Modelling-based Learning (MbL) is relevant because it can support students in representing, interpreting, and explaining scientific phenomena, particularly those that are abstract, complex, or not directly observable.

MbL is particularly important at this time because science education in Cyprus, as in many other contexts, is increasingly expected to move beyond the transmission of factual knowledge and to promote deeper understanding, active participation, and the development of scientific competences. Modelling can contribute to these aims by helping students externalize their ideas, examine relationships between variables, evaluate explanations, and revise their understanding through evidence and discussion.

Although modelling and modelling-related practices can be linked to the curriculum, especially in relation to inquiry-oriented science learning, their classroom implementation is not always systematic or explicit. Teachers' use of MbL may depend on their professional development, teaching experience, available resources, and individual initiative. For this reason, examining how teachers and stakeholders understand and experience MbL is important for identifying current strengths, challenges, and priorities for further development in the Cypriot context.

2 Educational Context

In Cyprus, the Natural Sciences are institutionalized within both primary and secondary education and are taught as part of the national curriculum. The curriculum provides a general framework for science education, including broader aims such as inquiry, explanation, problem solving, critical thinking, collaboration, and scientific literacy. Within this framework, modelling and modelling-based approaches can be linked to inquiry-oriented science learning.

In primary education, modelling appears to be more visible. In secondary education, modelling is also relevant to subjects such as biology, physics, and chemistry, although its use appears to be less systematic and more dependent on subject area, teaching materials, and individual teacher practices.

Professional development initiatives in Cyprus have supported teachers in implementing inquiry-based science teaching, while more limited efforts have included elements related to modelling-based learning. However, the curriculum mainly provides broad guidelines rather than detailed practical instructions for classroom application.

Overall, the Cypriot educational context reflects a system where MbL is recognised at a conceptual and curriculum level, while its practical implementation continues to depend on professional development, teaching experience, available resources, and individual teacher initiative.

3 Method

In Cyprus, two focus groups were conducted and hosted by the University of Cyprus (UCY). Specifically, one focus group was conducted with primary school teachers and one with stakeholders. The focus group discussions were conducted in Greek, as this was the participants' first language and allowed them to express their views, experiences, and meanings more comfortably and in greater depth. The discussions were transcribed in Greek, and selected excerpts were translated into English for reporting purposes. The methodology followed for each focus group is outlined below.

3.1 Focus Group 1

The first focus group was carried out with five primary school teachers. Participants were recruited through convenience sampling, on the basis that they were known to be more actively engaged with science in their teaching practice and to have experience with a range of teaching practices, including MbL. Prior to the session, the teachers were informed about the purpose of the focus group and the wider aims of the study, and they were invited to notify UCY if they wished to participate. The discussion was conducted online at a time convenient for all participants. Upon agreeing to participate, the teachers were provided with an information letter outlining the purpose of the discussion and the procedure to be followed, together with a consent form.

The focus group lasted approximately 90 minutes and was moderated by two researchers. The moderators followed the focus group protocol developed by the EMPOWER project consortium, while also facilitating the discussion, supporting the flow of conversation, and ensuring balanced participation among all participants. With participants' consent, the discussion was recorded, transcribed, and anonymised. The anonymised transcript was then subjected to qualitative analysis.

3.2 Focus Group 2

The second focus group involved four participants holding key roles in science education at the institutional level: one primary science inspector, two primary science consultants, and one secondary physics consultant of Physics from the Cyprus Pedagogical Institute. Participants were invited to take part because of their professional involvement in curriculum implementation, teacher support, and the development of science education within the Cypriot context. Before the session took place, they were informed about the purpose of the focus group and the broader objectives of the study, and were asked to indicate to UCY whether they wished to participate. The meeting was held online at a time that suited all participants. Following their agreement to participate, they received an information letter describing the purpose of the discussion and the research procedure, together with a consent form.

The session lasted approximately 90 minutes and was facilitated by two researchers. The discussion was guided by the focus group protocol developed by the EMPOWER project consortium, while the moderators also ensured the smooth flow of the conversation and encouraged balanced contributions from all participants. With the participants' consent, the discussion was recorded, transcribed, and anonymised. The anonymised transcript was subsequently analysed qualitatively.

4 Findings

4.1 Knowledge

4.1.1 Focus Group 1

The participants seem to attribute to models primarily the role of representing a phenomenon or system that cannot be directly observed. A model is not perceived as "the phenomenon itself", but rather as a means through which the phenomenon can become visible and open to discussion. They pointed out that a model may take the form of a drawing, a picture, a construction, a simulation, a diagram, or even role play or a verbal description.

At the same time, one teacher noted that models can also serve an interpretive function, emphasizing that they can be used as means through which students formulate initial explanations for "black boxes", that is, complex systems that they do not yet fully understand. In this sense, a model functions as a temporary cognitive bridge between observation and scientific explanation.

An important aspect of the participants' knowledge is that they recognize that models have limitations and discrepancies. They emphasize that every model is a human construct and is therefore subjective and may lead to misconceptions. For example, the participants referred to simulations of electricity or to the colours used to represent veins and arteries, which, as they stated, require explicit clarification in order to avoid misconceptions.

With regard to modelling, the participants do not fully agree on a single definition. For some, modelling is primarily the creation of a representation by the students themselves and therefore differs from the simple use of ready-made models or simulations. For others, modelling extends to a broader range of actions: forming an initial hypothesis, drawing, creating a diagram, providing a verbal description, revising, evaluating, and improving the model. Characteristically, one participant stated that:

> *"for me, modelling is the active process of learning. The entire scientific process that we follow in lessons, that is, the hypothesis, the experiment, our conclusions and so on, is modelling for me,"*

while another participant stated in another part of the discussion:

> *"I do not think that modelling goes through all the stages of the experimental process. I think that modelling in itself is a separate issue."*

Thus, knowledge about modelling appears to be rich, but not yet fully conceptually stabilised.

Learning based on the modelling approach is understood mainly as a student-centred approach. The participants consider that it is based on identifying students' initial ideas, externalizing these ideas through some form of model, and progressively revising them on the basis of discussion, data, and new information. However, a certain degree of caution also appears in their responses: some participants question whether modelling is always the most appropriate route when the goal is the rapid achievement of very specific learning outcomes.

The participants consider modelling-based learning to play an important role in science education, because it promotes active learning, makes abstract concepts more visible, connects theory with practice, helps students understand that scientific knowledge is evolving rather than static, and at the same time cultivates aspects of epistemological understanding and scientific literacy. One participant described it as an early phase of questioning and inquiry.

Finally, the participants' knowledge seems to derive mainly from postgraduate studies, research projects, personal teaching experience and, to a lesser extent, from the curriculum and the teacher's guide. At the same time, many state that systematic professional development specifically focused on models and modelling is not frequently available, indicating that their knowledge has been built more through personal inquiry and professional experience than through organised institutional support.

4.1.2 Focus Group 2

The stakeholders who participated in the focus group seem to position modelling within a broader framework of goals in science education. The main aims they identify for science teaching are not limited to conceptual understanding, but also include skills, attitudes, critical thinking, argumentation, problem solving, collaboration, and, more generally, 21st-century skills. Within this framework, modelling is viewed as one of the complex skills of scientific methodology, rather than as an isolated teaching tool.

With regard to the concept of a model, the participants define it mainly as a representation of a concept, a phenomenon, a relationship, or a situation in the natural world. This representation, as they stated, can take many forms: objects, constructions, analogical models, diagrams, virtual and digital forms, verbal descriptions, and even dramatic play. Therefore, the participants seem to adopt a particularly broad definition, according to which almost any organised representation that supports the understanding of a phenomenon can be considered a model.

At the same time, they place particular emphasis on the need for critical examination of the model. One participant noted that:

> *"Something important is to compare the model, to evaluate it, to judge the validity of the model, the extent to which it resembles the real phenomenon, and where it diverges."*

This indicates that the participants do not view models as neutral or fully accurate representations, but recognize the importance of examining their limitations and validity.

With regard to modelling, the participants understand it primarily as a process. In contrast to the model, which is described as a product or a form of representation, modelling is associated with the creation, use, interpretation, comparison, and alignment of the model with reality. It is also mentioned that modelling constitutes a complex skill with different levels, ranging from the construction of a simple model to the interpretation of the relationships that govern a phenomenon.

The participants also recognize that the term "model" is not self-evident for students, especially in the lower grades. One participant stated that:

> *"when we start referring to models in the lower grades, students will say car models, fashion models."*

This suggests that the scientific meaning of the term needs to be built pedagogically and differentiated from the everyday uses of the word.

Learning through modelling is presented as an approach that helps students understand phenomena more deeply, investigate factors, and demonstrate their understanding. One participant stated that:

> *"Primarily, it can be used for understanding a phenomenon, because the model may have removed various other related situations, related factors that do not essentially affect it, but in reality may draw the child's attention elsewhere... I would also say that the construction of an accurate model, a representation of a phenomenon, also shows the children's deep understanding, perhaps of the phenomenon itself."*

Finally, regarding the origin of their knowledge about models and modelling, the participants describe a complex but not always systematic pathway. Some state that their knowledge comes mainly from the curriculum and from their experience of implementing it, while others refer to a combination of studies, research literature, curriculum development, and the study of teaching materials. Particularly important is one participant's explicit statement that:

> *"I have not received systematic professional development on the topic of modelling. My knowledge emerged fragmentarily from various things."*

4.2 Teaching experience

4.2.1 Focus Group 1

At the level of practice, teachers report that they use models and elements of modelling across a variety of topics, such as electricity, the circulatory system, the solar system, the digestive system, and the human body. Their practices include both the use of ready-made models (e.g. simulations, diagrams, videos, maps) and activities in which students create their own models.

The roles they assign to themselves and to their students are clearly differentiated. Students are presented as those who are expected to express their initial ideas, represent their thinking, compare, test, evaluate, and improve models. The teacher, correspondingly, appears as the designer and facilitator of the process: selecting appropriate prompts, regulating the level of openness, providing support, setting boundaries, identifying when a model is productive, and guiding the discussion toward more scientifically acceptable explanations.

Regarding the question of whether they make explicit reference to the term "models" with their students, some responded that they do, in order to address possible misconceptions that may arise from the models provided, while others reported that they do not intentionally do so.

> *"You can look at the model in a matter of seconds. It is important that these limitations of models, especially in teaching, are explained, because they are often seen as identical to the phenomenon itself, and this may also create misconceptions."*

A strong pattern emerging from the discussion is that modelling is linked to the elicitation of pre-existing ideas. Teachers believe that through drawings, diagrams, or other representations they can see how students think before instruction, so that they can build on these ideas and transform them. In this sense, modelling is described not only as a teaching method, but also as a way of gaining diagnostic access to children's thinking.

With regard to learning goals, the participants associate learning based on the modelling approach mainly with the development of observation and interpretation skills, the strengthening of inquiry and scientific thinking, the cultivation of the ability to explain phenomena, and the deeper engagement of students in the learning process.

At the same time, some express doubts as to whether learning based on the modelling approach is always the most effective approach for achieving cognitive goals or for teaching specialized scientific knowledge under tight time constraints.

Assessment within modelling appears to be understood mainly as formative and process-oriented: comparing models, identifying correspondences and discrepancies, discussing limitations, improving different versions, and engaging in group critique. At the same time, some participants noted that assessment may also include more conventional forms, such as a test or short quizzes, when the aim is to determine the extent to which students have understood the phenomenon under study. One participant added that another means of assessment can also be the students' final model:

> *"The final model is, in a way, an assessment product, because depending on how many elements of the system the student used, depending on which processes they included, depending on the quality of the processes or the correctness of the processes or the logical coherence of the processes that the student incorporated into their model, it is a way through which you can assess the model, its quality."*

Several challenges and uncertainties also emerge. First, teachers are concerned about the extent to which students' models may deviate from what is scientifically accepted and how easy it is to restructure them afterwards. Second, issues of age appropriateness are raised, as it is considered that younger students can handle simpler representations, whereas more complex forms of modelling require greater cognitive maturity.

> *"As a parameter that should also be taken into account, I would mention age; that is, with students in the first, second, or third grade of primary school, I would expect them to represent how they understand something through a drawing, but from older students I would expect them to create a model through construction or to be able to interpret a dynamic model presented on the computer and use it or evaluate it, so it depends on age."*

Third, it is stated that modelling "is not free drawing," but requires structure, specifications, and close supervision by the teacher. One participant noted during the discussion:

> *"For example, do we expect a nine-year-old or a ten-year-old to create a model of the respiratory system? With what knowledge? With what images will they manage to do it? They will create an approximate model. At what point should we accept a model from students and stop the teaching there?"*

Despite these difficulties, a number of promising practices are also highlighted: the use of simulations for invisible processes, explicit discussion of the limitations of a model, group evaluation of models, linking modelling with inquiry, and the use of creative activities that allow students to externalize their thinking.

4.3 Curriculum integration

4.3.1 Focus Group 1

Teachers seem to understand that the curriculum includes references to models and modelling, and that the teacher's guide also provides some relevant elements. However, this presence does not appear to be experienced as sufficiently specific or sufficiently supportive for everyday practice. Participants often report that they need to "recall" prior knowledge from their studies or from their experience in order to meaningfully implement learning based on the modelling approach.

In addition, teachers feel that existing teaching structures and textbooks often favour a more theoretical or information-based approach rather than an approach based on modelling. It is characteristically mentioned that older textbooks and worksheets were more experimental and therefore closer to the philosophy of modelling, whereas current materials are considered to be more theory-centred.

The participants point out that certain units of the curriculum could make greater use of modelling. As an example, they refer to units concerning the natural environment, such as pollution, which are presented in a theoretical way. At the same time, they argue that, in order for modelling to be implemented meaningfully, it is not enough simply to add relevant activities. Rather, a clearer specification of the core knowledge of each unit is also required, so that what is essential can be distinguished from what is secondary, and space can be created for more inquiry-based and interpretive learning.

4.3.2 Focus Group 2

From the perspective of stakeholders, modelling seems to occupy an important place in science curricula, particularly in primary education. One participant characteristically stated that:

> *"Modelling is embedded throughout the success and adequacy indicators of our curricula… I can hardly think of a lesson that did not take it into account… Modelling was seriously considered by the curriculum development team."*

This excerpt shows that, from their perspective, modelling is not a peripheral element, but an integrated part of the logic of the curriculum. As mentioned, modelling appears progressively across the grades of primary education. The participants support this view with many examples from primary education. They refer to units such as the sky and Earth, the movements of the planets, the succession of day and night, the far side of the Moon, eclipses, rocket launches, the musculoskeletal system, the respiratory system, electricity, and energy chains. In these cases, as they stated, modelling appears either through the construction of physical models or through the use of simulations, virtual laboratories, and other digital environments.

On the other hand, a more cautious position is also recorded: even if students come into contact with many models, it is not certain that they will all be able, in the end, to define what a model is or to express clearly its nature and purpose. Some participants estimate that students may be able to recall examples of models they have used, but may find it more difficult to provide a general definition or to talk about the nature of models. This suggests that the integration of modelling does not automatically lead to a fully developed metacognitive or epistemological understanding of models among all students.

Particularly important is also the distinction between primary and secondary education. For secondary education, the picture presented is clearly more fragmented. One participant noted that:

> *"In secondary education, I think there is nothing systematic that helps colleagues make use of modelling… At least in upper secondary school, I do not think there is such a systematic reference to models or modelling… Therefore, I would say that*

the use of modelling takes place somewhat fragmentarily; it depends on each colleague's approach to models and modelling."

4.4 Teacher support and needs

4.4.1 Focus Group 1

The discussion indicates that teachers consider multifaceted support necessary in order to strengthen the implementation of modelling in teaching practice. The first need, as stated by all participants, is targeted professional development. Participants reported that they need more opportunities to understand what modelling actually is, how it differs from other practices, and how it can be implemented across different subject areas and grade levels. They also added that they need professional development on how they can use students' final models as a means of assessment.

A second key need, as they stated, is the existence of a bank of tried-and-tested materials. They mentioned that it would be helpful to have materials that have already been tested in practice: prompts, lesson plans, simulations, and activities that can be used directly and reliably. This need is linked to the fact that the development of such activities is described as a time-consuming process that requires years of experience, trial, and revision.

Third, particular emphasis is placed on material, technical, and structural conditions. Participants referred to limited space, the absence of laboratories, the lack of appropriate equipment, and the cost of materials, all of which substantially hinder the implementation of modelling.

A fourth need is time. Participants stated that the available teaching framework is very demanding and leaves little room for meaningful inquiry, creation, discussion, and revision of models. Time pressure often forces them to prioritize shorter, more direct, and more theoretical forms of teaching, even though they consider modelling to be pedagogically more powerful.

Finally, the discussion highlighted the importance of collaboration. Participants considered demonstration lessons, peer observation, the exchange of practices, and even connections with teacher educators who could bring new ideas into schools to be valuable. One participant suggested that student teachers who teach in schools as part of their school practicum could implement material based on modelling, so that in-service teachers could be inspired by the student teachers' activities. Therefore, the support requested is not only individual professional development, but also the development of professional learning communities around learning based on the modelling approach.

4.4.2 Focus Group 2

The participants consider that teachers need more targeted and systematic support in order to make meaningful use of modelling in their teaching. The most prominent need that emerges is professional development. Specifically, they stated:

> *"Professional development is needed… so that we can focus on the skill of modelling and on teachers' own understanding of modelling."*
>
> *"Professional development is certainly needed, mainly systematic professional development on the theoretical background of modelling."*

These excerpts show that the participants do not consider the existing fragmented support to be sufficient. At the same time, it was stated that an explicit theoretical framework for the use of models is missing. As was pointed out, many teachers "do" modelling, but are not always able to recognize it, name it, and use it consciously as a pedagogical approach.

A second key need concerns the provision of specific examples of implementation. The participants suggest the development of lesson examples directly connected to the curriculum, descriptions of good practices, video-recorded lessons, teaching snapshots, and, more generally, material that demonstrates in practice how modelling is implemented and why it is effective. In addition, reference is made to platforms, software, simulations, lesson plans, instructional designs, as well as more contemporary forms of representation such as virtual and augmented reality. Another important need emerging from the participants' responses is continuous advisory and practical support. One participant also mentioned that it would be useful to have simulations available in the Greek language.

The participants also propose more flexible forms of professional development, such as a longer optional seminar, regional training sessions, or even massive open online courses (MOOCs), so that teachers can engage in professional learning in their own time.

Finally, one participant raised the issue of avoiding the replacement of real experiments with models for reasons of convenience, noting that some teachers may:

> *"instead of teaching electricity and handling wires, go directly to the model."*

5 Conclusions

Overall, the findings indicate that MbL is recognised as an important approach in science education, both by teachers and by stakeholders. Participants understand models as representations that can help students make sense of abstract, complex, or not directly observable phenomena. At the same time, they recognize that models are not exact copies of reality, but have limitations, simplifications, and possible discrepancies, which need to be explicitly discussed in teaching.

One key strength that emerges is that modelling appears to be present, to some extent, in the science curriculum, particularly in primary education. Stakeholders present it as embedded in the success and adequacy indicators of the curriculum and connect it with broader aims, such as scientific literacy, inquiry, problem solving, collaboration, and 21st-century skills. Similarly, teachers report that they use models and elements of modelling in different units, such as electricity, the human body, the circulatory system, and the solar system, using drawings, constructions, diagrams, simulations, and other forms of representation.

However, an important critical point is that modelling does not appear to have a fully stabilised conceptual meaning for teachers. Although several teachers use models or activities related to modelling, it is not always clear whether they understand modelling as a distinct pedagogical approach or as a more general use of representations, experiments, and inquiry-based activities. In some cases, modelling is almost equated with the entire scientific or experimental process, while in others it is distinguished from it. This suggests that, although there is a positive attitude towards modelling, greater theoretical and pedagogical clarification is needed.

In addition, teachers seem to approach modelling mainly through the practical needs of the classroom. They connect it with eliciting students' initial ideas, externalizing their thinking, identifying misconceptions, gradually revising their ideas, and promoting their more active participation in learning. This is a particularly positive finding, as it shows that teachers recognize the potential of modelling as a student-centred and formative process. At the same time, however, it appears that its implementation depends largely on each teacher's personal experience, initiative, and confidence, rather than on a systematic framework of support.

Another critical observation concerns the gap between curriculum intentions and everyday teaching practice. While stakeholders consider modelling to be embedded in the curriculum, teachers do not always experience this presence as sufficiently clear, specific, or supportive. On the contrary, several teachers report that existing textbooks and teaching materials tend to favour a more theoretical or information-based approach rather than a meaningful approach based on modelling. This suggests that the existence of relevant references in the curriculum is not sufficient on its own unless it is accompanied by practical examples, guidance, time, and appropriate resources.

Teachers also identify several practical difficulties that limit the implementation of modelling. The main ones concern lack of time, limited equipment, absence of appropriate laboratory spaces, cost of materials, and pressure to cover the curriculum. They also express concerns about the extent to which students' models may deviate from scientifically accepted explanations, as well as about how and when the teacher should intervene. These points indicate that modelling cannot be considered a simple or easily implemented approach; rather, it requires planning, pedagogical judgement, and appropriate conditions.

The issue of assessment is also particularly important. Participants seem to recognize that students' models can be used as assessment products, as they reflect the way students understand the elements, relationships, and processes of a system. Nevertheless, there does not yet seem to be a clear and commonly accepted framework for assessing the quality of a student model. Therefore, assessment in modelling is an area that requires further development, particularly in relation to criteria, tools, and forms of feedback.

The support needs that emerge are clear. Both teachers and stakeholders emphasize the need for targeted and systematic professional development. This professional development should not be limited to general references to the importance of modelling, but should focus on its theoretical background, its distinction from other teaching practices, the design of activities, the management of students' models, assessment, and the adaptation of the approach to different ages and subject areas. At the same time, there is a need to develop banks of tried-and-tested materials, examples of good practice, lesson plans, simulations in Greek, video-recorded lessons, and opportunities for collaboration among teachers.

In conclusion, model-based learning appears in the national context as an approach with significant pedagogical value, but with uneven and not fully systematic implementation. Its main strength is that both teachers and stakeholders recognize its contribution to the understanding of complex phenomena, active learning, inquiry, and the development of scientific thinking. The main challenge, however, is the transition from a general recognition of the value of modelling to its more conscious, systematic, and supported implementation in the classroom. For this reason, the main development priorities concern the theoretical clarification of the approach, the strengthening of teachers' professional learning, the production of practical materials, and the creation of conditions that will allow modelling to function meaningfully rather than fragmentarily in science teaching.

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