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Research and Design teachers’, and students’ frame of reference around the concept of 'model’

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Abstract

This pilot study investigates the way that young students and teachers of a Dutch Science Technology Engineering and Mathematics (STEM) secondary school subject Research and Design (R&D) reason about the concept of ‘model’. The core of the Dutch Technasium secondary school course Research and Design curriculum (R&D is in Dutch called Onderzoeken en Ontwerpen O&O) is to involve students in real-life design (or research) problems with a problem owner at a company or organisation. Students explore the nature of the design problem, establish a design brief, explore possible solutions and work out one option into a design, a prototype or a product depending on the level of complexity. Students work and learn in teams coached by Technasium teachers. Some secondary school teachers are qualified to teach at Technasium if they obtain a certificate from the Technasium foundation through a number of short training courses. They are originally teachers in various subjects like mathematics, physics, physical exercise, language and so on. The other part of the teachers has a teaching degree in R&D next to a degree in engineering. Thanks to different backgrounds the teachers offer a variety of angles and know-how in different fields of expertise needed during R&D activities. Such a composition is enriching and STEM supporting at the level of knowledge transfer. It is clear that some R&D teachers have no design pre-knowledge. A pilot survey of R&D students and teachers on the concept of ‘model’ within design activities unexpectedly showed similar doses of confusion about the concept of ‘model’ among students and teachers. Therefore, when asked to teach a concept of ‘model’ in design related activities teachers provided a different definition of concept. Often a physically built scale ‘model’ or prototype is the form of ‘model’ they recognize in designing. The danger of such an approach is that the students obtain different, incomplete, or incorrect knowledge about the concept of ‘model’ in relation to design. Therefore, the set of values and norms within the group of Technasium teachers is needed, to establish a design related frame of reference.

Keywords

STEM, Stichting Technasium (ST), Research and Design (R&D), Concept, ‘model’, Pedagogy of Design, Project based learning, Design Based Learning (DBL).

Dutch innovative STEM project-based course

A core goal of the ‘Technasium’ curriculum and of the course Research and Design (R&D), which in Dutch is called O&O (Onderzoek & Ontwerpen, 2022), is to have students involved in real- life problems set by interdisciplinary companies or organisation while learning about different technical professions. This unique approach, initiated by the Dutch Ministry of Education, Culture and Science and set up in 2004 by two inventive teachers (Schalk & Bruning, 2014), connects companies and institutions of all sizes with secondary schools and supports the learning of engineering through research and design. As a primary goal of the subject, students get acquainted with different professions and issues in engineering at an early age. This helps them to make an informed decision when choosing their future studies (Van der Veen & Blume-Bos, 2015). The final assignment, the Master's test called in Dutch ‘Meesterproef’ was named after a piece of work made by a craftsman with the aim of becoming a member of a guild (ANW r.d.) The Master’s test also involves Polytechnic or University experts as a support during the project (Onderzoek & Ontwerpen, 2022). The professional companies that own problems are not necessarily involved in engineering but do need engineering support. The company or institution provides these tasks in consultation with a teacher through project assignment descriptions. Technasium students always work in a cooperative team on real life and current science and technical projects. As there are no textbooks for this subject, for each project a unique assignment is written, together with the client, which is then used instead of the text course book.

Project assignments ought to be written on the level of educated adult professionals asked to solve the problem and are therefore not being adjusted to students’ age or skills level. These project assignments are in lower grades written by the teacher (in consultation with the companies, assignment field experts and/or institutions) but later in their R&D career, in upper grades, the students will go out to find problem-owners themselves and write their own projects in consultation with the company or institution. The projects run for about 10 weeks in the lower grades (in grades 7–9, ages 12–15); and in the upper grades, students choose projects themselves which last for 16 or 20 weeks (in grades 10–12, ages 16–18). In upper grades R&D is an elective subject. R&D aims to integrate different disciplines from natural sciences into technological research and design projects through real life problems. Research and Development (R&D) is a subject that contributes to a more comprehensive approach, aligning with the core concept of the Science, Technology, Engineering, and Mathematics (STEM) movement. STEM education is based on the principle of interdisciplinary learning, aiming to educate students in four specific disciplines through an applied approach. STEM involves integrating disciplines into a cohesive learning based on real-world applications (Horn, 2014).

Disruptive innovation (Christensen et al., 2016) refers often to a technological development, for example, Artificial Intelligence robots, that significantly affect the way markets or industries operate. The need to equip students with the skills for ‘disruptive thinking’ is recognized by some governments (Innovation and Science Australia, Australian Government, 2017). Although the need for STEM education is in general recognized the implementation of STEM education is complex and challenging due to different approaches, practical, pedagogical, and didactic implementation obstacles advocating the need for productive alignment of disciplinary knowledge with interdisciplinary contexts (Lyn, 2020).

STEM R&D teachers

A significant portion of the latest and most valuable knowledge encompasses multiple subjects. Interdisciplinary STEM education has the potential to inspire students towards careers in STEM fields and could enhance their engagement and proficiency in mathematics and science. Ensuring effective STEM education is imperative for the future accomplishments of students.

Equally crucial is the preparation and support provided to teachers of integrated STEM education to realise these objectives (Rossouw et al., 2011).

But as we know the most integrated STEM teachers are originally educated to teach subjects in single disciplines. This applies to R&D teachers as well. At the moment, all secondary school teachers are qualified to teach at Technasium if they obtain a certificate from the Technasium foundation through a number of short training courses at Technasium Academie (Technasium Academie 2023). The only difference is the field of teachers' activity known as first grade (upper grade 16-18 years) or second grade (lower grade 12-15 years) of secondary teaching. This means that the R&D teaching team is usually composed of many different teachers who have competence in different subjects from physics to history to languages but also on different levels of the content. Implementing a relatively new integrated STEM subject such as R&D as part of the curriculum presents teachers who teach the subject with several challenges. They still must master the content of the new subject (Stohlmann et al., 2012). They also need to get used to project-based and student-centred teaching methods and pedagogical approaches that contain different jargon and concept descriptions (Henze et al., 2007). This makes the new integrated STEM subject R&D potentially more difficult to teach. Furthermore, they need to possess effective communication skills to establish valid contact with companies and institutions, as well as to define valid project design problems or research questions.

Importance, defining and exploring concepts

During the execution process of research or design assignment, technological education and technological literacy in general is an important aspect of the R&D subject. The outcome of a Delphi study on the set of basic concepts that are most relevant for technology education was that the following five concepts were the basic for technology education: design-as-a-verb (‘designing’), systems, modelling, resources, and values (Rossouw et al., 2011). Therefore, we can infer that the concept of modelling is particularly important to learn accurately. The meaning of technological concepts, like the concept of ‘modelling, have in students’ minds directly affected their learning in technology because these concepts form a framework from which to construct other concepts and base actions on (Jones, 1997). Ensuring that teachers share a collective understanding of key concepts is essential for delivering a consistent, effective, and high-quality education, particularly in interdisciplinary fields like R&D. It enables teachers to provide consistency in the curriculum through effective and coordinated instruction, thereby standardising the learning experience. Students benefit by receiving clear and unambiguous curriculum content and can apply learned concepts in various interdisciplinary contexts.

There are several possible approaches for learning concepts. One of them, learning by design (LBD) is a project-based approach. The way in which this approach stimulates concept learning is by learning from experience. Learning concepts through design combines two different pedagogical approaches, namely problem-based learning, and case-based reasoning. Solutions to new, real-life problems are found by adapting existing knowledge and already known solutions (Van Breukelen et al., 2016). The learning by design approach uses real-life design problems. This problem is solved through two cycles of activities. One cycle for design and one cycle for investigation which are related to each other (Kolodner, 2002). Kimbell et al. (1991) described this as an iterative process of imaging (inside the head) and ‘modelling (outside the head) until sufficient details are resolved for the concept to be realised physically as a working prototype.

An interesting way to learn concepts, within the framework of course R&D, is learning by design. A project-based approach; learning by design (LBD) uses real life design problems. Designing brings up questions, inquiry on lacking knowledge. Gained knowledge will be than used for designing. Need to know and need to alternate and are inseparably connected to each other by the design process. (Kolodner, 2002). There are few good reasons to choose design as a learning context such as: collaborative learning process, contextual learning, and reflective learning (Van Breukelen, 2017).

Although learning to design or by designing is not even one of the learning goals of the course R&D, as students are learning through projects based on the design process they come in touch and get acquainted with concepts and terms of design and designing. The learning by design approach stimulates concept learning by learning from experience. The problems used in learning by design, certainly in Technasium widely undefined projects, deliberately provide the conflict in the students' approach so that the existing knowledge is not sufficient for solving the problem, thus making it necessary to gain new knowledge and develop new ideas (Van Breukelen et al., 2016).

During the design process, students are confronted with various tasks and terms, which are complex and/or unknown to them as starting designers. A crucial part of technological literacy is understanding design and the design process. (International Technology Education Association, 2007). It sounds simple but concepts, such as: Designing, Modelling, Design brief are complex, dependent on professional context and difficult to define.

Defining the concept of 'a 'model' within STEM subjects

Concept of a 'model' may differ between different fields such as science and technology. This is caused the term 'model' being understood in different ways. Therefore, a concept with the same name can work out differently in different domains. What students and teachers have in mind as the concept for example of an educational physical scale 'model' of an ear, is important, because it informs how teachers and students support, communicate about, and apply it in practice. When both teachers and students have a clear and shared understanding of what a concept is, it can significantly improve the effectiveness of teaching and learning. Shared language understanding of different types and functions of 'model's promotes a common language between teachers and students. This makes communication more effective because both parties use the same terminology and conceptual frameworks. This can reduce misunderstandings and allow for a smoother exchange of ideas.

The focus of research is concept of 'model' and how it is used to communicate ideas with R&D rather than the process of 'modelling' (an R&D skill). So, what do students and teachers of R&D understand by the concept of a 'model'. Will the different types of 'model's without a science or technology purpose like playmobile horse (an abstracted physical scale 'model') also be seen as a 'model' or not? In order to explore the R&D frame of reference for the concept of a 'model', the natural science, mathematics and R&D have been examined in advance for the meaning of the term 'model' and classification of types of 'model's. Natural science includes earth science, physics, chemistry, astronomy, and biology, while mathematics is considered one of the four core subjects taught in schools, alongside physics, chemistry, and biology.

In the literature, the concept of ‘model’ is defined in various ways. Lijnse (2008), Schwarz & White (2005), and Hestenes (1987) all describe a ‘model’ as a representation of reality with a goal and an alleged area of validity. They differ in their specifics, with Schwarz & White (2005) emphasizing representation rules and reasoning structures, and Hestenes (1987) focusing on observable patterns in physical phenomena. In secondary education SLO (2020), a simplified definition is often used, describing a ‘model’ as a schematic representation of reality.

Although there are various definitions of the term ‘model’, no unequivocal meaning or definition has been found within the natural sciences, mathematics, and R&D for the term ‘model’. The definition depends on the field of knowledge. A common definition is that a ‘model’ is 'always a simplification of reality'. Reality is according to Cambridge dictionary (2023) the state of things as they are, rather than as they are imagined to be. Several scientists Wegner (2017), Buede, & Miller (2016), including Lijnse (2008), argue that a ‘model’ always has a purpose. In the absence of a definition, Van Driel et al. (1997, p. 179-180) has provided a number of characteristics by which a ‘model’ can be recognized in the natural sciences such as:

- A ‘model’ is always a ‘model’ of something, namely of an object of investigation. The object of research can be a system, but also a phenomenon, a process, a 'thing', or something that does not exist (anymore) (such as a dinosaur) or whose existence is uncertain (such as a black hole).
- A ‘model’ is a tool for research into the object in question. It is used as such because the object itself is not accessible for direct examination.
- A ‘model’ shows a number of similarities with the object of research. Thus, a statement about a certain ‘model’ can be 'translated' into a hypothesis regarding that object. Assessing such a hypothesis (if possible) leads to new knowledge about the object of research.
- A ‘model’ differs from the object of research in that reductions are applied when drawing up a ‘model’ (for example, by deliberately ignoring certain aspects of the object of research in the ‘model’), by scaling or in some other way. The pursuit of simplicity plays an important role in the development of ‘model’s (Ockham's principle).
- A ‘model’ has a built-in compromise character, and the researcher has a certain freedom in choosing a ‘model’. The research question plays a role in that choice.
- A ‘model’ is not derived directly from the object of study, such as a photograph or a measurement result. It contains elements that the object of investigation does not possess. Creativity therefore plays a role in the choice of a ‘model’.
- During a study, a ‘model’ may undergo an iterative development. The object of research is always studied in more detail.

Different classifications are possible to classify ‘model’s within the natural sciences, engineering and mathematics. This classification can be made, for example, based on a level of abstraction, the purpose of a ‘model’ or type of ‘model’. By exploring the different classifications of ‘model’s, educators could help students develop a more nuanced, flexible, and practical understanding of science, engineering and mathematics. In the classroom, not all students learn the same way. Some might grasp concepts better through visual models, while others might prefer abstract, mathematical representations. By teaching about the different types of models and their classifications, educators can provide multiple pathways for students to understand the material.

Therefore following possible classification of 'model's based on their function could help R&D students to better understand their purpose and utility in various contexts, whether it is education, research, engineering, or information management. If we classify 'model's on their function we can think of didactical (to learn, practice, assess, visualise), explorative (to experiment, optimise, simulate), theoretical (to predict, focus, generalise) or informative 'model' (to inform about structure, constraints, meaning, rules).

In architecture and industrial design, 'model's are often defined and classified based on the design process (Eger et al., 2010; Knoll & Hechinger, 2007; Karssen & Otte, 2018). Different types of 'model's are used at different stages of the design process. Usually, those 'model's then go from coarse to fine with regard to simplification of reality (level of abstraction). Abstraction is the opposite of reality according to Cambridge dictionary (2023), abstraction is the situation in which the subject is very general and not based on a real situation. The word 'abstraction' comes from the Latin verb 'abstrahere' which means: to distract. It is the act of withdrawing or removing something to focus on a sort of property.

Type of 'model's could be divided into physical like a 'model' of an ear in biology or a scaled car 'model', conceptual like electrical circuit or competition organisation schemes and symbolic like a chemistry or mathematical formula.

It seems that there is no agreement on the use of the term 'model'. There is no clear and unambiguous definition and classification available. Therefore, teachers and students have different ideas about the term 'model' (Lijnse, 2008). This makes it difficult to instruct students about a 'model' within the design process.

Exploring Conceptual Understanding

The aim of the research was to investigate the conceptual understanding of the term 'model' among R&D teachers with very different subject backgrounds and R&D students. The cause for this was an informal conversation among a small number of students in their final R&D year which revealed that the students had various frames of references of the term 'model'. After informally asking subject teachers of the R&D subject what they understood by the term 'model', these teachers also did not appear to have the same frame of reference, which may have led to different ideas about what constitutes a 'model'. It appears from various conversations that there may be no agreement on how to use the term 'model' in high school R&D education. This implies that students of R&D possibly do not receive enough unambiguous information on the topic and more attention and development of effective teaching strategies for this topic in the curriculum is necessary. Because during the execution process of research or design assignment, concept learning is a very important aspect of the R&D subject. The meaning technological concepts have in students' minds directly affect their learning in technology because these concepts form a framework from which to construct other concepts and base actions on (Jones, 1997).

According to Findell at al. (2001):

> *Conceptual understanding within mathematics refers to an integrated and functional grasp of ideas. Students with conceptual understanding know more than isolated facts and methods. They understand why an idea is important and the kinds of contexts in which is it useful. They have organized their knowledge into a coherent whole, which enables them to learn new ideas by connecting those ideas to what they already know. Conceptual understanding also supports retention. Because facts and methods learned with understanding are connected, they are easier to remember and use, and they can be reconstructed when forgotten. (p. 118-119).*

Lijnse (2008) states that a lot of research has been done that shows that both teachers (Van Driel et al., 1997) and students (Grosslight et al., 1991; Vollebregt, 1998) have all kinds of problems with ‘model’s. He cites the statement of Schwarz & White (2005): “there is ample evidence that students may not understand the nature of ‘model’s or the process of ‘modelling even when they are engaged in creating and revising ‘model’s”. Teachers and students therefore have problems using ‘model’s. How did that happen?

The Technasium has also not provided a definition of the concept of a ‘model’ within subject R&D. In secondary education, individual subject teachers may explain the term ‘model’. However, the question is whether this also happens in interdisciplinary subjects such as R&D. As previously stated, at the moment, all secondary school teachers are qualified to teach at Technasium if they obtain a certificate from the Technasium foundation through a number of short training courses at Technasium Academie, (Technasium Academie 2023). Only difference is the field of teachers' activity known as first or second grade of secondary teaching. This means that the R&D teaching team is usually composed of many different teachers who have competence in different subjects.

Ensuring that teachers have a shared understanding of key concepts, such as the ‘model’, is crucial for delivering consistent, effective, and high-quality education, especially in interdisciplinary fields like Research and Development (R&D). This shared understanding enables teachers to align their teaching methods, ensuring a cohesive and coordinated approach to instruction. As a result, the curriculum becomes more standardised, providing students with clear and consistent learning experiences. When teachers share a common understanding of concepts like ‘model’,' they can integrate them seamlessly into their lessons, making the content more accessible and relevant to students. This consistency in instruction allows students to grasp complex ideas more effectively.

As research about conceptual understanding on the concept of ‘model’ is not new in the field of science and mathematics, but it is important to recognize that in the field of R&D pedagogy, this is one of the first pilot studies on the understanding of the concept of ‘model’ among students and teachers. A pilot survey among students and teachers was designed to explore the diversity of interpretations of the term among the students.

Research method

The first part of the research was a survey consisting of three parts. First part were open-ended questions about the different types of ‘model’s to assess the previous knowledge of students and teachers, as well as their understanding of the concept of a ‘model’. In the second part of the survey, students were presented with pictures of various types of ‘model’s. This section aimed to assess the ability of both students and teachers to recognize and identify different types of ‘model’s. The third part of the survey consisted of a multiple-choice question. This section aimed to gauge the students' understanding of the purposes behind creating ‘model’s. The survey was conducted among three groups: one comprising twenty-two novice students aged 12 in the lower grade, another consisting of nine students aged 17 in the upper grade, and a third group comprising 14 R&D teachers. The second part of the research involved a small comparison of the answers provided by five R&D teachers to a multiple-choice survey based on the characteristics of a ‘model’ from the literature according to Van Driel et al. (1997) and Wegner (2017).

Results part one

First part of the survey were open-ended questions about the different types of ‘model’s to assess the previous knowledge of students and teachers, as well as their understanding of the concept of a ‘model’. The first question: "What is your definition of a ‘model’?" reveals an overlap in goal- and example-oriented definitions in all three groups highlighting that ‘model’s serve as simplified representations or descriptions of reality and can be used as examples for something. Furthermore, the definitions given were diverse.

The question of why we create ‘model’s uncovers different perspectives between students and teachers. While students, both in their first and last year, focus on the purpose of ‘model’s, such as testing or exploring and emphasize the benefits and advantages of creating them, such as providing visually appealing representations of how something looks or works, teachers, on the other hand, emphasize the clarifying, communicative, and explanatory role of ‘model’s, as well as the benefits of visualization that they offer. Even though a definition from literature also clearly plays a role here, namely that the ‘model’ always has a purpose, Wegner (2017), it emerges that description of the purpose of the ‘model’ changes with the role that respondent fulfils within the school. The students opt for informative or explorative functions, such as testing and presentation, while teachers choose didactic functions, like clarification and explanation.

In the second part of the survey, students were presented with pictures of various types of ‘model’s, see Figure 1. This section aimed to assess the ability of both students and teachers to recognize and identify different types of ‘model’s. From the answers, we observed that physical ‘model’s which are very close to reality such as scaled car ‘model’s, villa maquettes, cardboard Vespa were recognized as a ‘model’ by all groups. By lower grade 12-year-old (first year of secondary school) students' recognition of ‘model’s mostly remained at physical level, while in upper grade by 17-year-old (the last year of secondary school) was an increase of recognition of conceptual and symbolic type of ‘model’, see Table 1. The interpretations among teachers varied greatly and show in % less confidence in recognition of the ‘model’ than last year students.

Next to the picture of the 'model' (see Figure 1), the following statement was placed: "This is a 'model'." Do you agree, disagree, or not know?

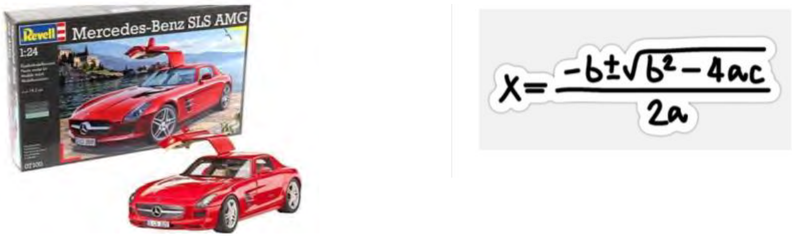

Figure 1. Two 'model' examples: scale car (www.modelwereld.eu) and mathematical formula.

Table 1. Results overview - rough division in two-step level from remarkably close to reality to different from reality

1 = low level of abstraction, remarkably close to reality, physical
2 = high level of abstraction, a 'model' differs from reality, conceptual or symbolical

This is a 'model'. Yes, No, I don't know	Twenty-two students first class high school	Nine students last year high school 9	Fourteen teachers from one school
1 Scaled car physical	yes 73% no 27%	yes 100%	yes 93% no 7%
2 Villa maquette physical	yes 100%	yes 100%	yes 86% no 7% do not know 7%
3 Playmobil horse physical	yes 32% no 54% do not know 14%	yes 44% no 56%	yes 50% no 50%
4 TV schema conceptual	yes 50% no 45%, do not know 5%	yes 89% no 11%	yes 58% no 21% do not know 21%
5 Mathematical formulas symbolical	yes 13% no 73% do not know 13%	yes 56% no 44%	yes 14% no 72 % do not know 14%
6 Organisation schema - organogram conceptual	yes 5% no 73% do not know 22%	yes 56% no 33% do not know 11%	yes 28% no 58% do not know 14%.
7 Map of the Netherlands symbolical	yes 33% no 77%	yes 44% no 56%	yes 28% no 50% do not know 22%
8 Paper vespa physical	yes 82% no 9%, do not know 9%	yes 78% no 11%, do not know 11%	yes 64% no 22% do not know 14%
9 FM radio schema conceptual	yes 45% no 45% do not know 10%	yes 78% no 11%, do not know 11%	yes 64% no 22% do not know 14%
10 Stuffed animal toy physical	yes 18% no 73% do not know 9%	yes 22% no 78%	yes 50% no 35% do not know 15%

The third part of the questionnaire consisted of a multiple-choice question. This section aimed to gauge the students' understanding of the purposes behind creating ‘model’s. The participants from three groups could choose from; to simplify something from reality, to calculate something, to predict something, to show correlation between quantities, to highlight important components, to learn about something, to solve a problem, to understand a problem, because an experiment in reality is too expensive, a ‘model’ does not have to have a goal, and otherwise. In all three groups, the majority of respondents (70%) selected "To highlight important components" as their answer. Additionally, among the students, two other commonly chosen answers were "To simplify something from reality" and "To test prototypes." All three answers show again a physical type of ‘model’ being recognised.

Results part two

The second part of the research involved a small comparison of the answers provided by five R&D teachers to a multiple-choice question based on the characteristics of a ‘model’ from the literature according to Van Driel et al. and Wegner (see Table 2) with the answers to an open-ended question: "What is a ‘model’?" First characteristic to choose was “A ‘model’ is always a ‘model’ of something, namely of an object of investigation” has been chosen unanimously. Second answer chosen by 80 % of teachers was a; “A ‘model’ is a tool for research into the object in question.” Least c The second part of the research involved a small comparison of the answers provided by five R&D teachers to a multiple-choice question based on the characteristics of a ‘model’ from the literature according to Van Driel et al. and Wegner’s chosen answer was “A ‘model’ differs from the object of research in that reductions are applied when drawing up a ‘model’ by scaling or in some other way.” This is an interesting answer because it shows clearly not understanding of changing ‘model’ level to abstraction.

Table 2. Results of a multiple-choice question

Characteristics of ‘model’ from literature according to Van Driel et al. (1997) and Wegner (2017)	Teachers answers	Teacher’s answers overlap characteristics of ‘model’ from literature
1 A ‘model’ is always a ‘model’ of something, namely an object of investigation.	5 x yes	5/5
2 A ‘model’ is a tool for research into the object in question.	4 x yes	4/5
3 A ‘model’ differs from the object of research in that reductions are applied when drawing up a ‘model’ by scaling or in some other way.	2 x yes	2/5
4 A ‘model’ shows a number of similarities with the object of research	3 x yes	3/5
5 A ‘model’ is not derived directly from the object of study, such as a photograph or a measurement result. It contains elements that the object of investigation does not possess. Creativity therefore plays a role in the choice of a ‘model’.	3 x yes	3/5
6 A ‘model’ therefore has a built-in compromise character, and the researcher has a certain freedom in choosing a ‘model’. The research question plays a role in that choice	3 x yes	3/5

7 In the course of a study, a 'model' may undergo an iterative development. The object of research is always studied in more detail.	3 x yes	3/5
8 A 'model' should always have a purpose (for R&D)	3 x yes	3/5
100% = 40 Similarity with features offered	65% = 26 Similarity with features offered	

Coding given answers on the open question "What is a 'model'" showed an understanding by 60% of respondents of a 'model' being a 'model' of something (object). Just one respondent (20%) has an overlap with literature drawn characteristics (Van Driel et al., 1997; Wegner, 2017) mentioning purpose and reality. Although the answers do not correlate to literature they correlate to each other. The word simplified was named unanimously, representation and scale by 60% of respondents, see Table 3. Respondents were all from the same school so this could show an already existing frame of reference.

Table 3 Identifying characteristics drawn from literature coding answers from respondents

Respondent	Answer to the open question "What is a 'model'?"
Teacher 1	A representation (3D or 2D) of a scaled-down object
Teacher 2	A representation of the original object to scale
Teacher 3	A simplified or scaled-down representation of a real object or concept.
Teacher 4	A simplified representation of reality, with the purpose of providing insight into certain properties (such as proportions, functioning mechanisms, etc.).
Teacher 5	A simplified representation of a complex system, where there are multiple possibilities/perspectives to depict this system

Discussion

It is clear from this pilot study that R&D teachers lack unambiguous knowledge about the concept of a 'model'. Regardless of the number of similarities in answers there are many differences in answers. Comparison between different R&D teams from different schools can provide more clarity about similarities which may be related to school. Nevertheless, focusing on high abstraction conceptual and symbolic 'model's which differ from reality could be interesting for further research and provide a frame of reference which can connect a curriculum and learning about different types of 'model's and their uses in R&D. In this pilot, the suitability of examples in uncovering underlying R&D concepts can still be improved. The pictures - example section was intended to assess the ability of both students and teachers to recognize and identify different types of 'model's with a focus on the level of abstraction. There are other characteristics that are important and that were not included in the study, for example the function, type of goal of the 'model'. This can be investigated in further studies together with other characteristics. This can be crucial for promoting conceptual understanding. Probably due to physical place of research that took place during R&D classes only one person of all researched in description of a 'model' named a 'model' as fashion icon. Continuous evaluation and refinement of these examples, based on research and feedback from students and teachers, are essential to ensure that they serve their intended purpose. By carefully selecting and using examples, we can capture conceptual understanding. This pilot enriched us with knowledge about the narrow frame of reference within R&D teachers regarding the different 'model' characteristics and purposes. There is a need for more specific/varied language that would enable differentiation between the different forms that a ‘model’ within R&D takes. This pilot does not provide an answer why that is so and how we can solve it. It just indicates a problem which occurs in heterogeneous STEM subject communities than this specific R&D one.

Conclusion

The provided results highlight several interesting points regarding the definition and understanding of ‘model’s among students and teachers. One significant finding is the overlap in purpose and example-oriented definitions of ‘model’s, emphasising their role as simplified representations or descriptions of something, often referred to as reality. However, the recognition of different ‘model’s remained predominantly at physical type among young students, with an increase in recognition of conceptual or symbolic ‘model’s among older students.

Surprisingly, the recognition of ‘model’s among teachers showed unexpected variation, despite the anticipated increase in conceptual and symbolic type of ‘model’ recognition among older students. This suggests a potential gap in understanding and knowledge among R&D teachers regarding the recognition and abstraction levels of ‘model’s and does not explain increasing knowledge about type of ‘model’s in upper grades.

The majority of respondents, across all three groups, identified "To highlight important components" as the main reason for creating ‘model’s. Additionally, students commonly chose "To simplify reality" and "To test prototypes" as their reasons for making ‘model’s.

The second survey aimed to compare the characteristics of ‘model’s found in literature with those named by teachers. It revealed that teachers understood a ‘model’ to be a representation of something, often referred to as reality. The majority of teachers agreed with the statement that "A ‘model’ is always a ‘model’ of something, namely of an object of investigation." But at the same time, they do not recognise that the ‘model’ could be different from reality.

Although we can detect similarities between the teachers at the same school on the definition of concept of ‘model’, those similarities are a fraction of the available knowledge about the ‘model’s' goals and definitions. These findings indicate a need for broadening and deepening the set of values, norms, and knowledge among R&D teachers regarding the definition and use of ‘model’s. Providing teachers with more comprehensive knowledge about the characteristics of ‘model’s, considering the lack of unanimous choice among the provided definitions, is crucial to establish a common frame of reference and enhance their ability to teach students effectively. Furthermore, the absence of unanimous answers about what a ‘model’ is and why we make one suggests a potential need for cross-disciplinary courses for teachers in STEM subjects to foster a more cohesive understanding of the different types of ‘model’s across disciplines. The conceptual understanding of the term '‘model’' among R&D teachers with very different subject backgrounds, within this pilot, is incomplete and ambiguous.

Possible implementation

In order to improve the conceptual understanding of the term '‘model’' among R&D teachers, gained knowledge from this pilot, should support and encourage collaborative learning and sharing of experiences specifically for R&D teachers to delve into the concept of a ‘model’ and its significance in interdisciplinary fields. This could provide resources and materials to support ongoing learning and implementation of learning concepts in the classroom. Expanding the frame of reference beyond the concept of a ‘model’ could encompass other related technology concepts relevant to R&D education. Encouraging teachers to adapt and integrate the concepts into their lesson plans and classroom activities, fostering a culture of innovation and interdisciplinary learning. By implementing these strategies, R&D teachers can develop a strong frame of reference for essential technology concepts like ‘model’, design, system, empowering them to enhance their teaching practices and effectively prepare students for success in R&D fields. So by giving R&D teachers enough time to discuss their teaching and learning practices with each other, explore the concepts their students need to apply and support the unambiguous learning of concepts within the pedagogy of the subject. The form in which discussion time is used is up to the team of teachers to decide (workshop, discussion, lecture, game etcetera.)

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