David F. Treagust, Reinders Duit and Hans E. Fischer (Eds), Multiple Representations in Physics Education, Models and Modelling in Science Education (Volume 10), Cham: Springer, 2017; 322 pp.: ISBN 978-3-319-58912-1

Reviewed by Neja Benedetič[1]

Teaching is a mission in which we strive to demonstrate new concepts in many ways, so that pupils and students acquire new information and are enable to construct entirely new concepts. This is only possible with the prudent use of multiple representation. Most teachers do not teach only verbally; they also use a lot of models, pictures, diagrams and analogies. However, in using multiple representation, we have to be careful not to add, change or omit information that influences the understanding of the new concept. Teaching physics and natural sciences is no exception. Using different types of representation (pictures, experiments, photos, films, sketches, etc.) enables teachers to catch all of the important events that could be missed without representations. We then start to analyse the events in many ways (diagrams, graphs, formulas) in order to obtain complete information and make it easier to understand.

The book *Multiple Representation in Physics Education* deals with multiple representation and the doubts that we may have about its correct use. The book is divided into three parts, with the introductions to the individual parts being written by the editors David F. Treagust, Reinders Duit and Hans E. Fischer. David F. Treagust has the title of John Curtin Distinguished Professor at Curtin University in Perth, which is the university's highest honour. Reinders Duit is a Professor Emeritus for Physics Education at the National Centre for Science Education Research at the Institute for Science and Mathematics Education in Kiel, and Hans E. Fischer is a Professor Emeritus at the University of Duisburg-Essen in Essen.

The first chapter is an introduction to the book, with the authors (Maria Opfermann, Annett Schmeck and Hans E. Fischer) clarifying the concept
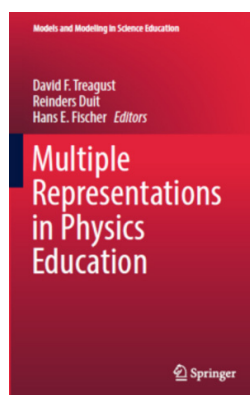
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of multiple representation according to different theories (CTML – Cognitive Theory of Multimedia Learning, ITPC - Integrated Model of Text and Picture Comprehension, and DeFT – Design, Function, Tasks). They conclude that multiple representation does not overload a single channel of information (as is the case if we use only one type of representation); instead, the complementary information that we acquire with multiple representation enables us to construct and reconstruct the new concept. This is the only way to avoid misunderstanding of a new topic.

The book is then divided into three parts. The first part contains three chapters focused on models and analogies. In the second chapter, Per Morten Kind, Carl Angell and Øystein Guttersrud present the project PHYS21, which was performed in a physics course for upper secondary students in Norway. The aim was to develop teaching materials and strategies to teach physics and to observe the effects of these new materials in the classroom. The project had three sections: the first was about what happened in classroom, in the second the focus was on teachers' conceptions of teaching and the curriculum, and the last part was about the effects on student learning. Analysis was undertaken using interviews with teachers, as well as a comparison of data from student questionnaires in experimental and control groups. The authors conclude that teachers need more support to achieve an adequate level of multiple representation; the researchers will therefore attempt to develop specific activities in this regard.

In the third chapter, Brian E. Gravel and Michelle H. Wilkerson write about the integration of computational artefacts into a multi-representational toolkit for physics education. They present two cases in which they use computational artefacts to understand new content (in the first section, the behaviour of liquid crystal, and, in the second, the formation of a cloud) and introduce three discursive moves used in making the computational artefacts.

In last chapter of first part, Jing-Wen Lin and Mei-Hung Chiu reflect on how to design multiple analogies to achieve better effects than a single analogy, but without additional cognitive load. Their research focuses on an electric circuit system and its analogies as simple water circulation, complex water circulation and an obstacle race. The authors found that students preferred analogies that were familiar to them. They concluded that there was positive feedback about the use of multiple analogies and that they could play a powerful role in knowledge construction in learning science. There is a large gap between students' prior knowledge and new concepts, and multiple analogies can be used to bridge this gap.

The second part of the book contains four chapters in which the authors present different approaches to and conditions of multiple representation.

In this part, it is shown that multiple representation has an important role in physics, as it presents different levels of abstraction, enabling abstraction to be linked to the functional rules of constructing and predicting effects, and to the development of physics concepts.

In chapter five, John Airey and Cedric Linder derive multiple representation in physics from a social semiotic approach (examples of the semiotic resources used are graphs, diagrams, mathematics, specialist language, etc.). They suggest that teachers need to enable their students to use multiple representation, so that they can achieve fluency in its use and create critical constellations of given concepts. Students must be aware that, in order to achieve fluency and critical thinking, they have to use multiple representation as much as possible (process of repetition).

In chapter six, Yen-Ruey Kuo, Mihye Won, Marjan Zadnik, Salim Siddiqui and David F. Treagust present multiple representation used in learning optics. The authors investigate students' use of multiple representation in a first year physics course for non-major students over two years at a university in Australia. They found that correct use of multiple representation increased during the investigation. When students are able to use multiple representations, it is easier for them to integrate different representations and to understand new concepts.

In the next chapter, the authors (Peter Hubber and Russell Tytler) explain guided inquiry as an intermediate teaching approach between open-ended, student-directed learning and traditional, direct instruction. The aim of their study was to document the experience of four secondary teachers in implementing a representation construction approach, and to investigate the quality of student learning of astronomy. They discovered the importance of the use multiple representation (sketches, illustrations, text, mathematical formulas, graphs, etc.) in conjunction with classroom discourse to understand certain astronomical phenomena.

In the eighth chapter, Pasi Nieminen, Antti Savinainen, and Jouni Viiri studied the concept of force among 16-year-old students taking only one physics course. They found that an interaction diagram is a suitable learning tool and should be used systematically in teaching. Furthermore, they are convinced that multiple representation should be used appropriately not only in the classroom, but also in textbooks and homework.

In chapter nine, Chee Leong Wong and Hye-Eun Chu focus on representations of electric current in textbooks. They warn teachers to be wary of inconsistent representations in textbooks, which can result in students misunderstanding some concepts. The authors also point out that, despite the best efforts of the teacher, students may not always understand multiple representation.

In the third part of the book, the authors of all four chapters focus on reasoning and representational competence, which students need in order to use and apply different representations. In addition, students have to use their abilities to explain and assimilate the representations appropriately.

In the tenth chapter, authors Andreas Müller, Rosa Hettmannsperger, Jochen Scheid and Wolfgang Schnotz introduce representational coherence ability and representation-related conceptual change in geometric optics. Their investigation was performed in German schools and they chose experiments in geometrical optics due to their ability to incorporate the use of multiple representations. They conclude that students have to acquire the ability to achieve representational coherence (i.e., correct and fluent combination of multiple representation is essential for proper understanding of an experiment) and then to link scientific experiments and their conceptual bases with different multiple representations with various levels of abstraction (realistic drawing, diagrams, graphs, text, mathematical relations, etc.).

Chapter eleven is written by Patrick B. Kohl and Noah Finkelstein, whose aim was to understand and promote the effective use of representation in physics learning. They investigate the assumption that if students answer a question in one form they will also be able to answer it in other forms. Their research showed that the representational form of the question and the teaching environment influence students' performance and their ability to reason across representations. The authors' findings also suggest that it is sensible to develop representational competence in a content-bound manner, and it is fruitful to provide opportunities for students to practise the use of coordinated representation.

In chapter twelve, Jennifer Yeo and John K. Gilbert focus on the role of representation in students' explanations of four phenomena in physics: dynamics, thermal physics, electromagnetic induction and superposition. They investigate what type of representation is most commonly used by students to explain each of these four physics phenomena. The authors examine the students in three dimensions: function (to provide an answer to specific types of question), form (structural organisation) and level (precision, abstractness and complexity). The authors found that students use an interpretive explanation of dynamics and thermal physics (descriptive and quantitative style of reasoning) and a casual explanation of electromagnetic induction and superposition (narrative and qualitative style of reasoning).

The last chapter of the book was written by Florence R. Sullivan, W. Richards Adrion, Dave Hart, Christopher N. Hill, Kofi Charu Nat Turner, Jeff Xavier, Youngkwan Cha, Sangchil Lee and Bradford Wheeler, and is focused

on learning about global heat transfer using multiple visualisation in an online learning environment. The authors claim that if students are supported to understand representation in two- or three-dimensional scales, they understand the overall concept better. In addition, they observed that 3D videos lead to more sophisticated responses by students, while 2D representations are more focused on physical descriptions.

The book *Multiple Representation in Physics Education* offers a comprehensive overview of using multiple representation: its positive side, as well as warnings about excessive use or lack of use, and about multiple representation used in textbooks, which is sometimes inappropriate. The studies contained in the book were made on different levels of education and on different physics topics, and therefore provide a good insight into the use of multiple representation. In conclusion, we can say that multiple representation has a significant role in teaching physics. Different representations allow students to introduce concepts from different aspects, combining graphs, text, mathematical formulas, schemes, gestures, etc. into a whole. In physics, we frequently use equations to describe dependence between quantities, but for students it is often a challenge to combine physics equations and modelling tools; for them, equations and physics concepts are two different objects. It is therefore crucial for the teacher to use multiple representation and to enable students to establish correlations between different representations.