What Can Educational Case Studies Reveal About How Teachers Implement the Model of Educational Reconstruction in Biology Instruction?

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Abstract

The Model of Educational Reconstruction (MER) tightly links subject matter analysis and research on pupils' preconceptions to design the teaching and learning environments of school science subjects, including biology [1]. The paper will be focused on a qualitative analysis of how comprehensively biology teachers implement components of the Model of Educational Reconstruction into their lessons, i.e. whether they take advantage of pupils' preconceptions in designing instruction of different biology topics. The multiple-case study design with a theoretical replication was used in this study [2], together 18 individual case studies were included in the analysis. Each case study was based on a video record of a biology lesson and selected teaching and learning situations were qualitatively analyzed by 3A procedure (annotation – analysis – alteration), which enabled an in-depth assessment of the integrity of the instruction using the conceptual structure diagram [3]. Transcripts and conceptual structure diagrams of teaching and learning situations were analyzed using the principles of grounded theory and inductive approach [4] to identify and categorize components of MER and the level of its implementation in each educational case study. The multiple-case study results revealed several different levels of MER implementation into biology lessons ranging from solely diagnostics of pupils' preconceptions without their further use in the instruction to comprehensive use of MER in the design of teaching and learning environment in the analyzed lesson. The complex incorporation of MER into biology lessons with an emphasis on (re)construction of pupils' pre-scientific conceptions was very rare, as it was identified only in one educational case study. Particular examples of MER implementation into biology instruction will be highlighted in the paper.

Keywords: *biology instruction*, *educational case study, Model of Educational Reconstruction, biology teacher*

1. Introduction and theoretical framework

The *Model of Educational Reconstruction* (MER) was developed by Ulrich Kattmann and his coworkers as a theoretical and research framework to design the teaching and learning environments of different school science topics [1; 5]. The model consists of three very tightly interconnected components: *„(a) clarification and analysis of science content; (b) research on teaching and learning; (c) design and evaluation of teaching and learning environments"* [1; 5; English terminology adopted from Duit et al., 2012, pp. 21–23, see reference 1]. An important feature of the MER is that it equally takes into account the analysis of scientific content (subject matter) and students' pre-instructional conceptions when designing the teaching and learning environments of a particular science (biology) topic [1; 5]. Many biological and environmental topics have been reconstructed for educational purposes so far, including genetics [6], growth and cell division [7; 8], ecology [9], or climate change [10]. A decade later, a new research model called *Educational Reconstruction for Teacher Education* (ERTE) was developed [11]. This model integrates the concept of pedagogical content knowledge (PCK) [12; 13] within the framework of the original MER for research-based (re)construction of pre-service and in-service teacher education [1; 11; cf. 14]. According to the ERTE model, pedagogical content knowledge studies focused on specific educational topics (e.g. evolutionary theory) [c.f. 14] and knowledge of how to design teaching and learning environments based on the MER [11; 14] are critical components for the effective and meaningful (re)construction of teacher education and its improvement [1; 11]. There are many results of research studies on students' pre-scientific conceptions of particular biological topics available [for a summary see e.g. 15]

and researchers present these results within the MER framework comprehensively to the community of biology teachers [16; 17; 18].
The MER represents one of the theoretical and research models that aim at improving everyday instructional practice in schools [1]. Janík et al. (2019) [3] emphasize the content-focused approach as a way how to prevent "*the shedding of content*", which they consider "*the great challenge of teaching and learning in today's schools*" [3, p. 185]. Based on the content-focused approach and particularly inspired by the MER, the authors developed a qualitative research method called *the 3A procedure* to study instructional practice in schools and to propose (if necessary) its improvements [3; 19]. The output of an in-depth content-focused analysis using the 3A procedure is a comprehensive educational case study that represents the original and illustrative instructional approach to a particular educational topic [3; 19]. In our previous study [20], we performed a metaanalysis of 18 educational case studies of biology instruction at lower and upper secondary schools (grades 6 to 12). The metaanalysis was focused on: (a) the quality of the teaching and learning (TL) situation; (b) the development of key competencies during the TL situation; and (c) the prevalence of educational (didactic) formalisms within TL situations [20, pp. 159–188]. In the current study, we would like to focus on a novel metaanalysis of the same set of educational case studies [20, pp. 43–51] with an emphasis on whether and how biology teachers implement the MER into their lessons.

2. Methodology

For the metaanalysis of educational case studies of biology instruction, we have used the multiple-case study design [2; c.f. 3 and 20] with a theoretical replication [2, pp. 55–59]. Together 18 individual case studies were included in the analysis when, according to Yin (2018) [2, p. 55 and p. 65], this number of single cases should be sufficient to obtain relevant findings in the multiple-case study. Each educational case study in the research sample was originally based on a videorecord of a biology lesson, and selected teaching and learning situations were qualitatively analyzed by 3A procedure (annotation – analysis – alteration) [for more details on 3A procedure see reference 3, pp. 188–189 and reference 19, pp. 677–680]. Single educational case studies in the research sample described and analyzed biology instruction at lower (12 case studies) and upper secondary schools (6 case studies) and covered different biological topics (botany – 4 case studies including one case study focused on laboratory exercise; zoology – 7 case studies including two cases focused on practical & laboratory work; human biology – 4 case studies; genetics and molecular biology – 2 case studies; 1 case study was focused on the geological topic because geology is a part of extended biology curriculum [21; pp. 62–63] at lower secondary schools in the Czech Republic). A complete list of educational case studies with further details (original case study codes; grade; pre-service / in-service teacher; topic of instruction; and bibliographical source of the case study) is available in our previous study [see reference 20, pp. 43–51]. Individual case studies were marked with the codes CS_1 to CS_18 (abbreviation CS stands for case study, the number indicates the serial number in the multiple-case study; c.f. [20]). Entry criteria for inclusion of a case study in a multiple-case study were as follows: (a) compliance of the case study with the 3A procedure; (b) concept analysis of the selected TL situation(s) using the conceptual structure diagram was performed in the case study; and (c) transcripts of the selected TL situation(s) were provided in the case study [c.f. 3; 19; 20]. Transcripts and conceptual structure diagrams of the TL situations were analyzed using the principles of grounded theory and inductive approach [4] to identify and categorize components of MER and the level of its implementation in each educational case study. Development of the categorical system was also inspired by recommendations of biology education researchers how to take advantage of students' everyday ideas in the biology instruction within the MER framework [16; 17; 18].

3. Results

The multiple-case study results show that in 8 case studies (approx. 44.5 %) were not identified elements of the MER either in transcripts or conceptual structure diagrams of the TL situations. In the remaining 10 case studies (approx. 55.5 %) the multiple-case study approach revealed five different levels of the MER implementation into biology lessons ranging from solely diagnostics of student's preconceptions without their further use in the instruction to comprehensive use of MER in the design of teaching and learning environment in the analyzed lesson. The most frequent category of the MER implementation in biology lessons (5 case studies; approx. 28 %) was reduced only to diagnostics of student's pre-instructional (pre-scientific) conceptions in the course of discussion with students. However, in these case studies teachers did not take advantage of identified student's pre-instructional conceptions for construction of learning tasks and their subsequent solution by students or to design the teaching and learning environment of the lesson. In 2 case studies (approx. 11 %; CS_1 and CS_5; [20]) teachers firstly identified student's pre-instructional conceptions. Subsequently students solved learning tasks designed by the teacher that allowed them to bridge misconceptions and reconstruct their pre-instructional concepts towards scientifically correct ideas. However, teachers used principles of the MER only during time-limited TL situation and not to design the teaching and learning environment of the whole biology lesson (or unit). This was the case of CS_1 [20] where teacher identified student's pre-instructional conceptions on plant leaves morphology (e.g. leaf shapes or leaf margins) during their solution of learning task in order to reconstruct their pre-instructional everyday ideas. Another category of the MER implementation in biology lesson was detected in CS_6 [20], where teacher accidentally identified during the course of solving the learning task student's misconception about heart anatomy and based on this misconception the topic was explained in more detail in order to bridge this misconception. In one educational case study (CS_2; [20]) the teacher designed the teaching and learning environment in order to support student's active learning during peer discussion about the floral morphology (comparison of different types of flowers). However, due to an inappropriate choice of plant species for observation (*Gerbera* as an example of the heterochlamydeous flower) the students were in fact learning the misconception. The complex incorporation of MER into biology lessons with an emphasis on (re)construction of pupils' pre-scientific conceptions was very rare, as it was identified only in one educational case study. In this case study (CS_10; [22]) the teacher designed teaching and learning environment as follows: (a) diagnosis of student's pre-scientific conceptions about insect morphology (drawing pictures of insect morphology, e.g. bee or ant); (b) inquiry-based unit on insect morphology with an emphasis on practical work; (c) identification and correction of mistakes (anthromorphisms) in drawings of insects in children's books based on student's knowledge of insect body plan; (d) reconstruction of student's pre-instructional conceptions – correction of insect drawings from the beginning of the lesson according to gained knowledge during the instruction.

4. Discussion and conclusions

The *Model of Educational Reconstruction* is a powerful theoretical and research tool to design the teaching and learning environments in the classroom [1; 5]. Results of research within the MER framework on different biological topics are available to the teacher community [16; 17; 18] and the effective use and of these results in designing the teaching and learning environments in the classroom could help to improve the teaching of biology in schools [1; 5; 16]. Findings of our multiple-case study indicate that teachers implement elements of the MER in their instruction only occasionally and complex use of the MER to design the teaching and learning environments is rather rare. Teacher's knowledge of student's pre-instructional (i.e. pre-scientific) ideas about variety of biological topics represents an integral part of their pedagogical content knowledge [11; 12; 13]. However, based on results of our research biology teachers very often do not take advantage of student's everyday ideas about nature for either construction of learning tasks or to design the teaching and learning environments of biology lesson(s). Therefore we propose the (re)construction of pre-service biology teacher education and also lifelong in-service biology teacher education within the framework of the model of *Educational Reconstruction for Teacher Education* [11; 14]. Although this paradigm shift in biology teacher education will be somewhat challenging, we believe that in the long term it will help to improve both biology teacher education and everyday teaching practice of biology in schools.

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