Scientific Representations in Biology Class – the Relation among Teachers' Professional Knowledge, Quality of Instruction and Students' Achievement

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Abstract. This project investigates the relation among teachers' subject-specific professional knowledge (content knowledge and pedagogical content knowledge), quality of instruction concerning the use of scientific representations, and the students' abilities to deal with scientific representations. According to models of instructional quality and empirical studies, one can assume that the teacher's subject-specific professional knowledge influence the quality of instruction which in turn influences students' abilities. In order to analyze this relation we construct questionnaires for teachers and students which cover all these variables and use multilevel structural equation modeling. 150 biology teachers (secondary school) and their biology courses are taking part in the main study that is being conducted in a pre-/post-test design. A pilot study is still in progress where the questionnaires will be evaluated. At EARLI-SIG 2 we plan to present the results of the pilot study.

Keywords: teachers' professional knowledge; quality of instruction; scientific representations

Theoretical Background

According to scientific literacy, the goal of science education is to enable students to participate in the social discourse about science. One crucial requirement for participation is the ability to understand and use different external scientific representations appropriately and relate them to one another (Yore & Treagust, 2006; Stäudel, Franke-Braun, & Parchmann, 2008). In this study, we take verbal (e.g. scientific texts), symbolical (e.g. chemical formula) and visual representations (e.g. diagrams) of biological subject matter into account. Verbal and symbolical representations are descriptive representations whereas visual representations are depictive representations. However, empirical studies revealed that the use of scientific representations in science classes is inappropriate: students' abilities to comprehend and produce scientific representations as wells as to integrate multiple external representations are not promoted (Stäudel et al., 2008). Therefore it is necessary to improve the integration of scientific representation aspects in science classes and thus enhance the quality of science education regarding the demands of scientific literacy.

In models of instructional quality, the professional competence of the teacher is an important factor that determines the quality of education (Helmke, 2008). One can assume that students' abilities to deal with different scientific representations is influenced by the quality of instruction concerning the use of scientific representations which is in turn affected by teachers' professional competence. One pivotal aspect of teachers' professional competence is professional knowledge (Kunter et al., 2007). The core categories of teachers' subject specific professional knowledge are (1) content knowledge (CK) and (2) pedagogical content knowledge (PCK) (Krauss et al., 2008). The following section enlarges the subject-specific components CK and PCK that are taken into account in this study.

(1) CK is a necessary condition for teaching a subject. It encompasses the domain's key facts, concepts, principles, structures and explanatory frameworks (Shulman, 1986). The teacher's content knowledge is also important relating to the use of scientific representations in class. The different visual, verbal or symbolical representations for a topic can originally be regarded as subject matter.

(2) PCK is used to transform subject matter content into forms that are easier to understand for students. In this study three major theoretically derived cognitive aspects of PCK are taken into account (modified from Abell, 2007; Park & Oliver, 2008): knowledge of (a) students' understanding in science, (b) instructional strategies in science and (c) science curriculum. In matters of the quality of instruction concerning the use of scientific representations, PCK might be necessary to use and translate the different representations in a way that suits subject matter and students' abilities.

The COACTIV study (Brunner et al., 2006) showed that teachers' PCK and CK are predictors of the quality of instruction in mathematics. It also was shown that PCK, mediated by aspects of instruction, influences positively students' achievement in mathematics

Research Questions and Hypotheses

We want to investigate the following research questions:

1) Do teachers' CK and PCK influence the quality of instruction concerning the use of scientific representations?
2) Do teachers' CK and PCK influence their students' abilities to deal with scientific representations?
3) What kind of relation can be detected among students' abilities to deal with scientific representations, the quality of instruction concerning the use of scientific representations, and teachers' CK and PCK?

We hypothesize that teachers' CK and PCK positively influence the quality of instruction concerning the use of scientific representations and the students' abilities to deal with scientific representations. We also expect the quality of instruction concerning the use of scientific representations is a mediator between teachers' CK and PCK and the students' abilities.

Research Design and Methodology

In order to investigate the effects of teachers' CK (independent variable 1) and PCK (independent variable 1) on the quality of instruction concerning the use of scientific representations (dependent variable 1/mediator) and the impact on students' abilities (dependent variable 2) we use questionnaires for teachers and students.

- A questionnaire for teachers is constructed to gather data about their CK and PCK. The CK test (closed item format, multiple choice) focuses on teachers' knowledge about photosynthesis. The PCK test (open item format) covers the components mentioned above.
- Students and teachers are asked to evaluate instruction in order to survey the quality of instruction concerning the use of scientific representations (closed item format, Likert scale). According to Clausen (2002), the students' common perception is a valid measurement to describe instruction, whereas the teacher's perception is a valid measurement of didactical aspects of instruction.
- In order to collect data about students' abilities to comprehend and produce scientific representations as wells as to integrate multiple external representations in the context of photosynthesis a questionnaire (closed item format) is used. The students' knowledge about photosynthesis is also surveyed (closed item format).

Multilevel structural equation modelling is used to test the hypotheses. The sample comprises 150 biology teachers (secondary school) and their biology courses (11th grade). The study is conducted in a pre-/post-test design (teaching unit "photosynthesis" takes place in between the pre- and post-tests).

Findings

A pilot study evaluating the questionnaires is still in progress. At EARLI-SIG 2 we plan to present the results of the pilot study.

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