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How research-based learning can increase teacher students' knowledge and abilities – a design-based research project in the context of pupils' (mis)conceptions in science

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Abstract

The beliefs and preconceptions that pupils bring into the classroom influence their understanding of scientific topics. Empirical studies show that many teachers know little about pupils' (mis)conceptions and are therefore unequipped to handle them in an appropriate way. The design-based research project presented in this article describes the development and evaluation of a seminar in the didactic education of chemistry teachers. This seminar introduces teacher students to the topic of pupils' conceptions according to the principle of research-based learning. The seminar is based on an expert-validated model of knowledge and skills that teachers need in the context of pupils' conceptions. Furthermore, the article describes a structural model of design-based research (DBR) that can be used for structuring DBR projects. The article concludes by presenting a theory development derived from the evaluation results and their theoretical embedding which describes how subjective theories can be affected and changed by research-based learning.

Keywords

Design-based Research; pupils' (mis)conceptions; research-based learning; teacher beliefs

1 Background

The importance of everyday beliefs and experience that pupils bring to science classes is undisputed in educational research. Empirical studies show that many teachers know little about pupils' conceptions and are therefore ill equipped to assess their causes and respond appropriately (e.g. Gabel, 1999; Uhren, Ralle, & Di Fuccia, 2013).

Teachers, who are confronted with unscientific conceptions, often characterise pupils' answers as "wrong". However, there can be logical ideas contained in these conceptions. For example: Pupils observe the wax of a burning candle disappear; they logically conclude that fire can "destroy" substances (Kind, 2004). Chemistry classes ask pupils to accept a different understanding that contradicts this perceived destruction. Burning substances react with oxygen, which results in an increase in mass! It is not only everyday experience, however, that obstruct the understanding of chemistry. The chemistry class itself contains obstacles – such as vague models or technical language – which lead pupils to develop a variety of unscientific ideas (Schmidt, Marohn, & Harrison, 2007). A preliminary study of this design-based research (DBR) project disclosed that many teacher students explain learning difficulties either by a lack of interest on the pupils' side or by a lack in the teacher's ability to explain the issue convincingly. The subjective theories[1] they use to explain scientifically wrong answers were often deficit-oriented.

[1] The term subjective theories comes from the German research program "Subjektive Theorien" (Groeben et

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While innovative attempts to generally improve the didactic knowledge of science teacher students exist, see e.g. the evaluation of two such instruments by Bertram (2014), the transfer of specific knowledge about diagnosing and handling pupils' conceptions from educational research institutions into the classroom does not seem to have been sufficiently successful yet.

Against this background, the presented DBR project developed a seminar for teacher education, which is based on the principle of research-based learning.[2] This seminar is intended to more closely connect theory and practice in the context of pupils' conceptions and enable teacher students to professionally approach pupils' conceptions.

2 Design-based research model

Design-based research was chosen as a methodical approach for this project because this project implements all characteristics, e.g. its embedding in a real educational context, that are typical for DBR projects (Anderson & Shattuck, 2012; van den Akker et al., 2006).

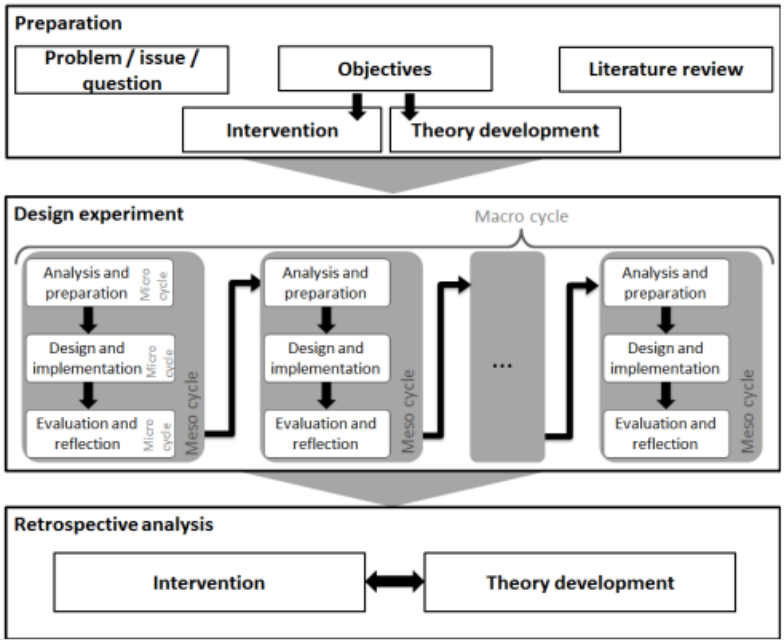


Figure 1: Structural model of design-based research built on the basis of a comprehensive literature review

Based on a comprehensive literature review (e.g. Mc Kenney & Reeves, 2012; van den Akker et al., 2006; Cobb et al., 2003), a structural model of design-based research (see Figure 1) was built, which was used as a guide to implement and present the DBR project. The structural model describes an idealised course of a DBR project following the three steps of

al., 1988; Kroath 1989). There is no English-language translation for the technical German term that considers all parts of its definition. In English, action-guiding cognitions of teachers are often summarized under the generic term "teacher beliefs". The term subjective theories will henceforth consistently be used in this article.

[2] This article includes elements of the following dissertation as submitted to the University of Münster in December 2017: „Design-Based Research zur Weiterentwicklung der chemiedidaktischen Lehrerausbildung zu Schülervorstellungen: Entwicklung und Evaluation eines an Forschendem Lernen orientierten Seminarkonzepts" by Friederike Rohrbach-Lochner.

preparation, design experiment and retrospective analysis. Reverting to earlier phases or omissions of individual phases are possible at any time.

This model is designed in a flexible and non-specific way so that it can be used for structuring and presenting DBR projects of various disciplines.

3 Preparation

Project's objectives

The aim of this research project was the development and evaluation of an intervention in the form of a seminar in didactic education for chemistry teachers, which – theoretically substantiated – contributes to prepare students for the professional handling of pupils' conceptions.

The seminar was aimed to ...

- sensitise students to the importance of pupil's conceptions in science classes.
- provide students with knowledge, skills and abilities to deal with pupils' conceptions.
- make students aware of their subjective theories about pupils' conceptions and, if necessary, encourage them to change their subjective theories.

Model on knowledge and skills in the context of pupil's conceptions

During the design process of this seminar intended to prepare teacher students for a professional handling of pupils' conceptions, the question arose what exactly a professional handling should encompass. A specific manual or model describing these abilities and skills did not exist. Based on an extensive literature research, a model (validated by experts) was developed for this project, which uses a four-level matrix to depict knowledge elements and skills needed by teachers to adequately deal with pupils' conceptions in the classroom (Marohn & Rohrbach, 2013), see Table 1.

	KNOWLEDGE	UNDERSTANDING	USE/ANALYSIS	SYNTHESE/EVALUATION
CONCEPTIONS	Know typical conceptions	Identify ideas in pupils' statements	Anticipate conceptions	Draw conclusions for the design of lessons based on conceptions
ORIGINS	Know origins of conceptions	Identify origins of conceptions	Anticipate origins of conceptions	Draw conclusions for the design of lessons from sources of conceptions
DIAGNOSIS	Know about diagnostic instruments and methods	Identify advantages and disadvantages of diagnostic instruments and methods	Use diagnostic instruments and methods	Develop and evaluate diagnostic instruments and methods independently

HANDLING	Know established ways of dealing with ideas	Identify ways of dealing with conceptions as being more or less suitable	Apply and reflect on ways of dealing with conceptions	Develop and evaluate ways of dealing with ideas independently

Table1: Necessary knowledge and skills in the context of pupils' conceptions

The model was used to select the topics of the seminar and to design specific evaluation tools. The goals and hopes associated with the development of the model thereby go beyond the original objective of a theory-based foundation and justification of the contents of the seminar. This model allows deriving objectives concerning various abilities and skills student teachers should acquire. Future teachers should deal sensibly with the treatment of chemical content, statements of pupils and their own actions. Furthermore, they should consider that statements of pupils are multi-layered and be able to diagnose pupils' conceptions. The student teachers should also know strategies to respond appropriately to pupils' conceptions and they should be aware of their own ideas and attitudes and reflect on them.

The model provides researchers and teachers with starting points for discussion and reflection on their own conceptions and how they deal with the issue of pupils' conceptions. It was deliberately designed in an open manner so that it is not only suitable for field of chemistry didactics but also for other science education.

4 Design experiment

The seminar was integrated as a required course into chemistry teacher education classes at the university and, therefore, in real educational situations. Each meso cycle includes the preparation, implementation and evaluation of one seminar.

The first meso cycle of DBR project had three aims: to test the method of research-based learning, to develop a preliminary design of the intervention, and to develop appropriate evaluation tools (Marohn & Rohrbach, 2013). This first meso cycle is not the focus of this article.

The second and third meso cycles together constituted the main study in which the developed intervention was tested and evaluated on basis of evaluation tools.

In the following, this main study and the evaluation tools are presented.

Analysis and preparation

The seminar was integrated as a regular class in chemistry teacher education. The composition of the participants was a result of students' self-selection; it was not affected or determined by the researchers.

In order to adapt the course to the teacher students' previous knowledge and requirements, a pre-course questionnaire collected relevant personal and study-related data. In addition, the students were asked about their needs and wishes for the seminar. Both were integrated into the specific planning to the extent possible.

In the main study 48 students (22 men / 26 women aged 21 to 36) attended the seminar. Most students were either studying for a bachelor or master's degree for teaching at primary (secondary) and comprehensive schools.

Design and implementation

Especially the skills around syntheses and evaluation of pupils' conceptions (see Table 1) cannot be implemented in a teacher-centred class. Therefore, the seminar was based on the academic teaching concept of research-based learning, which originally goes back to the foundation of the first modern university in Germany (von Humboldt, 1810). Since then, research-based learning has become an established teaching concept in teacher education. Wildt (2009) for example developed the Learning Cycle shown in Figure 2 for use in educational studies.

Based on the Learning Cycle by Wildt, a didactically reduced model of the research process on pupils' conceptions was developed, which is mirrored in the phases of the seminar (Rohrbach & Marohn, 2016) (Figure 2).

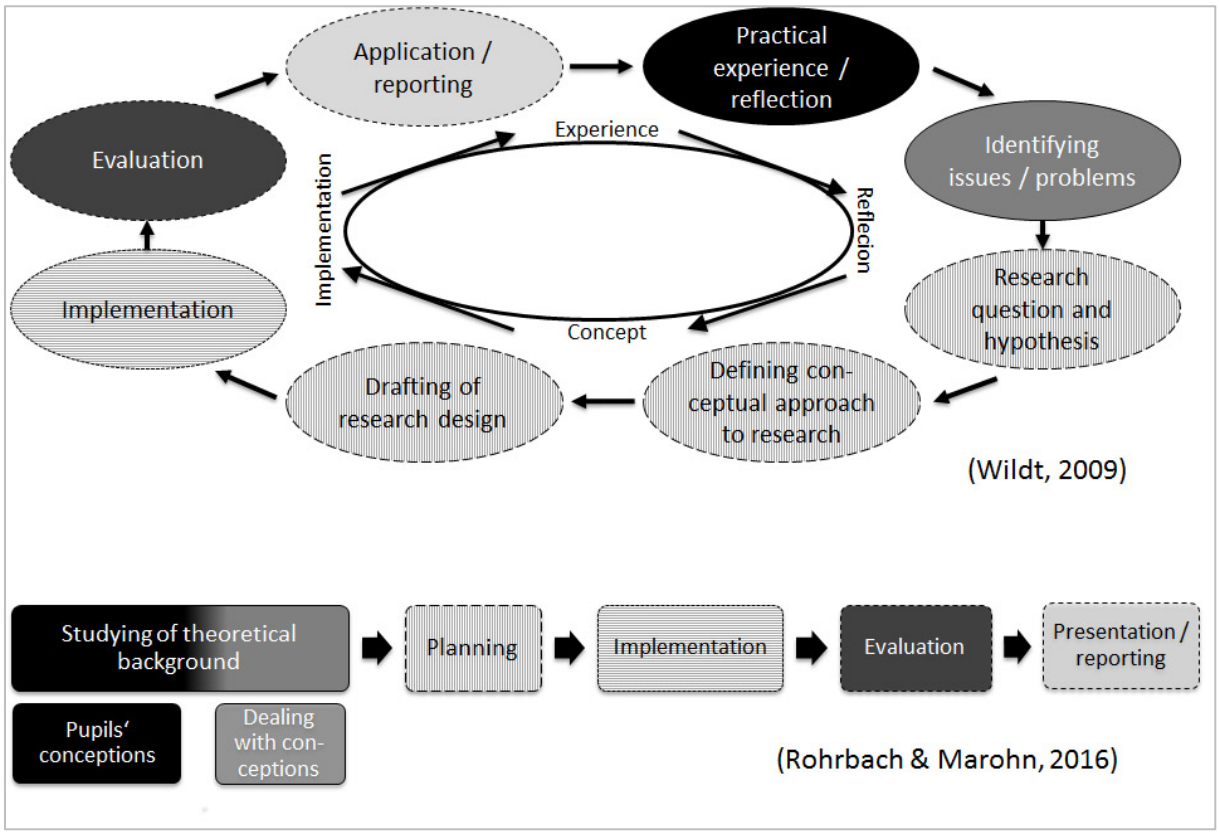


Figure 2: Learning Cycle by Wildt and the course of the presented seminar

During the first part of the seminar (theoretical foundation) students learned about pupils' conceptions, their causes, and about diagnostic tools to identify them. The students not only learned about diagnostic tools, they also developed and trialled theory-based questionnaires or interviews independently. The results were evaluated and presented in class. Next, knowledge such as learning theories were also part of this phase of the seminar. Studying learning theories such as moderate Constructivism and Conceptual-Change and -Growth theories illustrated the students that a permanent correction of pupils' misconceptions

cannot be achieved by explaining the right answer (again). Instead, pupils need to independently deal with the content and make it accessible to themselves.

Afterwards the students planned a lesson dealing with the diagnosis or change of a pupils' conception and applied this in a class with pupils.

To test the lessons, classes from local schools were invited to the university's teaching-learning lab. Use of videography during class sessions allowed students to reflect on their work with students in the evaluation phase of the seminar. Videography has already proven to be suitable to promote the ability to reflect and develop teaching in teacher education classes (Dorlöchter et al., 2008). During the individual evaluations the students reflected on the options they can use in their teaching. Subsequently, the students presented their results in class.

Evaluation und reflection

After each semester, the seminar was evaluated based on collected pre-post-follow-up questionnaires, pre-post-interviews with each student and portfolios which documented the students' process of learning. Collected data was merged by triangulation with the aim to assess the quality and usefulness of the research-based learning approach in teacher education. The seminar was adjusted and improved according to these findings. In the following, the final evaluation tools used during the main study are presented with examples and sample results:

Questionnaires

The questionnaire used in the main study to evaluate the seminar was developed as an evaluation tool specifically adapted to the seminar, which not only raised students' knowledge of pupils' conceptions and diagnostic options in chemistry lessons, but also disclosed information on subjective theories and strategies for dealing with pupils' conceptions.

The questions about pupils' conceptions were derived from the model on knowledge and skills in the context of pupils' conceptions (see Table 1). They asked to what extent students

- knew examples of empirically researched pupils' conceptions,
- diagnose and anticipate pupils' conceptions,
- diagnose and anticipate causes of pupil's conceptions,
- were able to reflect on the content and process of teaching with regard to the development or modification of pupils' conceptions, and
- develop strategies to deal with pupils' conceptions in chemistry education.

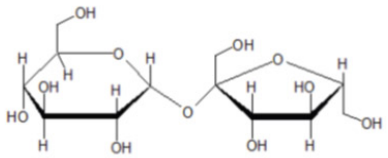
The second part of the questionnaire explored subjective theories of students with respect to causes of pupils' conceptions and ways of dealing with them. The third part of questions collected personal and study-related data of the participants.

The questionnaire described here was presented in two consecutive semesters in the manner shown here - unchanged - and answered by all students of the seminar. After about six months, all students were contacted via e-mail and asked to answer the questions again. The last data collection, the "follow-up test", was to provide insights as to whether observed effects were long-term.

The evaluation was carried out depending on the question format using t-tests, Wilcoxon tests, McNemar´s tests or Fisher´s exact tests.

In the following, a sample question of the questionnaire and the results of its evaluation are described: The first task questioned causes for the formation of technically false conception for solving (see Marohn, 2008). The students' responses to this question can provide insights as to whether students are able to anticipate origins of conceptions (see Table 1).

Describe and outline the dissolution process of sugar in water at the level of particles.



Structural formula of sucrose

The answers and drawings show that the pupils explain the dissolving of sugar in water with the breaking of bonds within the sugar molecules.

What cause(s) for this idea do you suspect?

Figure 3: Questionnaire question on conceptions in the context of the dissolving of sugar

Before participating in the seminar half of the students saw the cause of this pupils' conceptions in the pupil. Causes were usually formulated with a focus on the deficits of the pupil in the sense that the pupil did not have enough knowledge, misused existing knowledge or had difficulty in dealing with the complex structural formula of sucrose. More than 40%[3] of the students also identified causes within the chemistry classroom, which may lead to the formation of the aforementioned technically incorrect conception, e.g. conceptions for solving ionic bonds or an ambiguous use of symbols for molecules or ions as well as a misunderstanding of the solution process as a chemical reaction. 22% of respondents named everyday observations - the sugar is no longer visible after dissolving in water - as possible causes for the formation of the wrong conception. About 10% of the students either did not answer the question or in a way that did not answer the question.

After completing the seminar, most students rated the influence of the individual pupil on the formation of the technically wrong concept much less significant than before. Less than 10% of students mentioned ignorance of the pupil or difficulties in applying the learned knowledge as a source of difficulty in understanding. Everyday observations and the influence of everyday language on the formation of pupils' conceptions were judged to be significantly more important after the seminar.

[3] Answers to open questions like this were subject to a content analysis. Therefore a coding guide was created, which was used by two coders. If the coding across both coders was at least 70% consistent (Jaccard coefficient > 0.7), the respective results entered the evaluation. If the coding was less than 70% consistent, the coding guide was revised (multiple times if needed until the required consistency was achieved). The coded results were then evaluated quantitatively by either Fisher's exact test or McNemar's test (depending on the calculated frequency of responses). Both tests provide information on whether there was a significant change between the pre- and the post-test in how many times the respective cause was mentioned (** = level of significance 5%).

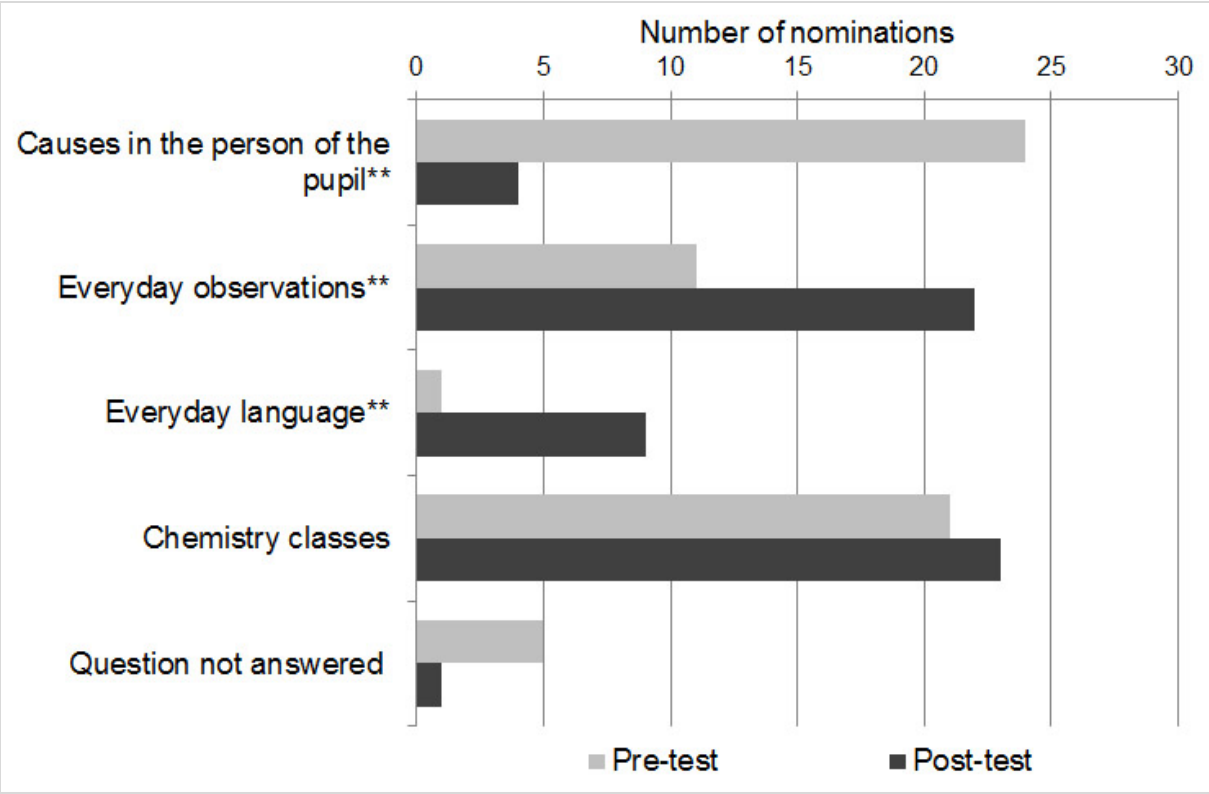


Figure 4: Causes of scientific wrong conceptions in the context of the solving of sugar

A comparison of the students' answers before and after the seminar shows that students rate the pupil's deficit-oriented role as significantly less important for the formation of scientific incorrect conceptions after the seminar. Instead, they rate the influences of everyday observations and everyday language as significantly more relevant. The comprehensive discussion and study of different causes for the formation of pupils' conceptions in the seminar presumably made the students aware of the complexity of possible causes and the relevance of other, non-personal causes.

There were no significant differences between post-test and follow-up-test half a year later. The described change in students' sensibility to different causes of scientific incorrect conceptions seems to persist half a year after the end of the seminar, which points to a certain stability of the changed knowledge.

Interviews

As part of the evaluation, individual interviews with all students were conducted before and after the intervention.

The pre-interview questions focused on students' knowledge, abilities, skills and subjective theories in the context of pupils' conception.

The questions related, for instance, to the model of desirable knowledge, skills and abilities (Table 1) and covered three of its four areas: causes and diagnosis of pupils' conceptions as well as possible ways of dealing with them.

The post-interview contained the same questions as the conversation at the beginning of the seminar. In addition, the students were asked questions regarding the evaluation of the seminar and the use of videography during the implementation of their work with pupils.

As an example, the statistical results of this question are presented in the following: *What possibilities do teachers have to diagnose comprehension difficulties and pupils' conceptions?* The students' responses to this question may indicate if students know diagnostic instruments and methods (see Table 1).

During the pre-interviews with 22 students in the third meso cycle, 18 different possibilities were identified.[4] The students mentioned very different possibilities, which included both indirect forms of diagnosis (e.g. the analysis of tests) as well as instruments specifically developed for diagnoses (e.g. the use of questionnaires). On average, each student named two or three options.

45% of students said that analysing the content of tests and class work could be used as a diagnostic tool. 36% of the students would advise the teacher to ask pupils specific questions and to obtain further information about comprehension difficulties and wrong ideas of their pupils. Encouraging pupils to explain their thoughts with further inquiries was what 23% of students described as an appropriate diagnostic tool, and 32% indicated that analysis of pupils' statements in class discussions was well-suited for a targeted diagnosis. These results shows similarities with the research by Morrison and Ledermann, who noticed – as a result of a small interview study – that teachers mainly identified discussions and asking questions as diagnostic tools (Morrison & Lederman, 2003).

After the seminar, a total of 20 different options were named in order to diagnose difficulties in comprehension and professional misconceptions. All students together named 89 diagnostic options, which corresponds to an average of 4 diagnostic tools per student. Significant changes can be observed in items that describe specific diagnostic options, e.g. the use of a questionnaire or special diagnostic tasks. The number of students who rated having pupils explain and justify their conceptions as a meaningful diagnostic tool doubled compared to the pre-interview. The significant changes in the responses of the students show that they are aware of the benefits of the diagnostic tools that they learned and tested in the seminar, and that they name them as diagnostic options for the generally formulated question.

Portfolios

Throughout the seminar students developed a portfolio. This portfolio served the students as an instrument of reflection regarding their own learning processes (Paulson, Paulson, & Meyer, 1991) and enabled them to link theory and practice. Furthermore the portfolio helped students to become aware of their own conceptions and attitudes regarding pupils' conceptions. Additionally, it helped them to reflect on general aspects of learning and teaching. The portfolio also formed the basis for assessing the students' performance and supports the evaluation of the seminar unit (Paulson & Paulson, 1990).

The following impulse questions were asked several times during the theoretical foundation phase of the seminar:

[4] For oral statements from the interviews another type of analysis was designed and implemented. The need for this resulted primarily from the fact that most oral statements were more complex and less precise than written answers from the questionnaire. In order to achieve the highest possible validity of the results, the answers were also subject to a content analysis; the individual codes were subject to interpersonal consensus validation.

- Outline the contents of the seminar.
- What did I learn today?
- What significance do the newly learned and repeated contents have for my future work as a teacher?
- The most remarkable part of the seminar session was for me ...

These questions were formulated in such a way that they could be reasonably answered for several seminar sessions and were supplemented by at least one question tailored to the specific session. The generally formulated questions could help students beyond the actual seminar to create a portfolio, e.g. in other university classes or as part of school teacher education.

During the preparation, implementation and follow-up of the teaching-learning laboratory, the follow-up nature of the questions was changed. Instead, the questions helped students plan and follow-up on the practical phase and helped them to structure what was a challenging task for many of them.

The impulse questions of the last seminar session asked whether the expectations of the students were fulfilled or not, requested a reflection on the learning processes that had taken place in the seminar, asked for an evaluation of the videography, and finally for an evaluation of the seminar.

The desired effect of the portfolios on stimulating students to reflect on their learning processes seems to have occurred, as the following representative quote shows:

"At the beginning of the seminar, I was unaware of how important pupils' conceptions are for everyday school life. I learned from the seminar that as a teacher I have to deal intensively with the conceptions of the pupils and monitor them."[5]

5 Retrospective analysis and theory development

Retrospective analysis

The retrospective analysis was carried out by reviewing the objectives of the research project formulated in the preparation with reference to the comprehensive evaluation results of the study. In the following, the three objectives of the research project are examined to see if they could be achieved by the presented intervention.

1. *During the course of the research project, a seminar was to be designed to sensitise students to the importance of pupils' conceptions in chemistry lessons.*

This objective was achieved by using the presented seminar in teacher education. After the piloting of the seminar, statements from seminar participants already indicated that the seminar concept might be suitable for sensitising students. A student formulated in his portfolio:

„As mentioned in the beginning, my perception, evaluation and even understanding of pupils' conceptions were sensitised."

[5] Statements made in the portfolios were mainly used as quotes proving or disproving certain theories as part of the evaluation.

The evaluation of the main study showed that the perception and evaluation of pupils' conceptions had changed among all participating students. Many students who did not have prior knowledge of pupils' conceptions prior to the intervention stated that they were more aware of the importance, opportunities and difficulties associated with pupils' conceptions when teaching chemistry lessons after the seminar. A student wrote in his portfolio:

„I am now, I think, sensitised to pupils' conceptions that are not easily identified at first glance. That was not so easy or even impossible [before the seminar], because I did not think along those lines."

Even students who had already acquired knowledge about pupils' conceptions before the seminar stated that their perception of the topic had changed. Most of these students anticipated that the knowledge and skills they had acquired would help them deal with pupils' conceptions professionally in the future.

2. *In the course of the research project, a seminar was to be designed to provide students with knowledge, skills and abilities to deal with pupils' conceptions.*

During the piloting, this question was answered in a purely descriptive manner based on the questionnaires and on the statements of the interviewed students. Both sources showed positive tendencies in acquiring knowledge about pupils' conceptions and their origins, as well as the ability to recognise them. This finding was included in the revision of the second and third meso cycles. The evaluation of the main study questionnaires and interviews showed that the students were able to acquire skills, abilities and knowledge in the context of pupils' conceptions. After the seminar many students knew significantly more typical pupils' conceptions and their causes than before attending the seminar. In addition, after the seminar, the students were, on average, able to refer to more specific ways to diagnose and detect pupils' conceptions. The use of a follow-up test half a year later indicated that the knowledge acquired during the seminar was relatively stable. Observations during the development and execution of lesson sequences in the teaching-learning laboratory and the evaluation of the portfolios showed that the students were able to choose a diagnosis tool or to design it themselves for a self-chosen pupils' conception.

Increases of knowledge and abilities in dealing with pupils' conceptions were less pronounced. In the post-interview, for example, on average, only one additional method of treatment is mentioned relative to the pre-interview, and only two specific methods were mentioned significantly more often after the seminar. Conclusions on the durability of these slight changes were not possible. Although this result indicates that learning processes have taken place, further knowledge in this area would be desirable for a professional handling of pupils' conceptions. In this regard, the seminar can be understood as a first step towards professionalization, which should be further enhanced in the future education of teacher students.

3. *During the course of the research project, a seminar was to be designed to make students aware of their subjective theories about difficulties in comprehension and misconceptions, and which possibly stimulates them to change their subjective theories.*

The analysis with the evaluation tools gives reasonable indications that this objective was achieved for many students. The evaluation of the main study first confirmed the hypothesis – based on an interview study conducted in advance of the presented work – that students often attribute the emergence of pupils' conceptions to person-centered and deficit-oriented causes. In addition it was shown that the students surveyed after the seminar rated

causes that are due to the learners' world and the influence of other subjects as significantly more important than before the seminar. With regard to the causes, it appears that there has been a change in subjective theories regarding causes for the development of pupils' conceptions, which was still detectable six months after the end of the seminar. That the seminar led to an increased recognition of the importance of pupils' conceptions and their causes is evident based on statements made by students in their portfolios.

„Before I attended the seminar, I did not know that so many misconceptions exist. I assumed that students might misunderstand something one time or another, but I did not realise that there were so many misconceptions. In this respect, the seminar has shaped my view and my perception of misconceptions in chemistry lessons. Therefore, it is also important for me to incorporate pupils' misconception in my later lessons, that is, to diagnose and also work to reduce misconceptions."

Significant changes could also be detected with regard to subjective theories on ways of dealing with pupils' conceptions in the classroom. After the seminar, students were more likely to ask pupils, who had given an incorrect or correct answer, for an explanation, or in both cases to have the question answered by another student. The students seemed to be more aware of the importance of learning as individual constructions than they were before the seminar, and they responded with the desire to learn more about the reasoning behind the answers. The fact that at least some students became aware of this change in their subjective theories is illustrated by the portfolio entry cited below as an example:

„[My thinking] has changed to such an extent that it became even clearer to me how many, in part creative and thought-though, trains of thought can also be behind a technically incorrect answer."

The changes of subjective theories on ways of dealing with pupils' conceptions also seem to persist for more than half a year on the basis of the follow-up test, indicating a relative stability of the newly acquired subjective theories.

Theory development

The results of the retrospective analysis shows that the intervention in form of the presented seminar can lead to changes of knowledge and abilities in the context of pupils' conceptions as well as to the change of subjective theories. The following theory thus seeks to explain the effectiveness of the seminar.

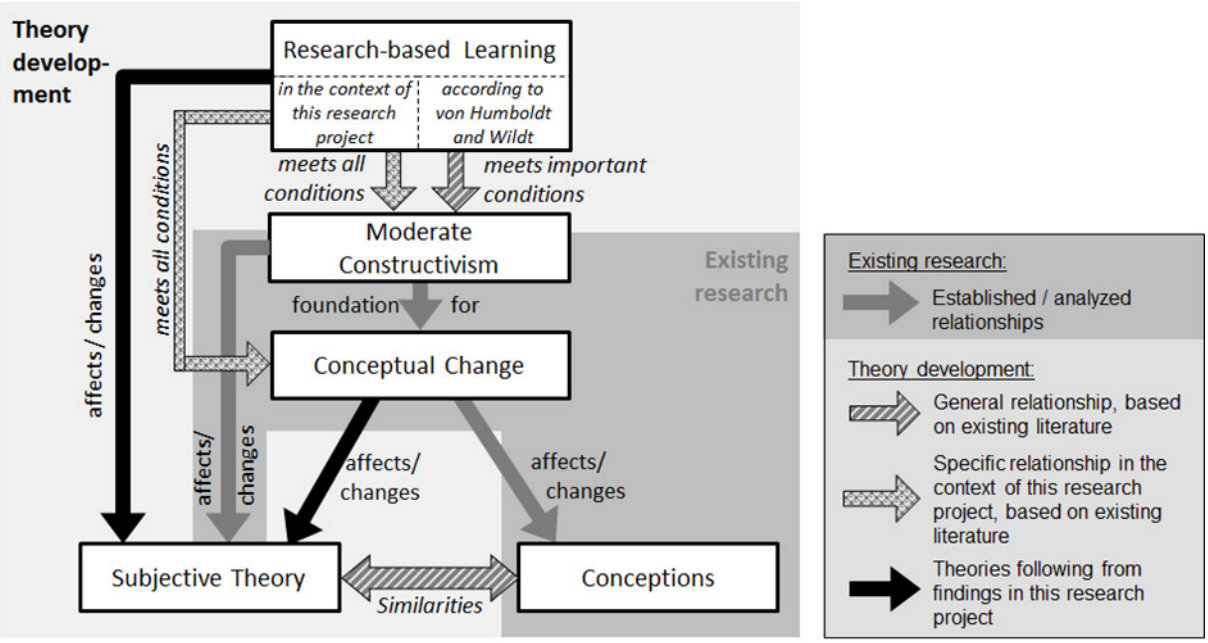


Figure 5: Graphical representation of the DBR projects theory development

Figure 5 presents the theory development graphically. Parts shaded in darker grey had already been scientifically studied and published.

Parts shaded in light grey include theory that has been formed in the context of the presented DBR project. Within this, a distinction is made between universally valid contexts (represented by striped arrows) and contexts that relate specifically to the presented seminar (represented by dotted arrows). The relationships shown by black arrows in Figure 5 describe new theories that arise on the basis of the literature-based theories and the results of the evaluation of this work.

The result of the evaluation was the beginning of the theory development, which showed that the active participation in the seminar could lead to changes of subjective theories about pupils' conceptions in science education. The theory in the following presents a possible explanation for this change.

Research on pupils' conceptions has shown that these can be changed through interventions. These interventions, which are usually based on the teaching-learning theory of moderate constructivism, should follow the principles of Conceptual Change theories and encourage learners to reflect on existing ideas and thus to change concepts (see Kleickmann et al. who were able to demonstrate that seminars oriented towards Conceptual Change theories could also lead to a change in the conceptions of teachers).

While studying "pupils conceptions in science education" and "subjective theories" it was noted that both constructs have substantial parallels. A literature-based comparison of the two theoretical constructs confirmed this impression and showed that all definitional features of subjective theories published by Dann (1989) can be related to pupils' conceptions (Rohrbach-Lochner, 2017).

Pupils' conceptions can thus be understood as a subset of subjective theories and as strongly domain-specific subjective theories in a scientific context. From these parallels and the existing research results on concept changes, the following theory emerged:

Theory 1: An intervention that meets the conditions for a change of concept can lead to a change of subjective theories!

The construction of the seminar was then examined for the existence of Posner and Strike's conditions for promoting a conceptual change (Posner et al., 1982; Strike & Posner, 1992). To demonstrate that the conditions created had the desired cognitive effects, portfolios of third-meso-cycle students were analysed. This analysis showed that the seminar fulfilled all the conditions for a change of concept. Theory 1 can thus be supported by the evaluation results of the seminar. Since the focus of the design of the study was not on meeting of conditions for a conceptual change, but on meeting the condition of research-based learning, a second theory emerged:

Theory 2: Interventions based on research-based learning can lead to the modification of subjective theories.

Due to the large diversity of publications describing research-based learning it is not possible to make a general statement in this regard. For the two forms of research-based learning underlying the seminar (research-based learning according to von Humboldt and Wildt), it was possible to prove that they both fulfill essential conditions of moderate constructivism (Rohrbach-Lochner, 2017). According to Richardson, constructivist-oriented teacher education programs are more likely to produce changes in subjective theories than interventions developed on the basis of other learning theories (Richardson, 1996). Under the condition that theory 1 is correct, research-based learning in the two reviewed versions can lead to a change of subjective theories. However, as not only a general theory was sought, but above all the effect of the developed seminar should be explained, it was also examined whether this specific form of research-based learning also met the criteria for moderate constructivism. The review concluded that the seminar meets all conditions of moderate constructivism. The results of the evaluation of the seminar thus also confirm theory 2.

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