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Developing a Tool to Evaluate Differences in Beliefs About Science Teaching and Learning Among Freshman Science Student Teachers from Different Science Teaching Domains: A Case Study

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This paper presents a pilot case study on developing a qualitative tool to evaluate science student teachers' beliefs concerning science teaching and learning. The study is based on student teachers' drawings of themselves in a typical classroom situation and four open questions. Data was collected from 104 freshman science student teachers, and evaluated based on the basic tenets of Grounded Theory. Applying Grounded Theory led to a framework of categorising the student teachers' beliefs in three categories: (I) Beliefs about Classroom Organisation, (II) Beliefs about Teaching Objectives, and (III) Epistemological Beliefs. All three categories were expanded to a dimension between more traditional beliefs and beliefs in line with modern educational theory. The participants in the study were from different groups of student teachers in one of four domains of science teaching: secondary school Biology, Chemistry or Physics or Primary Science. The tool proved to be interesting for gaining insights into the beliefs of freshman science student teachers. The initial results from this case study indicate that secondary student teachers of Chemistry and, even moreso, Physics hold teacher- and content-structure-centred beliefs about science teaching and learning, whereas Biology student teachers, and even more pronouncedly Primary Science student teachers, hold more student-centred and scientific literacy-oriented beliefs.

Keywords: Chemistry Teacher Education, Student Teachers' Beliefs, Grounded Theory

INTRODUCTION

Science education research in the last decades focused extensively on students' learning and understanding. Research evidence favours student-active and constructivistic learning environments, and orientation towards student–relevant contexts (Valanides & Angeli, 2002). Unfortunately, this perspective only rarely influences classroom practices in Germany where science teaching is still very teacher–centred, over–directed, and content-structure-driven (Fischer, Klemm, Leutner, Sumfleth, Tiemann, & Wirth, 2005; Ostermeier & Prenzel, 2005). Obviously, this occurs because science teachers in Germany are not

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sufficiently trained (or not trained at all) to apply constructivistic and student–centred teaching, and to use meaningful and authentic contexts. In Germany, teaching practices and teachers' behaviour are not aligned with current research evidence, while the learning environments in Chemistry and Physics are far from being constructivistic (Ostermeier & Prenzel, 2005). This seems to be also true for university science teacher education programs. Teacher training courses at German universities are not guided enough by research evidence concerning a constructivistic view of teaching (Weiler, 2003). University chemistry classes, seminars, and laboratory activities usually focus more-or-less exclusively on content knowledge and seem to reinforce learning as being mainly receptive (Koballa, Gräber, Coleman, & Kemp, 2000).

Similarly, a lot of school teachers tend to teach the way they have been taught as pupils at school (or even at the university), and their teacher education does not really affect their initial conceptions about learning and instruction (Larsson, 1986; Koballa et al., 2000). Sears, Marschall and Otis-Wilborn (1994) stated that teacher education doesn't seem to be effective in changing central dispositions and characteristics of the personality of prospective teachers:

> "Teaching is a moral craft with social and political consequences. However, developing the necessary dispositions or characteristics, like those above (means wish to offer service to students) is, in the short period of time available in teacher preparation programs, not possible. Individuals must come to teacher preparation programs with those dispositions and characteristics." (p. 57)

Teachers often are guided by past events that create intuitive screens through which new information is filtered and transformed, and teachers' beliefs predict their teaching behaviour to a certain extent (Goodman, 1988). Wubbels (1992) also stated that beliefs or preconceptions that student teachers bring to the university teacher education programs are strongly affected by their earlier experiences as learners, and that this is more the case when the presence of these pre–experiences is not consciously realized.

Although knowledge and research evidence about students` learning and alternative conceptions in science is extensive, and almost unanimously agreed upon, there is much less knowledge about the way science teachers' beliefs and knowledge affect the way they teach science. Nespor (1987) and Pajares (1992) stated that teachers' beliefs are a neglected field in science education research. Fischler (1999) acknowledged that there is too little research evidence about German science teachers' beliefs and knowledge concerning their perceived role, science teaching objectives, and their influence on students' learning.

Despite the persistent acknowledgment of the importance of teachers' conceptions (Thomas, Pederson, & Finson, 2000; van Driel, Beijaard, & Verloop, 2001), research studies concerning teachers' and prospective teachers' beliefs are recognized as being of increasing importance (e. g., Fischler, 1999; Fischer et al., 2005). This new research approach should enable university science teacher education programs to not only investigate the way knowledge is constructed, but also how to modify science student teachers` beliefs about teaching, learning, and educational objectives, and how to design and develop science teacher education programs based on constructivistic ideas (Koballa et al., 2000).

University teacher education should be aligned with constructivistic ideas (Fischler, 1999; Marion, Hewson, Tabachnick & Blomker, 1999), and teaching should continuously target the identification of student teachers' pre–knowledge and initial beliefs. Undeniably, teachers` beliefs about teaching and learning play an important role in affecting the nature of teachers` intentions in the classroom and in influencing their professional work, like lesson planning, assessment, and evaluation. These beliefs have an impact on teachers' decision making during classroom interaction with students (Nespor, 1987; Pajares, 1992).

Obviously, there exists a need to identify student teachers' initial beliefs and to develop tools that can make these beliefs explicit. Veal and Hill (2004) suggested that science teacher education development had been influenced by research about teachers` beliefs and their knowledge base. Those two "areas", teachers' beliefs and their knowledge base, separately affect teacher education and form the basis of teacher professional development. From a constructivistic point of view, more research is needed related to student teachers' beliefs about teaching and learning, about the curriculum structure, about the objectives of science education, and about the implications of the learning environment on children's learning. Research evidence is also needed for designing courses that can effectively support changes in student teachers' initial beliefs about science teaching (Koballa et al., 2000).

There is, however, limited research concerning teachers' beliefs about science teaching that is considered very helpful for guiding new research efforts. For example, several studies investigated teachers' beliefs and related aspects of teachers' knowledge (e.g., Brickhouse, 1990; Brookhard & Freeman, 1992; Czerniak, Lumpe, & Haney, 1999; Cheung & Ng, 2000; Loughran, Berry, & Mulhall, 2006; Nilsson, 2006). Some researchers also evaluated the relationship between student teachers` pre-admission beliefs and attitudes, and their actual teaching performances (Shechtman & Godfried, 1993; Ackley & Arwood, 1999).

From this perspective, the present study attempted to develop a new qualitative approach to evaluate the beliefs that science student teachers bring with them as they enter a university science teacher education program. The approach was inspired by the central idea of the Draw-a-Science-Teacher-Test Checklist by Thomas, Pedersen, and Finson (2001) which asks teachers or student teachers to spontaneously draw themselves in a typical classroom situation. In the German science teacher training system, there are different groups of freshman student teachers relating to Primary Science and the different secondary science subjects (Biology, Chemistry and Physics)[1]. The tool also attempted to pinpoint differences (if any) in the beliefs of student teachers from the different science teaching domains on teaching their respective school science subject. Special emphasis was placed on 1) gaining knowledge about science student teachers` beliefs before they had had any lessons in their university teacher training program and 2) comparing groups of student teachers from different programs of study (secondary Biology, Chemistry, Physics and Primary Science) with the same regional and educational background.

Theoretical framework

Several studies refer to 'teachers` beliefs' as a theoretical framework for investigating how (and why) teachers behave the way they do (Pajares, 1992). The concept of 'beliefs' is also used as a construct in science education research to describe ideas that may lead to decisions why teachers teach, act, and organise their teaching behaviours the way they do (Beck & Lumpe, 1996). Bandura (1986) stated that beliefs are considered to be the best indicators of why a person behaves, handles information, and makes decisions in a certain way. Koballa et al. (2000) concluded that beliefs influence the kind of interactions between teachers and pupils, and suggested that teachers` beliefs about teaching and learning always include aspects of beliefs exclusive to their discipline or subject.

Calderhead (1996) also accepted the importance of teachers' beliefs and tried to differentiate among five interrelated areas of teachers' beliefs: beliefs about learners and learning, beliefs about teaching, beliefs about the subject matter, beliefs about learning to teach, and beliefs about one's self and one's role. Nevertheless, the term 'beliefs' seems to be unclearly defined in some cases:

> "They [the beliefs] travel in disguise and often under alias names – attitudes, values, judgments, axioms, opinions, ideology, perceptions, conceptions, conceptual system, preconceptions, dispositions, implicit theories, explicit theories, personal theories, internal mental processes, action strategies, rules of practice, practice principles, perspectives, …" (Pajares, 1992, p. 309)

For the purpose of the present study, the term 'beliefs' refers to all mental representations that teachers or student teachers hold (consciously and unconsciously) in their minds that influence, to a certain extent, their (potential) behaviour as teachers of science. This perspective is aligned with Tobin, Tippins, and Gallard's (1994) ideas, which defined beliefs as a "form of knowledge that is personally viable, in the sense that it enables a person to meet his or her goal' (p. 55). From this perspective, all beliefs are personal constructs influenced by experience, knowledge, and societal backgrounds. Every science teacher has his or her own beliefs about teaching and learning that influence their teaching strategies and behaviour (Hewson & Kerby, 1993). Similarly, science student teachers' beliefs impact their teaching behaviour and understanding in every step of their pre-service teacher education. Fischler (1999) furthermore stated that student teachers have fixed beliefs about teaching and learning that guide their teaching behaviour and prevent them from following other alternate pathways.

Fischler (1999) evaluated Physics student teachers' beliefs in Germany in terms of thinking about their own Physics classes at school. They usually described a very dominant teacher, very passive pupils, and bad memories of Physics. He argued that the beliefs student teachers have are always linked with their experiences as pupils in school (Fischler, 1999). Veal and Hill (2004) also suggested that experiences in the classroom are much more important than any information given to student teachers by traditional methods.

From this point of view, it is less astonishing that not only practicing teachers but also student teachers often have problems with teaching in a constructivistic way (Hewson & Hewson, 1988), or that science student teachers conceptualise teaching as a widespread spectrum of 'knowledge transfer,' 'influence or change in understanding,' and learning as 'intake of knowledge,' 'attempt to make sense in terms of existing understanding,' and 'an affective response' (Aguirre, Haggerty, & Linder, 1990). Annerstedt and Sundqvist

[1] Secondary science in Germany is taught as separate school subjects (Chemistry, Biology, and Physics). The teacher training programs for the three secondary school science subjects are independent, five-year university programs, which partially overlap with other science programs. From the beginning, student teachers attend programs oriented towards becoming a teacher of secondary Physics, Biology or Chemistry, or a Primary Science teacher (grades 1-4). The term 'student teachers' in this sense is used for those students attending a university science teacher training program. Almost none of them had had any other university studies before this.

(as cited in Marton & Booth, 1997) concluded that the more advanced the level of education of Physics teacher educators, Physics teachers, and science student teachers is, the more they focus on the content rather than on the learners. Koballa et al. (2000) also described Chemistry student teachers' beliefs as reproductive rather than constructive. Furthermore, they stated that beliefs of teaching and learning Chemistry held by German university student teachers are similar to those held by Chemistry students who do not intend to become teachers.

The situation for Primary Science student teachers seems to be different, although there is nearly no evidence available about a direct comparison of primary and secondary Science teachers beliefs coming from a similar educational background. Skamp and Mueller (2001) concluded that Primary Science student teachers, at the beginning of their university education program, held beliefs that they would involve their students in hands-on activities, although students' active participation was directly guided by textbook approaches. After two years, they expressed beliefs indicating that good Primary Science teachers should involve their students in hands-on activities, where students are encouraged to explore materials and test new ideas. On the other hand, Meyer, Tabachnick, Hewson, Lemberger, and Park (1999) stated that Primary Science student teachers at the beginning of their program held beliefs of learning indicating that the learners` role was considered to be receptive to knowledge presented by several sources. Evidence from their study demonstrated that student teachers made progress towards the goals of the program that depended on their conceptions of knowledge, Science, and learning. In another study with secondary Biology student teachers, Lemberger, Hewson, and Park (1999) concluded that Biology student teachers had positivist ideas of knowledge and science that influenced them to have an understanding of teaching as a knowledge transfer.

These studies came from different countries, cultures, and educational systems. The overall evidence tends to indicate that secondary Science teacher trainees are more content-structure-focused, teacher-centred and less contructivistic in comparison with teachers and student teachers from Primary Science, but there are no data comparing student teachers with the same regional and educational background.

The present study was inspired by the central idea of the 'Draw-A-Science-Teacher-Test Checklist' (DASTT-C) by Thomas, Pedersen, and Finson (2001). The central idea of DASTT-C used here is to ask teachers to draw themselves and their students during a typical science teaching situation. DASTT-C is furthermore accompanied by two questions, which ask the respondents to describe both the teacher's and the students' activities in the specific teaching situation to better understand the drawing. For evaluating DASTT-C, Thomas et al. (2000) began with a listing of teacher- and student–centred attributes, and agreed on three sections (teacher, students, and environment). For each attribute of the three sections, there were scores of 1 and 0 representing the presence or absence of an attribute. Total scores range from 0 to 13, whereby the lower the score, the more student-centred the teaching situation is considered. Scores between 0–4 indicate a fairly student–centred teaching, scores between 7 and 13 a fairly teacher–centred teaching approach, while for scores 5 or 6 no decision can be made (Thomas et al., 2001).

As in DASTT-C (Thomas et al., 2000), we asked the participants the question 'How do you see yourself as a teacher?' This question forces a teacher, or in our case a student teacher, to be deeply involved in the situation of teaching and draw an image of himself/herself as a teacher in a classroom situation. Weber and Mitchell, (1996) considered an image as:

> "an idea or mental representation, a conception with a visual or physical flavour, an experiential meaning, a context or history, with a metaphorical, generative potential." (p. 305)

Wilson and Wilson (1979) stated that image-making is an important characteristic of human sense-making. Images are made in order to make sense of experiences and communicate that sense to others. These images (in our study drawings that science student teacher had to make) are considered to be an important package of information that can be read and decoded. Drawings usually provide an insight into human sense–making that is not easily discernible with written or narrative texts. With drawings, one can express things that, in some cases, are not possible, or deviate from written or oral descriptions. Drawings and pictures are helpful instruments to evaluate teaching identities that are often unseen, influenced through past and present stereotypes, and, in some cases, opposite to teacher identity and practice (Weber & Mitchell, 1996). It is, however, useful to state that the present approach is just a 'snapshot method' for identifying conceptions about specific aspects of the learning environment.

QUESTION, SAMPLE AND METHOD

The objective of the present study was to develop a tool to investigate freshman student teachers' beliefs about science teaching and learning prior to the start of their tertiary-level teacher training program. The study was also designed to compare student teachers with the same regional and educational background, who were studying to become science teachers in different science domains (secondary Chemistry, Physics and Biology or Primary Science).

The main questions to be addressed by the tool were:

Which beliefs do science student teachers have about science teaching and learning at the beginning of their university science teacher education program?

Are there any differences in freshman student teachers` beliefs concerning science teaching and learning of student teachers from Biology, Chemistry and Physics (for secondary education) and Primary Science respectively?

The chosen approach was image–making based on student teachers' drawings as described above. In an attempt to collect more information, we added two open questions relating to the teaching objectives and the approach towards the teaching situation that student teachers presented in their drawings.

Data was collected from 104 freshman science student teachers (11 Physics, 41 Chemistry, 34 Biology and 18 Primary Science student teachers) at the University of Bremen, during the first two weeks of their university science teacher training program in 2004. They were asked to draw themselves in a typical situation while teaching their subject at school, and to answer four open questions relating to teacher's activities, students` activities, the teaching objectives and the approach towards the teaching situation in their drawings.

The change towards a qualitative approach and the addition of more open-ended questions made the use of the suggested checklist method of DASTT-C (Thomas et al., 2001) inappropriate. Therefore, we decided to evaluate the totality of the data using Grounded Theory (Glaser & Strauss, 1967; Strauss & Corbin, 1990). Grounded Theory (GT) consists of three essential steps: open, axial and selective coding. With open coding, the material is read and re-read, and all relevant information about the field of interest is identified and initially coded. In axial coding, open codes are compared to each other, via a combination of inductive and deductive thinking. The open codes are then grouped together when they cover closely related aspects, so that few more inclusive categories are formed. Selective coding means the final process of selecting only one core category, relating it to the categories from axial coding, validating these relationships, and refining and developing the categories from axial coding further with respect to the core category.

Following GT practice, all information from the drawings and written student teachers' responses were open–coded, providing information related to teaching methodology, content, teaching objectives, textual approaches, media, etc. More than 300 different codes were given to describe the data, such as, 'teacher is standing in front of the class,' 'students conduct experiments,' 'students are not in the classroom,' 'objective is to learn about the pendulum,' etc. From this rich source of information, data were cyclically refined and grouped step by step into smaller numbers of categories. These codes were finally grouped together when they covered closely related aspects (e. g., learning about content is a central objective, but this objective is illustrated by different contents), or when there were elements that were considered to be causes of other elements (e. g., students sitting in rows with the teacher in front of the class indicates a teacher–centred style of teaching, using the overhead projector as an indicator for considering teaching as 'I explain the content to my students,' or the demonstration of experiments as a way of transferring knowledge to students). Each step was communicatively validated within the research group and referred back to the original data. Finally, three categories related to 'Beliefs of Classroom Organization', 'Beliefs of Teaching Objectives', and 'Epistemological Beliefs' were used as categories encompassing almost all the codes.

In the present study, the core category from selective coding (including the three categories from axial coding) was a spectrum ranging between student/literacy–centred beliefs and teacher/content-structure–centred beliefs. This core category can also be seen as the range between a more traditional understanding of science teaching and a modern understanding aligned with learning theory and research evidence. The traditional view is characterized by a transmission-oriented understanding of learning, strongly orientated towards learning science facts and science content structure, and less orientated towards problem-solving and competencies to function as an informed citizen within the framework of a science-technology-society. The modern view represents ideas from constructivism, is oriented towards developing scientific literacy for all, and puts emphasis on higher-order cognitive skills (Markic, Valanides & Eilks, 2006). For the purpose of refining and developing these categories, each of the three (Beliefs of Classroom Organization, Beliefs of Teaching Objectives, and Epistemological Beliefs) was assigned to the core category and was evaluated across a range of values from -2 to +2. These numbers were symbols for the description of each category along ordinary but nonlinear scales. The scales and descriptions are presented in Table 1.

The three scales were used for the final coding of the data by two independent raters, who believed that the three categories sufficiently represented the data. Three codes were used to represent student teachers' beliefs of classroom organization, beliefs of teaching objectives, and epistemological beliefs. The categories were saturated in the sense of GT. Agreement in coding the answers between the two raters was high (above 80%), while, in cases of disagreement, consensus was reached

Table 1. Description of the Codes from Selective Coding

Beliefs of Classroom Organization	-2	Strongly teacher–centred: The teacher is in the centre of any activity; dominates activity; is lecturing; uses media to focus students'
	-1	Rather teacher–centred: The teacher is in the centre of the activity, but interacts with the students; (s)he requires short answers from students, but dominates and directs every activity in the classroom
	0	Neither … nor: Teacher- and student–centred activities are in balance, the teacher shifts from teacher- to student–centred teaching.
	1	Rather student–centred: Students` activities are the core, but students` activities are initiated and controlled by the teacher.
	2	Strongly student–centred: Students` activities are the core; students are at least partially able to choose and control their activities.
Beliefs of Teaching Objectives	-2	Exclusively content-structure focused: Learning of facts and about the inherent structure of science content is the central objective.
	-1	Rather content-structure focused: Learning of facts and about the inherent structure of science content is in the foreground; but some non-cognitive objectives are targeted
	0	Neither … nor: Learning of content and applications/non-cognitive objectives is in balance; or motivational objectives are the core.
	1	Rather scientific literacy oriented: Learning of competencies, problem solving or thinking in relevant contexts and other affective outcomes are important.
	2	Strongly scientific literacy oriented: Learning of competencies, problem solving or thinking in relevant contexts and other affective outcomes are the main focus of teaching.
Epistemological Beliefs	-2	Learning is receptive: Learning is passive and over–directed, learning is dissemination of information
	-1	Over–directed learning with student–active phases: Learning follows a storyboard written by the teacher; conducted by the students, but organized and directed by the teacher.
	0	Over–directed learning with elements of constructivism: Learning is directed by the teacher taking into consideration students' preconceptions or problem-solving are used, but the learning process
	1	Rather constructive learning: Learning is an autonomous and self–directed activity, but is initiated and partially directed by the teacher.
	2	Strongly constructive learning: Learning is an autonomous and self–directed activity, starting from students` ideas and initiatives.

after discussion using inter–subjective agreement (Swanborn, 1996).

RESULTS AND DISCUSSION

Table 2 shows the proportions of science student teachers in each of the identified categories for secondary Physics, Chemistry and Biology and Primary Science.

The results in Table 2 indicate that the respective groups of science student teachers held a wide range of beliefs regarding Classroom Organization, Teaching Objectives, and Epistemological Beliefs. Thus, the 34 Biology student teachers expressed a diversity of beliefs about themselves as teachers, their teaching objectives, and their students' ways of learning. Chemistry student teachers exhibited extreme differences in their expressed beliefs in the three categories. The group of Chemistry student teachers showed an evenly distributed picture along the three categories. But, there were more than 50% of the Chemistry student teachers who were rated with a '-1' in the category 'Epistemological Beliefs'. This means that they understand learning as primarily over–directed with student–active phases. Learning for them follows a storyboard written by the teacher; conducted by the students, but organized and directed by the teacher (see Table 1). The Physics student teachers' group was the smallest (only 11 students), but they also exhibited different beliefs about themselves as teachers, their teaching objectives, and their conceptions of learning. For classroom organization, both teacher–centred and student–centred approaches for Physics student teachers appeared to be in a balance.

Table 2. Overview of the Results

	Physics	**Chemistry**	**Biology**	**Prim. Sci.**
Number of student teachers	11	41	34	18
Beliefs of Classroom Organization				
-2	4 (36.4 %)	9 (21.9 %)	6 (17.6 %)	1 (5.6 %)
-1	2 (18.2 %)	9 (21.9 %)	11 (32.4 %)	2 (11.1 %)
0	0 (0.0%)	5 (12.2 %)	1 (2.9 %)	1 (5.6 %)
1	3 (27.3 %)	14 (34.1 %)	10 (29.4 %)	7 (38.9 %)
2	2 (18.2 %)	4 (9.8 %)	6 (17.6 %)	6 (33.3 %)
not coded	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (5.6 %)
Beliefs of Teaching Objectives				
-2	4 (36.4 %)	6 (14.6 %)	8 (23.5 %)	1 (5.6 %)
-1	3 (27.3 %)	2 (4.9 %)	5 (15 %)	0 (0.0%)
0	0 (0.0%)	19 (46.3 %)	9 (26.5 %)	3 (16. 7 %)
1	2 (18.2 %)	10 (24.4 %)	4 (11.8 %)	7 (38.9 %)
2	0 (0.0%)	3 (7.3 %)	7 (20.6%)	5 (27.8 %)
not coded	2 (18.2 %)	1 (2.4 %)	1 (2.9 %)	2 (11.1 %)
Epistemological Beliefs				
-2	3 (27.3 %)	7 (17.1 %)	8 (23.5 %)	1 (5.6 %)
-1	4 (36.4 %)	21 (51.2 %)	8 (23.5 %)	2 (11.1 %)
0	1 (9.1 %)	8 (19.5 %)	4 (11.8 %)	5 (27.8 %)
1	3 (27.2 %)	3 (7.3 %)	9 (26.5 %)	4 (22.2 %)
2	0 (0.0%)	2 (4.9 %)	5 (14.7 %)	5 (27.8 %)
not coded	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (5.6 %)

Numbers and percentages of the student teachers in the respective categories. The categories refer to table 1.

The drawings and the answers of the Primary Science student teachers indicated that this group was quite different from the other groups. They held rather more student–centred beliefs about classroom organization, only one of them emphasized content–oriented objectives, and they mainly supported constructivistic learning.

Two extreme views on a classroom situation are shown in Figure 1.

Another important interpretation of the data relates to the various combinations of the data represented by the three categories form axial coding (Beliefs of Classroom Organisation, Beliefs of Teaching Objectives, and Epistemological Beliefs respectively). Table 3 gives the frequency of the different combinations concerning the different groups of student teachers.

An interesting question within the development of the tool relates to whether the imposed core category from selective coding allowed for independent answers within the three categories. In other words, the question was whether the core category was well-selected, meaning that the three categories were interdependent on each other. Because of the qualitative character of the data and the evaluation procedure, this was not done via statistical methods. Instead, we chose a visual approach. By connecting all three test dimensions in a diagram, each of the student teachers was located within a three dimensional space. We represented the three codes representing the three categories from axial coding and for each student into the same diagram and got 3D–pictorial representations. The axes in these representations correspond to the categories from axial coding and represent the student teachers' beliefs of classroom organisation, beliefs of teaching objectives, and epistemological beliefs, respectively. If a student has similar classifications in each of the three categories, then she/he appears along or near the diagonal from (+2, +2, +2) to (-2,-2,-2) in the diagrams of Figure 2. As it is shown in Figure 2, all the diagrams have a high proportion of the code combinations from student teachers near the diagonal in the 3D–representations. It can be interpreted that the core category which was imposed over the three separate dimensions makes sense in the means of GT.

Coming from this proof of our core-category selection, each student teacher could now be rated to see whether (s)he had more traditional or more modern beliefs about science teaching and learning. The closer the rating for a student teacher is to the lower, front, left corner of the diagram, the more (s)he has traditional beliefs about teaching. The opposite is the case for the upper, rear, right corner of the diagram.

Table 3. Overview about the Frequency of Combinations from the Three Categories from Axial Coding and for the Different Groups of Student Teachers

Code – Combination	Physics	Chemistry	Biology	Primary Science
(-2/-2/-2)	3 (27,3%)	4 (9,8%)	2 (5,9%)	
(-2/-2/-1)			2 (5,9%)	
(-2/-1/-2)			2 (5,9%)	
(-2/-1/0)	1 (9,1%)			
(-2/0/-2)		3 (7,3%)		1 (6,3%)
(-2/1/-1)		1 (2,4%)		
(-2/1/0)		1(2,4%)		
(-1/-2/-2)			3 (8,8%)	
(-1/-2/-1)		1 (2,4%)		1 (6,3%)
(-1/-1/-1)	2 (18,2%)	1 (2,4%)	2 (5,9%)	
(-1/0/-1)		4 (9,8%)	2 (5,9%)	
(-1/0/0)		3 (7,3%)	1 (2,9%)	
(-1/0/2)			1 (2,9%)	
(-1/1/0)			1 (2,9%)	
(-1/2/-1)			1 (2,9%)	
(0/-2/1)			1 (2,9%)	
(0/0/-1)		1 (2,4%)		
(0/0/0)		3 (7,3%)		
(0/1/-1)		1 (2,4%)		
(0/1/0)				1 (6,3%)
(1/-2/-1)		1 (2,4%)		
(1/-1/-1)	2 (18,2%)		1 (2,9%)	
(1/0/-1)		6 (14,6%)		
(1/0/0)			2 (5,9%)	1 (6,3%)
(1/0/1)			4 (11,8%)	
(1/1/-1)		3 (7,3%)		1 (6,3%)
(1/1/0)		1 (2,4%)		2 (12,5%)
(1/1/1)	1 (9,1%)	2 (4,9%)	3 (8,8%)	2 (12,5%)
(1/2/-1)		1 (2,4%)		
(1/2/1)				1 (6,3%)
(2/-2/1)	1 (9,1%)			
(2/-1/-1)		1 (2,4%)		
(2/0/2)				1 (6,3%)
(2/1/1)	1 (9,1%)			1 (6,3%)
(2/1/2)		1 (2,4%)		
(2/2/1)		1 (2,4%)	1 (2,9%)	
(2/2/2)		1 (2,4%)	5 (14,7%)	4 (25,0%)

Numbers and percentages of the student teachers in the respective categories. The categories refer to table 1 in the sequence Classroom Organisation, Teaching Objectives, and Epistemological Beliefs.

Most of the Primary Science student teachers were located in the upper, right, back part of the diagram. That means Primary Student teachers had combinations of positive classifications in the three categories indicating a student/literacy–centred teaching approaches and beliefs. The data from the Biology student teachers appeared more widely distributed in the respective 3D–representation. Nevertheless, the group of Biology student teachers included student teachers who had more combinations of positive values and were located in the upper, right, back part of the respective 3D - diagram.

Contrary to this, Chemistry and Physics student teachers appeared to favour more teacher/ content-structure–centred approaches. Both 3D-diagrams corresponding to Physics and Chemistry student teachers had code combinations in the lower, left and frontal part of the diagram, indicating that there were more student teachers having combinations of negative values in the three categories from axial coding which indicate teacher/content-structure–centred beliefs. The data from the Chemistry student teachers was more widely distributed and also indicate a high portion of students in the middle of the diagram and only few of them in the upper, right, back part of the diagram. The data from the Physics student teachers appeared almost identical to those from the Chemistry student teachers, but due to the smaller number of cases (only 11 Physics student teachers) should be interpreted cautiously.

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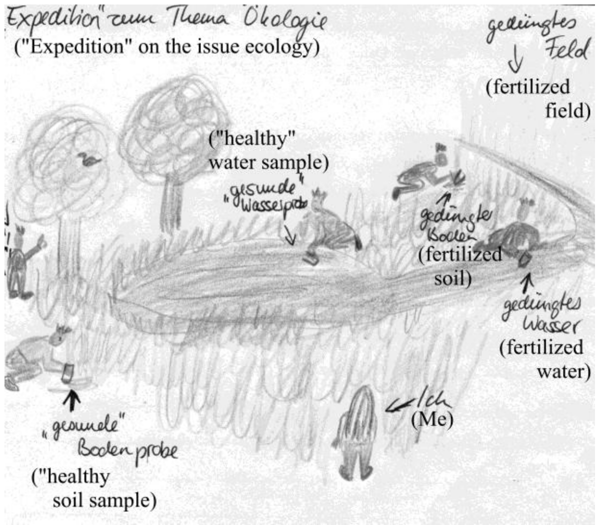
Teacher's activities:
I explain our universe to the students with beautiful new media, and support everything with the trusty old blackboard.

Students' activities:
Students write down the information from the blackboard and listen carefully to my briefings.

Objectives of the drawn situation:
Comprehending laws of physics.

Approach towards the drawn situation:
First lesson in grade 11



Teacher's activities
I took the students to an ecologically endangered/ interesting place. Before that, we talked about what to do. I was available for questions. Aside from this, I'm more in the background and observe and supervise the students.

Students' activities:
Students should collect samples for the topic 'ecology', e. g., soil and water. Later on, the samples should be analysed (nitrite, nitrate, oxygen, etc.). From these results, understanding of the damage caused to the environment and protection of the environment should be constructed. Aside from this, it should be recognised how typical models of flora and fauna, e. g., at a lake, are applicable, whether there are intact ecosystems. Finally, the students should prepare a presentation.

Objectives of the drawn situation:
Awareness of protecting of the environment and problems with fertilisers, clearcutting, and pesticides will be raised. The damage caused to nature should be recognised. Skills in analysing samples, writing a journal and reasoning should be developed/trained.

Approach towards the drawn situation:
In advance, ecological models of the forest/lake were discussed on a general level. The students were asked to devise an open project (e. g., how to take water samples), and to develop a plan for the project work. The students were asked to present the plan to the instructor and later to improve the plan with help from the instructor.

Figure 1. Two Examples from the Sample. The Picture in the Left Side was Rated '-2' in All Categories, whereas the Picture in the Right Side was Rated '+2' in All Categories

Overall, Figure 2 indicates that a high proportion of both Primary Science and Biology trainees seem to favour a more-or-less student–centred approach with ideas stemming from constructivistic learning and orientation towards scientific literacy objectives, whereas Chemistry and Physics student teachers seem to favour more teacher/content-structure –centred approaches.

CONCLUSIONS AND IMPLICATIONS

The present study indicates that the tool developed and inspired by the central idea of DASTT–C (as described above) and the use of GT for evaluating the totality of the data provided an interesting approach for identifying differences among different groups of student teachers' beliefs about teaching and learning science. The results present a quite different picture for each category or group of science student teachers. Science student teachers at the University of Bremen, at the beginning of their university science teacher education program, appear to hold quite different beliefs of themselves as teachers and about classroom environment, learning objectives, and learning theories. The motivation to become a science teacher can be different not only from one person to another, but also from one group of students to another. Physics student teachers appeared to be the most teacher- and content-structure–centred; Chemistry student teachers were also teacher–centred, but more open than Physics student teachers, whereas the Biology student teachers and especially the Primary Science student teachers appeared to be much more open and student–oriented. Similar results have been reported by other researchers as well (Fischler, 1999; Koballa et al., 2000; Skamp & Mueller, 2001), although their teachers did not share the same regional and educational background.

Chemistry and Physics are not very popular subjects among German pupils. Both are usually described as being theoretical and far away from students' everyday life. The teaching methods in these subjects are generally characterized more-or-less as frontal teaching (Fischer et al., 2005) and thus Chemistry and Physics student teachers come to the university programs holding beliefs that orient them to behave as their previous teachers did when teaching. This raises several questions:

Will these beliefs persist and characterise these student teachers after completing their university science teacher education programs?

To what extent will the identified beliefs affect the way these prospective teachers will teach as professional teachers?

To what extent can these pre–existing beliefs predict students' decisions to select the teaching profession either for primary or secondary school Science, and in the latter case for Physics, Chemistry, or Biology?

What are the reasons that contribute to the positive image of Biology and Primary Science and to what extent do the respective teaching approaches determine these positive beliefs?

Answers to these and other questions should be targeted by future research efforts or follow–up studies based on the same instrument (e. g. Markic & Eilks,

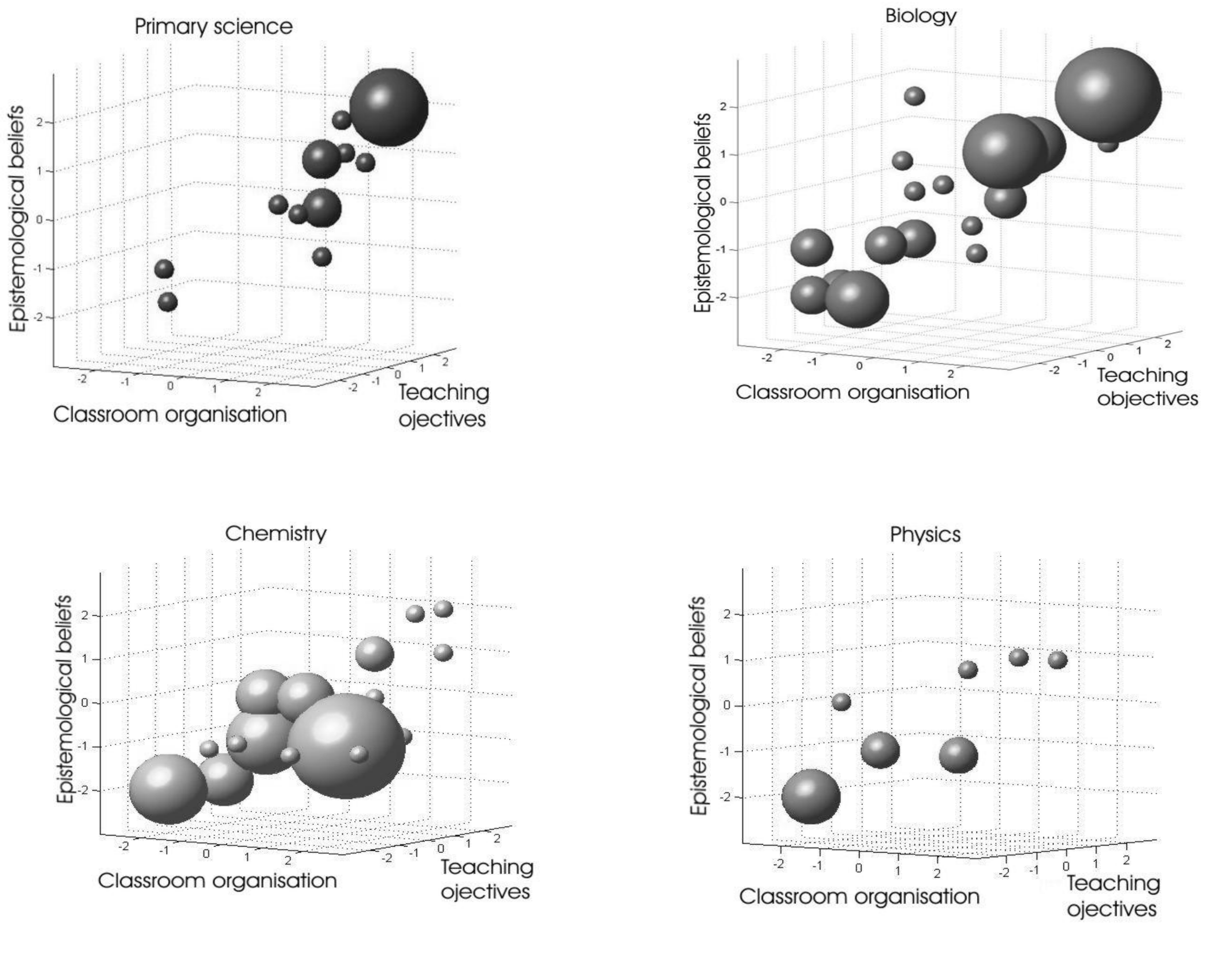


Figure 2. 3D–representation of the Data

2008) and in combination with other tools (Markic, Valanides & Eilks, 2006). It will be decidedly beneficial to identify the impact of beliefs on teaching and learning, and to find ways to change student teachers' beliefs, especially those that are very much teacher- and content-structure–focused. University science teacher education should devote continuous efforts to modify student teachers' beliefs about teaching and learning by mainly modelling constructivistic teaching approaches and by clearly indicating the importance of an orientation towards scientific literacy for all. Teacher education should also invest in student teachers' self–reflection, so that they become conscious of their beliefs concerning their future profession. Schon (1983) has illustrated that reflective practice can facilitate conceptual change and that professional reflection should be expanded beyond self–reflection by including discussion with other professionals (Gunstone & Northfield, 1986). Tools as described here may offer a possible first step in dealing with student teachers' preconceptions and beliefs is to make them explicit and to discuss them openly. The tool described here proved to be feasible in this intent. Making the students aware that they have beliefs in their heads which unconsciously influence their decisions and actions is a good starting point for self-reflection and further refining their beliefs.

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