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Pre-service Science Teachers' Development of Epistemological Beliefs

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ABSTRACT

Epistemological beliefs, which are defined as beliefs regarding knowledge construction, are thought to be closely connected to different pedagogical approaches and teaching goals. They are also important to the learning process because they function as a lens to a learner's view on content. In a cross-sectional study, we analysed the epistemological beliefs of pre-service science teachers in higher level secondary schools in Germany (n = 163). We used a closed, 26-item questionnaire that tapped the dimensions source, justification, development and certainty in the domain of science. Our findings suggest that pre-service teachers begin their professionalization with less sophisticated beliefs. Although we hypothesized that beliefs would differ across curricula, we found no differences. In addition we compared the beliefs of first, third and fifth semester students and also found no evidence of belief development as the students advanced through their semesters of professional training. Our findings suggest that pre-service teachers face a difficult start to their university education, most likely because of a predisposition to traditional teaching. Further the results may indicate that experience and knowledge alone do not strongly motivate change in the belief structure of pre-service science teachers. Our recommendation is that there should be a stronger emphasis on changing their epistemological beliefs during their academic training in an effort to improve science teaching.

BACKGROUND

Teachers are supposed to attend to the learning processes of their students (Simons, van der Lindern, & Duffy, 2000). They therefore should take into account students' knowledge construction and utilization as they help students to improve their learning strategies (Bolhuis & Voeten, 2004). In order to support this process, it is necessary to help pre-service teachers develop adequate epistemological beliefs as a factor that influences their behaviour in the classroom (Bolhuis & Voeten, 2004). Epistemological beliefs are beliefs about the nature and acquisition of knowledge (Bruning, Schraw, Norby, & Ronning, 2004).These beliefs are important to the learning process because they direct and constrain learner assumptions about content (Bromme, Pieschl, & Stahl, 2009).

There are two models for epistemological beliefs. There is a unidimensional developmental model (King & Kitchener, 2004) and a multidimensional approach (Schommer, 1990). From a developmental perspective, they are seen as a sequence of positions that differ qualitatively from each other (e.g. Kuhn, 1991). The Model of Systems of Beliefs (Schommer, 1990) however regards the various dimensions as more or less independent of each other (ibid.). Beliefs can be core or peripheral (Brownlee, Boulton-Lewis, & Purdie, 2002) or can be nested

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within each other as not necessarily discrete entities (Luft & Roehrig, 2007). Beliefs can be differentiated by different disciplines as academic domains (Muis, Bendixen, & Haerle 2006; Schommer-Aikins, Duell, & Barker 2003). Academic domains can be well- or ill-structured (Spiro, Feltovich, Jacobson, & Coulson, 1992). Well-structured domains like science or mathematics are characterized both by a limited number of principles for problem solving and a high agreement about reasonable results compared to ill-structured domains like pedagogy (Jonassen, 2000). Ill-structured domains like humanities show more different solutions, numerous criteria for evaluation of the solutions as well as undefined problems (ibid). A further definition of domains from Biglan divided domains into hard (with a paradigm, for example science) or soft (idiosyncratic for example humanities) as well as pure (pedagogic) or applied (engineering). Hofer (2000) compared college students' beliefs about psychology and science. He found significant differences: students considered science knowledge more certain and unchanging than knowledge in psychology. Buehl, Alexander and Murphy (2002) showed that students claim that more effort is needed to understand knowledge in mathematics than in history.

Summarizing different models of epistemological beliefs Hofer and Pintrich (1997) suggested dividing epistemological beliefs into two major categories. These are the "nature of knowledge" and the "nature of knowing". Conley, Pintrich, Vekiri and Harrison investigated epistemological beliefs in the context of how they develop. In following with Hofer and Pintrich, they defined four categories: source, justification, certainty and development. Source and justification reflect beliefs about the nature of knowing. Certainty and development involve the nature of knowledge. In particular, certainty of knowledge describes the perceived stability and strength of supporting evidence. Development is concerned with beliefs that regard science as an evolving subject and that ideas and theories can change on the basis of new evidence (Conley et al., 2004). Nature of knowing, however, comprises source of knowledge and justification. Source of knowledge focuses on whether knowledge resides internally or externally. Justification explains how individuals evaluate and justify knowledge (Conley et al. 2004). These four dimensions overlap with the models of Perry (1999), King and Kitchener (2004) and Schommer (1990) and, therefore, offer the possibility to compare some results.

Research in this area assumes that beliefs develop from less to more adequate (Pintrich, 2002). As such, epistemological positions range on a continuum from a dualistic view that knowledge is simple and certain, to a position that acknowledges the constructed nature of knowledge as complex, tentative and evidence-based (Brownlee, Walker, Lennox, Exley, & Pearce, 2009). Less adequate beliefs in the certainty dimension reflect a belief in one correct answer. In contrast, the more adequate view proposes that there may be more than one answer to a scientific problem. Students with more adequate beliefs in the development dimension endorse statements about ideas in science continuing to change or discoveries in science leading scientists to change their thinking on what is true. The less adequate beliefs position in the source dimension views knowledge as simple, certain and transmissible by authorities. In the justification dimension, a less adequate belief considers, for example, that a theory can be validated by a single experiment and the reliability of a theoretical fact can be assured by an authority figure such as a parent or teacher. Well developed beliefs in the dimensions certainty, development and source are further positively related to achievement, motivation and domain-specific self- concepts (Urhahne & Hopf, 2004). All four dimensions have been successfully replicated in studies in school and in university contexts (ibid.).

In contrast to the model of a stage-like development, Hammer and Elby (2002) suggested that epistemological beliefs are made up of a range of epistemological resources. Individuals can hold both adequate and not adequate beliefs simultaneously. Which belief is activated depends on the context (i.e. domain or situation). Schommer-Aikens and Duell (2013) proposed that the development of beliefs is influenced by the amount of knowledge or expertise. A context likely to provide change and allow for the development of epistemological beliefs could be science classrooms. For example, evidence suggests that involving students in the design, data collection and analysis of experiments may promote epistemological thinking (Mason & Boscolo, 2004; Solomon, Duven, & Scott, 1996). Engaging in these methods used in science might help students at school and at university to understand that scientific findings come from investigations rather than from authorities and are therefore subject to change (Conley et al., 2004). At the same time, epistemological beliefs are not only influenced by the learning context, but are also closely connected to various pedagogical approaches and to the different teaching goals of (pre-service) teachers (Kang &Wallace, 2005). For example, if pre-service teachers think that "knowledge is simple", they will tend to conceive of learning as the repetition and rehearsal of isolated pieces of information (Brownlee et al., 2009). Whereas if pre-service teachers think knowledge is uncertain and evolving, then it is more likely that they will carefully assess what they read and learn for meaning, which will then influence how they solve problems (Phillips, 2001). In general, before pre-service teachers enter university; their epistemological beliefs are influenced in school by experience with (mostly) traditional teaching and instruction, in which teachers provide explanations or solutions to problems instead of guiding students to solutions and understanding on their own terms.

Pre-service teachers are also influenced by their personal background and their experience with formal knowledge (Richardson, 1996). Consequently, the epistemological beliefs of pre-service teachers will vary significantly and may be very different from the demands of university (Brownlee et al, 2009). Further, pre-service teachers' beliefs, especially those which are formed and structured early, can affect how and what they learn during their teacher training. This, in turn, influences how and what knowledge can be gained. In a naive conception, the learner believes that she/he is acquiring knowledge from an external source without active knowledge construction. Knowledge can therefore be acquired without transformation (Brownlee et al., 2009). In a more adequate belief, learning is an active, constructive and self-directed process. The learner builds knowledge that is formed by personal interpretations or learning experiences (Vermunt, 1998).

In the exploration of teachers' beliefs', there has been a great deal of work on beliefs experienced and held by pre-service teachers, although these studies have lacked the connection to the possible influence of school experience on teacher beliefs. There have also only been a very few studies focussing on the development of the four dimensions of knowledge, namely source, justification, development and certainty. As such, the purpose of our study was firstly to examine the kinds of beliefs pre-service teachers of science held at the start of their university career in these four dimensions. Several studies have suggested that pre-service teachers may not hold very sophisticated beliefs (Olafson & Schraw, 2010; Walker, Brownlee, Whiteford, Exely, & Woods, 2012; White, 2000). Our assumption was that pre-service teachers we examined would also hold inadequate beliefs (hypothesis 1 (h1)). To better understand this phenomenon, we wanted to investigate whether different kinds of curricula had an impact on the epistemic beliefs of pre-service teachers (hypothesis 2 (h2)) and if time at university might also have an impact (hypothesis 3 (h3)).

Students in upper level secondary schools in Germany are required to participate in two advanced courses in a given subject, such as science, language, history, sports or music/arts. All advanced courses meet four to six times a week over a time period of two years. The courses require a higher performance level and the students have to apply higher-order thinking skills. The assessments demand deeper learning strategies than the other courses. The curricula of the advanced courses in science deepen understanding of the application of science to everyday life, cover ethical questions and also involve activities such as designing experiments and analysing data to a greater degree than do regular science courses. Students who have attended an advanced course in a scientific subject (chemistry, physics or biology) have deeper knowledge and more experience with the contents and methods in science than students without this background. We assumed that this deeper knowledge and greater experience would lead to more sophisticated epistemological beliefs (Schommer-Aikens & Duell, 2013). A change toward more sophistication would be evidenced by weaker beliefs in external authority in the source of knowledge dimension and weaker beliefs in the certainty dimension, resulting from discussions on the different ways that scientific results can be interpreted (Conley et al., 2004). These results were expected to be accompanied by stronger beliefs in the developing nature of science, because students in an advanced science course are guided in comparing different theories, i.e. evolution and should therefore be better able to assess scientific results (Mason & Boscolo, 2004; Solomon, Duven, & Scott, 1996). It was expected that their greater abilities would also be accompanied by stronger beliefs in the justification dimension because of their more extensive experience with the role of evidence and the nature of experimentation (Schraw, Bendixen & Dunkle, 2002). Accordingly, we also assumed that having more academic knowledge and experience with science and science teaching resulting from studying science at university would also relate to more advanced epistemological beliefs. In short, the more experience and knowledge about science and the way scientists work the students had, the more they developed their more adequate beliefs (Conley et al., 2004). In third to fifth semester students, a change toward more adequate beliefs would also be evidenced by weaker beliefs in source of knowledge and certainty of knowledge as compared to students in their first semester. It would also be accompanied by stronger beliefs in development and justification (Schommer-Aikens & Duell, 2013).

METHODOLOGY

Participants and Procedure

We used a cross-sectional design to study the belief structure in pre-service science teachers (*n* = 163) from 3 universities in Germany. Their average age was 23 years (*sd* = 3.90). The majority (72 %) of the respondents were female. 45 % were in the first, 13% in the third and 42 % in their fifth semester. The majority of the participants (71%) had chosen an advanced science course in biology, chemistry or physics in higher secondary school. All students were in the first phase of their teacher education which is mostly theoretically.

Instrument and data collection

We used a closed, 25-item questionnaire that tapped four dimensions of beliefs in the domain of science (Conley et al., 2004) (Table 1). The instrument had already been validated and used in previous research and as such, provided us with a basis for comparison. The four dimensions covered the nature of knowing as well as the nature of knowledge and provided a deeper insight in epistemological beliefs. Items were rated on a 5-point-Likert scale (1= strongly disagree; 5 = strongly agree). We used items previously translated into German, adapted and validated by Urhahne and Hopf (2004) that focussed on the domain of science (see the Appendix with the original and translated items). For comparison, the dimensions source and certainty were coded inversely, such that for each of the scales, higher scores reflected more sophisticated beliefs. The participants completed the questionnaires in class. Each group was introduced to the aims of the research and the process of the study was explained. Participation in the study was voluntary and all participants were assured that the information they provided would be confidential. The students were also advised that they could withdraw at any time and that no personal or emotionally disturbing questions would be asked.

Each research group (university of Bielefeld, university of Braunschweig and Freie Universität Berlin) followed a procedure in line with the recommendations of the committee for ethical questions in research at their particular university. In all three universities, it was not necessary to receive written consent from the participants. Instead, approval from each head of department sufficed, justified by the minimal effort for the students, anonymity and voluntary participation.

Dimension	Items	Cronbachs α	Item-Example
Source	5	.70	Everybody has to believe what scientists say (inverse).
Justification	9	.58	A good way to know if something is true is to do an experiment.
Development	5	.80	Ideas in science sometimes change.
Certainty	6	.81	All questions in science have one correct answer (inverse).

Table 1: Questionnaire used for measuring epistemological beliefs

The SPSS 21 statistical package was used for analysis. A factor analysis was conducted to determine the relevant dimensions. The four factors accounted for 58 % of the variance. We calculated the means and standard deviation of the four dimensions (hypothesis 1). We used a one-way ANOVA to explore differences between the epistemological beliefs of students with different knowledge and experiences resulting from different science curricula (hypothesis 2) and from the length of their attendance at university (hypothesis 3).

FINDINGS

Our study concerned the epistemological beliefs held by pre-service teachers. We examined how differentiated the epistemological beliefs of the pre-service teachers were (hypothesis 1). We also looked at whether the subjects teachers studied at upper-level secondary school framed their beliefs about science when they began university training (hypothesis 2). Further we examined how their beliefs developed over time at university (hypothesis 3). The results of the study revealed that pre-service teachers had less than adequate epistemological beliefs. Their means were high for source and certainty (Table 2). As such, they tended to agree that only experts could give a correct answer and that there was only one correct solution. The low means for justification and development indicate that they did not believe experiments were very important and that theories did not (often) change. These results supported hypothesis 1.

To examine possible influences, we compared the beliefs of those who had chosen an advanced science course at higher secondary school with those who had not. The comparison of the two groups in the first semester revealed no significant differences, providing no support for our first hypothesis. The ANOVA for the whole group also revealed no interaction between advanced science course and semester (source: F (1; 158) = .263; p= .557; justification: F (1; 158) = .003; p=.674; development: F (1; 158) = .008; p= .889; certainty: F (1; 158) = 1.46; p= .541). Thus hypothesis 2 was not supported. It seems to have made no difference to the epistemological beliefs of the pre-service teachers whether they had taken part in a course that deepened their understanding of the application of science to everyday life, covered ethics questions or where the meaning of scientific experiments was discussed. They still saw the source of knowledge as located with external authorities and not in themselves. Knowledge was still for them something stable that could not be developed by researchers at different times, cultures or with different aims. Knowledge, as they saw it, was a sure thing independent of the author and not influenced by experience, knowledge or context.

	Means (*SD*) of the whole group	Means (*SD*) with Advanced Science Course	Means (*SD*) without Advanced Science Course	ANOVA
Source	4.18 (.88)	4.14 (.89)	4.25 (.85)	$F(2;70) = .725$ $p= 0.219$
Justification	1.61 (.47)	1.63 (.49)	1.54 (.43)	$F(2;70) = 2.093$ $p= 0.127$
Development	1.58 (50)	1.60 (.52)	1.51 (.47)	$F(2;70) = .275$ $p= 0.760$
Certainty	4.26 (.68)	4.29 (.55)	4.12 (.94)	$F(2; 70) = .725$ $p= 0.552$

Table 2: Influence of taking part in an advanced science course at school on the Epistemological beliefs held by pre-service teachers during their 1st semester

In order to examine if studying science at university influenced epistemic beliefs (hypothesis 3), we compared students across their first, third and fifth semester. The ANOVA showed no significant differences in any dimension (table 3). Students in their fifth semester showed similar beliefs to those in their first semester, thus hypothesis 3 was not supported.

Dimensions	*M (SD)* 1$^{st\circ}$ semester	*M (SD)* 3rd semester	*M (SD)* 5th semester	ANOVA
Source	4.29 (.73)	4.41 (.70)	4.38 (.55)	$F(2, 163) = 0.57$ $p = 0.760$
Justification	1.56 (.46)	1.71 (.35)	1.47 (.47)	$F(2, 163) = 2.59$ $p = 0.083$
Development	1.58 (.52)	1.61 (.38)	1.58 (.57)	$F(2, 163) = 1.04$ $p= 0.219$
Certainty	4.34 (.62)	4.36 (.47)	4.43 (.58)	$F (2, 163) = 2.82$ $p =0.123$

Table 3: Differences of epistemological beliefs of pre-service teachers at 1st, 3rd and 5th semester

DISCUSSION

The aim of our study was to examine the epistemological beliefs of pre-service teachers that are closely connected to pedagogical approaches and teaching goals. They are also important to the learning process of the pre-service teachers because of their function as a lens to a learner's view on content. If our goal is to develop programmes that have a lasting impact on teachers, it is crucial to understand their epistemological beliefs (Luft & Roehrig, 2007).

Our first hypothesis addressed the beliefs held by pre-service science teachers when starting university. We found that they tended toward less adequate rather than adequate beliefs. They were more likely to agree that knowledge resided with external authorities and to assign a less important role to experiments. Further they believed that knowledge would not change much and that there was one correct answer to a scientific problem. We further hypothesized that students with greater knowledge in science, acquired in school (h1) or in university (h2), would have more sophisticated beliefs compared to students without this background. Our analysis found no differences between students who had participated in advanced science courses versus those who had not. Also in comparing the epistemological beliefs students held in the first or fifth semester, we did not find any differences in the four dimensions measured (h3).

A possible reason for the less adequate epistemological beliefs held by pre-service teachers at the beginning of their training might be that their own teachers also held these beliefs. It was surprising to find that greater experience in scientific methods and thinking seemed to bear no consequence on their beliefs. It is not clear whether this might have been also due to the influence of traditionally orientated teachers or if the experiences gained in the advanced science courses were not strong enough to have an influence.

The initial learning approach students used in their past classes seems to have a strong impact on how they approached learning in their present courses (Gijbels, Segers, & Struyf, 2008). Students with successful experiences with assessments focusing on surface approaches earlier in their education might not be able to adapt to deeper learning strategies (Gijbels et al., 2008). In addition, our results appear to indicate that the assessment did not strongly motivate the evolution of belief structure, nor did experience and knowledge have an effect on beliefs. The beliefs held seemed to work as a "reference frame" (Helmke, 2003) through which the pre-service teachers filtered all input that did not match their beliefs. Further, it may be the case that beliefs are not challenged enough to provoke a conceptual change. That said, it is almost impossible to 'change a teacher'; they can only change themselves on the basis of the needs and interests they experience (Huibregtse, Korthagen, & Wubbels, 1994), with their beliefs becoming more stable the longer they are part of the pre-service teachers belief system (Pajares, 1992). Teacher education at university seems to also not support a trend toward more adequate beliefs. Past experiences pre-service teachers may have had before university seem to have a greater impact on their belief system than the knowledge gained and experienced at university (Kagan, 1992, Gustafson & Rowell, 1995). Our research is in line with the observation that beliefs can be stable and therefore difficult to change (Richardson, 1996). For experienced teachers, Richardson concluded that professional development opportunities, such as real class teaching, were likely to impact beliefs. Other aspects that may have had an impact on beliefs are emphasizing teaching strategies and their underlying rationales (Holt-Reynolds, 1994). It may have also been helpful to support teachers in becoming aware of their own epistemological beliefs (Kang, 2008). It appears, however, that pre-service teachers' experience in teaching was too short to have any lasting impact (Richardson, 1996). As such, if teacher training at the university level could also offer opportunities for more teaching experience, the development of an adequate belief structure might be more successful.

Our results could also lead to the conclusion that second and third year students have limited research experience. While studying science, students might receive a great deal of input about methods and facts, but they may not necessarily be taught how to question results or authorities. Rather, they may in fact not be encouraged enough to discuss scientific issues. An alternative reason might be that the standardized secondary-school examinations in Germany may lead to "teaching to the test." Teachers in Germany often feel great pressure to prepare their students for final exams and this might result in less time to carry out experiments or discuss scientific findings. Also the examinations themselves, which demand a specific correct answer to a certain question, do not necessarily stimulate critical thinking, in particular with reference to the possibility that a question might have more than one solution. Marton and Säljö (1976) found that students adjusted their learning approaches depending on the requirements of the task. Therefore, it may also be necessary for teachers to deliberately realign their goals between the planned learning activities and the learning outcomes. This constructive alignment (Biggs, 2003) provides the students with the goal of deeper epistemological inquiry, thus underscoring the values of critical thinking. Further, this alignment has been shown to be an important factor for deep learning approaches (Gijbels et al, 2008).

There were also noteworthy limitations to our study. The number of participants in the third semester was only 13% and the majority had chosen an advanced science course in school. This may have minimised the potential variation within the sample. Further, we were not able to control the setting of the intervention in two universities and thus there may have been setting-specific confound that had an influence on our results. A third factor may have been a "sleeper effect" (Gijbels et al, 2008). The pre-service teachers probably needed more time to develop their beliefs than they could have by their fifth semester. So an effect might be visible after a longer time-period than two and a half years. Additionally, we conducted a cross-sectional- instead of a longitudinal study and therefore did not address individual development.

In our study we avoided the term "appropriate" epistemological beliefs (e.g. Schommer, 1990), but instead used the term "adequate" epistemological belief. The term "appropriate" connotes true, proper and correct epistemological beliefs, whereas "adequate" acknowledges the dependency epistemological beliefs have on context, as well as on their nature as social constructs (Hofer & Pintrich, 1997). With the term "adequate" we are in line with the current discussion on epistemological beliefs (e.g. Hofer, 2004; Luft & Roehrig, 2007, Pintrich, 2002; Schommer, 1990) and refer to a similar framework of reference. What is adequate depends on the context and is also socially constructed (Hofer & Pintrich, 1997). For example, beginning teachers tend to incorporate more transmissive beliefs when starting to teach in a classroom than they did while at university (Buelens, Clements and Clarebout, 2002). It is possible that they are motivated by their need to acclimatise to the new challenging classroom situation; beginning teachers tend to have less fully developed abstract knowledge structures to summarize information about many particular aspects of teaching and the relationships among them (Anderson, 1984). In addition, the transition to learning to teach can be painful and produce cognitive overload (Evans, 2014). A further impact can be the disparity between individual beliefs and those of the school (ibid.). Further, critical factors that foster transmissive epistemological beliefs are time pressure, curricula standards or group structure (Clark & Peterson, 1986). In this context, more transmissive beliefs could be more adequate for the teachers although not for the students. However, the context dependency can also be seen as domain-specific. For example, in the domain of classical mechanics, as with lever rules, it is adequate not to discuss the certainty of knowledge. On the other hand, in ethical questions in science, such as genetic engineering, it is adequate to discuss the role of experts and the certainty of knowledge in order to be able to take responsibility for decisions.

In order to make a developmental change, pre-service teachers must be dissatisfied with their existing beliefs and find alternatives intelligible and useful (Hofer and Pintrich, 1997). The dissatisfaction, however, should be at the intermediate level. It must focus on the teaching environment where the original beliefs emerged so as to create sufficient friction that can stimulate the pre-service teacher to challenge his/her existing beliefs and develop more adequate beliefs (i.e. constructive friction; Vermunt & Verloop, 1999). To succeed and to help students develop sophisticated beliefs, it may be necessary to re-conceptualize teacher professionalism at the university level (Brownlee et al., 2009) by focusing on pedagogies that promote the active treatment of complex issues and explicit reflection on epistemological beliefs (Schraw & Sinatra, 2004). Therefore, it may be useful to help teachers make their beliefs more explicit by providing them with opportunities to engage in inquiry and discussion on epistemological issues (Windschitl & Thompson, 2006). Opportunities such as these might include developing a feedback-culture. Feedback is a factor crucial to training students to be independent learners, who can monitor, evaluate and regulate their own learning (Evans, 2013). It helps students to develop an understanding of the nature of learning and of the roles played by students and lecturers (Evans, 2013; Tsai & Liang, 2007). By providing feedback, students can see themselves as active agents, working to acquire and compare knowledge. As such, feedback can foster the development of adequate epistemological beliefs (Evans, 2013). Explicit reflection is also related to metacognitive awareness of epistemological beliefs (Hofer, 2004). A well-designed assessment, as discussed above, provides the necessary criteria to give feedback to the learner. However, to be constructive, university teachers must be aware of the students' and their own epistemological beliefs. Further, teachers have to be conscious of the impact their beliefs have on pre-service teachers. Third, university teachers should make the method of feedback explicit in order to enable pre-service teachers to give feedback to other teachers and students themselves. Fourth, they should also be aware of possible preconceptions their future students might hold. Lastly, it may be helpful if teacher education could integrate academic and practical knowledge along with the teachers' conceptions of teaching and learning in order to support pre-service teachers in generating their own adequate knowledge and conceptions.

Our pedagogical implications can be summarized as follows: Pre-service epistemological beliefs should be evaluated and challenged by explicit teaching in the first phase as an essential element of teacher education. In addition it might be helpful to encourage students to compare and discuss their beliefs in order to become aware of the diversity and the appropriateness of teaching strategies and how their choices are influenced by their underlying beliefs. This could be supported by reconceptualizing teacher education towards more awareness of epistemological beliefs.

To conclude, the findings of our study suggest that pre-service teachers face a difficult start to their university education, most likely because of a predisposition to traditional teaching and may therefore face difficulties when teaching science. Teachers are now supposed to attend to the learning processes of their students and to listen and respond to the substance of students' thinking (Levin, Hammer, & Coffey, 2009). But they can only function in this capacity when they are aware of their students' knowledge construction and utilization. To this end, they must develop a belief system that directs and constrains learners' assumptions about content (Bromme et al., 2010). It is possible that pre-service teachers with less adequate beliefs may fail to reach these science education goals. Further, their epistemological beliefs influence what they extract from their pre-service training. Pre-service teachers may, as a result, not recognize opportunities at university to reflect on their beliefs before they start teaching a class. Monitoring and developing programmes, such as mentorships and feedback, may help pre-service teachers to develop more adequate epistemological beliefs during their academic training.

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APPENDIX A

Items from Conley, Pintrich, Vekiri, & Harrison (2004) and Urhahne & Hopf (2004):

Source

1. Everybody has to believe what scientists say.
2. In science, you have to believe what the science books say about stuff.
3. Whatever the teacher says in science class is true.
4. If you read something in a science book, you can be sure it is true.
5. Only scientists know for sure what is true in science.

Certainty

1. All questions in science have one right answer.
2. The most important part of doing science is coming up with the right answer.
3. Scientists pretty much know everything about science; there is not much more to know.
4. Scientific knowledge is always true.
5. Once scientists have a result from an experiment that is the only answer.
6. Scientists always agree about what is true in science.

Development

1. Some ideas in science today are different than what scientists used to think.
2. The ideas in science books sometimes change.
3. There are some questions that even scientists cannot answer.
4. Ideas in science sometimes change.
5. New discoveries can change what scientists think is true.
6. Sometimes scientists change their minds about what is true in science.

Justification

1. Ideas about science experiments come from being curious and thinking about how things work.
2. In science, there can be more than one way for scientists to test their ideas.
3. One important part of science is doing experiments to come up with new ideas about how things work.
4. It is good to try experiments more than once to make sure of your findings.
5. Good ideas in science can come from anybody, not just from scientists.
6. A good way to know if something is true is to do an experiment.
7. Good answers are based on evidence from many different experiments.
8. Ideas in science can come from your own questions and experiments.
9. It is good to have an idea before you start an experiment.

Items from Urhahne & Hopf, 2004

Quelle des Wissens

1. Was in Naturwissenschaftsbüchern steht, muss man glauben.
2. Nur Naturwissenschaftler wissen genau, was in ihrem Fach wahr ist.
3. Was Naturwissenschaftler herausfinden, muss man glauben.
4. Was der Lehrer im Naturwissenschaftsunterricht sagt, ist wahr.
5. Was man in einem Naturwissenschaftsbuch liest, ist sicher wahr.

Sicherheit des Wissens

1. Es gibt nur die eine Lösung, wenn Naturwissenschaftler einmal das Ergebnis eines Experiments gefunden haben.
2. Alle Fragen in den Naturwissenschaften haben genau eine Lösung.
3. In den Naturwissenschaften ist beinahe alles bekannt; es gibt nicht mehr viel, was man herausfinden könnte.
4. Das Wissen in den Naturwissenschaften ist für alle Zeit wahr.
5. Naturwissenschaftler stimmen immer darin überein, was in ihrem Fach wahr ist.
6. Der wichtigste Teil der Naturwissenschaften ist die Suche nach den einzig richtigen Lösungen

Entwicklung des Wissens

1. Durch neue Entdeckungen kann sich verändern, was Naturwissenschaftler für wahr halten.
2. Die Vorstellungen in Naturwissenschaftsbüchern verändern sich manchmal.
3. Einige Vorstellungen in den Naturwissenschaften sind heute anders als das, was Naturwissenschaftler früher dachten.
4. Manchmal ändern Naturwissenschaftler ihre Meinung darüber, was in ihrem Fach wahr ist. Manchmal verändern sich die Vorstellungen in den Naturwissenschaften.
5. Es gibt manche Fragen in den Naturwissenschaften, die auch Naturwissenschaftler nicht beantworten können

Rechtfertigung des Wissens

1. In den Naturwissenschaften können sich neue Vorstellungen aus den eigenen Fragen und Experimenten entwickeln.
2. Ein wichtiger Teil der Naturwissenschaften ist es, Experimente durchzuführen, um neue Ideen zu finden.
3. In den Naturwissenschaften kann es mehrere Wege geben, um Vorstellungen zu überprüfen.
4. Die Ideen zu naturwissenschaftlichen Experimenten kommen daher, dass man neugierig ist und darüber nachdenkt, wie etwas funktioniert.
5. Es ist wichtig, eine konkrete Vorstellung zu haben, bevor man mit einem Experiment beginnt.
6. Ein Experiment ist ein guter Weg um herauszufinden, ob etwas wahr ist.

7. Es ist wichtig, Experimente mehr als einmal durchzuführen, um Ergebnisse abzusichern.
8. Gute Theorien stützen sich auf die Ergebnisse aus vielen verschiedenen Experimenten.
9. Gute Ideen in den Naturwissenschaften können von jedem kommen, nicht nur von Naturwissenschaftlern

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