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An understanding of sustainability and education for sustainable development among German student teachers and trainee teachers of chemistry

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ABSTRACT: Sustainable development is a central concern of today's politics across the world. Different political agendas have been developed to promote sustainability and make it a political goal worldwide. As stated in Agenda 21, the political debate seems to agree that education has to play a key role in achieving sustainability. But practices focusing on Education for Sustainable Development (ESD) are rarely implemented in many educational domains, including chemistry teaching. A more thorough focus on ESD in chemistry teaching demands, among other things, a positive teacher attitude towards ESD, specific subject matter knowledge, and knowledge of suitable pedagogies. Such knowledge concerning ESD in these three areas is generally rare in the literature, particularly in the German context. This is why the current paper elaborates German student teachers' and trainee teachers understanding of sustainability and ESD, including their viewpoints on chemistry education. In this study, 87 student teachers and 97 trainee teachers answered a set of closed, Likert-type and open survey-questions that were analyzed both, qualitatively and quantitatively. The results of the study indicate that these groups show principally positive attitudes towards ESD in chemistry education. However, their knowledge is only vaguely informed in the theoretical sense. Few participants in this study possessed any clear, theory-supported concepts when it came to either sustainability, or ESD.

KEY WORDS: Chemistry Teacher Education, Education for Sustainable Development, Teacher knowledge, PCK, Teacher attitudes

INTRODUCTION

Sustainable development was defined by the Brundtland Commission as a development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN, 1987). With the arrival of Agenda 21 (UNCED, 1992) sustainable development became a regulatory idea in international policy (Rauch, 2010). Within its policy, Agenda 21 delegated part of the action necessary for sustainable development to education: "Education is critical for promoting sustainable development and improving the capacity of the people to address envi-

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ronment and development issues" (UNCED, 1992, Chapter 36.3). The term Education for Sustainable Development (ESD) was thus created. It became a political goal worldwide for education in general (UNESCO, 2005a) and in science and chemistry education in particular (Burmeister, Rauch & Eilks, 2012), thereby acknowledging the importance of education in the process of sustainable development.

Implementation of the UN Decade for Education for Sustainable Development (DESD) (UNESCO, 2005b) belongs to the direct political application of the concept of ESD. DESD spans the years from 2005 to 2014 and has the goal of thoroughly and internationally implementing ESD in schools and all other educational domains. All educational levels and domains are tasked with contributing to ESD, including science education. A particular focus is placed upon secondary school chemistry education. A recent review of the possible role chemistry education can play in ESD was presented by Burmeister et al. (2012). This paper justified the special emphasis chemistry education must make in implementing ESD due to the unique importance of chemistry in both the economy and the development of every society. The chemical industry provides most of the raw materials necessary for every other type of business or endeavor. Chemistry is the basis of a modern energy supply, agriculture, innovative materials, communication, biotechnology and pharmaceuticals (Bradley, 2005). Applying chemistry knowledge to industry and technology is also related to both the ecology and the social development of all societies at the local and regional levels. Unfortunately, chemistry-related technologies in the past were not always compatible with the ideas of sustainable development. Industrial chemistry often contributed to the pollution of the environment, caused environmental accidents and employed industrial production methods which were not always efficient when judged by modern social standards. However, in recent years, various production changes have made effective progress - at least in Western societies. Chemistry companies today seek cleaner production pathways, which decrease the overall amount of necessary raw materials and are in harmony with the social aims of the society in which they operate (ECCC, 1993). Part of this shift is embodied in the concept of Green or Sustainable Chemistry (Centi & Perathoner, 2009). Nevertheless, sustainable chemistry is still not implemented all over the world. In many countries, chemistry-related production is still far from being ecologically, economically, or socially sustainable. Even in Western societies, where sustainable chemistry efforts are quite strong, the positive aspects of recent chemistry developments are often repressed by the mass media in favor of poorly-informed, often biased, coverage (Hartings & Fahy, 2011). This reality dictates a new goal for chemistry education: chemistry education must contribute to developing a balanced and well-reflected system of understanding in our students as future citizens with regard to chemistry and chemistry-related businesses (Ware, 2001). It should promote knowledge and skills, which allow our students to participate in society debates and decision-making processes in an informed manner in cases where science- and technology-related issues are being decided. This places chemistry in a prominent position for teaching learners about sustainability issues and thereby contributing to ESD (Burmeister et al., 2012).

From the above discussion, it is clearly recognizable that chemistry education needs to contribute strongly to ESD under the inclusion of the societal dimensions of scientific literacy (Burmeister et al., 2012). Unfortunately, such a focus has not been the case in many past science curricula (Hofstein, Eilks & Bybee, 2011). Reform in chemistry education is desperately needed (Ware, 2001). This might start with innovations in teacher training, if it finally becomes widely recognized that past research reveals the most important shareholders in the effective innovation of changes in teaching practices are the teachers themselves (Anderson & Helms, 2001). Taking teachers, their beliefs, prior knowledge and attitudes into account is a necessary precondition for any success in educational reform (Haney, Czerniak & Lumpe, 1996).

Unfortunately, knowledge about secondary school teachers' knowledge and attitudes towards ESD in chemistry education is rare. In the case of German chemistry education it is even harder to find. This study is an attempt to reduce this lack of information. It intends to explore subject matter knowledge, pedagogical content knowledge and attitudes towards ESD, in particular their attitudes towards ESD in chemistry education of chemistry student teachers and chemistry teachers in the compulsory post-university teacher training program (teacher trainees').

THEORETICAL FRAMEWORK

The central focus of ESD is to prepare our younger generation to become responsible citizens of the future (UNCED, 1992). Students should be able to participate in a democratic society and help shape it in a sustainable fashion (de Haan, 2006). This focus is similar to the German philosophy of Allgemeinbildung ('general education') when applied to science education (Burmeister et al., 2012; Elmose & Roth, 2005; Hofstein et al., 2011; Sjöström, 2011). It also parallels Activity Theory when used to justify general educational skills for societal participation, which has become one of the central goals of science education (van Aalsvoort, 2004; Holbrook & Rannikmae, 2007). Students should learn how to take responsibility for both themselves and their society for today and in the future, based on the concept of sustainable development (de Haan, 2006; Mogensen & Schnack, 2010).

All educational domains and, thereby, all school subjects need to contribute to ESD, including secondary school chemistry education (Burmeister et al., 2012). Orienting chemistry education towards ESD requires a shift in both the content and contextual approaches in chemistry teaching, as well as in the pedagogies (Burmeister et al., 2012). ESD education does not only mean using new topics from the sustainability debate or the relatedness of chemical industry and the environment as the content of or context for chemistry teaching. ESD requires a comprehensive approach in taking up socially relevant issues and dealing with them in a multi-dimensional fashion (McKeown, 2006). This multi-dimensionality should include understanding the background of a given issue, which can stem from chemistry. But, chemistry education based on ESD principles must also focus on general educational skills for societal participation. It should deal with the impacts of developments related to chemistry and technology on the ecology, the economy, and the society at the local, regional and global level and develop skills in students to actively handle these aspects in the future (Burmeister et al., 2012; De Haan, 2006; Wheeler, 2000).

There are a wide range of models on how to implement ESD into general teaching (Paden, 2000) and chemistry education (Burmeister et al., 2012). All ESD focused models suggest the orientation of education around societal issues (either at the local, regional, or global level), use of an interdisciplinary approach, and changes in pedagogy which far exceed the simple rearranging or altering of curricula (Paden, 2000). ESD teaching brings together the different perspectives of socially relevant questions, combines chemistry with biology and physics, and incorporates all three with perspectives borrowed from economics, the social sciences and the humanities (e.g. ethics). ESD approaches demand implementation of a skills-oriented teaching paradigm in order to promote education for sustainable development which goes beyond education about sustainable development (McKeown, 2006).

From this discussion it becomes clear that teachers need specific knowledge to contend with ESD in general and chemistry lessons in particular. A teacher needs specific subject matter knowledge in those chemistry related issues which can form a core to start ESD teaching in the chemistry classroom. But this is not enough. The teacher will also need knowledge dealing with sustainability, sustainable development and their overall meaning. Knowledge is needed about the basic definitions, concepts and models used in the sustainability debate. Of the many different definitions and models developed for understanding sustainability and sustainable development, two ideas seem to form the core (Burmeister et al., 2012). The first is that of checking for sustainability in every process or development. Sustainability should be considered through a balanced view, combining ecological, economic and societal implications. The second important idea stems from the definition of sustainable development from the Brundtlandt Report, which brings the idea of intergenerational justice into focus (UN, 1987).

As early as the year 1987, Shulman emphasized that it is not only subject matter knowledge (SMK) that makes a teacher skilled in successful teaching, but also the level of investment in the teacher's pedagogical content knowledge (PCK) (Gess-Newsome & Lederman, 1999). Because the topics and objectives of ESD-driven chemistry teaching differ from traditional practices (Eilks, Rauch, Ralle & Hofstein, 2013), PCK development will also be necessary. According to Magnusson, Krajcik and Borko (1999), such PCK for science teaching consists of five components:

- Orientation toward science teaching,
- Knowledge and beliefs about the science curriculum,
- Knowledge and beliefs about students' understanding of specific science topics,
- Knowledge and beliefs about assessment in science, and
- Knowledge and beliefs about instructional strategies for teaching science.

Shulman (1987) and Bucat (2004) have explained the domain-specificity of PCK. Teachers who are expected to successfully apply ESD in chemistry education, specifically need to know about the potential orientations of chemistry teaching that fit ESD objectives. They require adequate ideas for connecting ESD with chemistry curricula, taking students' prior knowledge about sustainability into account, and using a suitable repertoire of pedagogies for operating ESD-based teaching in chemistry classrooms as recently described, e.g., by Burmeister and Eilks (2012). For this study, four indicators for PCK were chosen for examination: knowledge about the students' prior knowledge, ideas about the curriculum, ideas about domain-specific instructional strategies, and knowledge about justifications for a certain topic to be taught in science classes.

Liarakou, Gavrilakis and Flouri (2009) and also Summers, Kruger and Childs (2001) emphasize the importance of teachers' SMK for effectively focusing on environmental and ESD-based education. Summers, Corney and Childs (2003) researched teachers' pedagogical knowledge and PCK. But research has also shown how important the beliefs and attitudes of pre- and in-service teachers are when it comes to reforms in education (Tobin, Tippins & Gallard, 1994; Pajares, 1993). Beliefs and attitudes can act as filters through which new knowledge and experiences are screened for meaning. They also affect how knowledge and intentions are operationalized in class (Nespor, 1987; Pajares, 1992). Tuncer et al. (2009) argue that teachers will only produce students who are environmentally literate, if they themselves are knowledgeable and have positive attitudes towards the environment.

Therefore, a claim can be made that investment in science teacher education is necessary with regard to teachers' knowledge, attitudes and beliefs, if the goal is to carry out effective reform of ESD in science with chemistry education as a focus. However, research reveals that both effective teacher learning and reform can only take place when both take teachers' a priori knowledge, their attitudes and their beliefs into account (Haney et al., 1996). Trigwell, Prosser & Taylor (1994) state that any educational innovation is doomed to failure if it does not take teacher beliefs and attitudes into account. Therefore, addressing teacher beliefs is a necessary first step, if any attempt to change teaching practices is being planned (Van Driel, Bulte & Verloop, 2007). Unfortunately, the knowledge base of both pre- and in-service teachers' SMK is extremely limited in the context of the sustainability of chemistry-related issues, including teachers' PCK concerning an ESD environment. Very few studies are currently available.

Research analyzing the SMK of science teacher trainees concerning sustainable development has been most notably found in the UK in the fields of geography and primary education. Summers, Kruger, Childs & Mant (2000) began their research based on the understanding of 12 primary teachers regarding environmental issues. They found "that this group of primary teachers had substantial understanding of some aspects of the science underpinning the four environmental topics investigated. However, other key ideas that underpin these topics were muchless understood by the teachers, or they were absent" (p. 307). Another study by Summers et al. (2001) was based on a questionnaire filled out by 170 practicing primary school teachers, 120 primary trainees and 88 secondary science trainees and underpinned the above-mentioned findings. In 2004, Summers, Corney and Childs started examining student teachers in the subjects of science and geography. They examined educators' perceptions regarding sustainable development, following up this study in 2007 using a larger sample of teacher trainees (Summers & Childs, 2007) with similar results. They found that "substantial numbers recognized the centrality of environmental (72%), economic (53%) and social (31%) factors—but just 15% highlighted all three" (Summers & Childs, 2007, p. 307). Two studies, examining in-service teachers in 2003 and 2007, were conducted in southern Germany in which 787 primary school teachers and 1865 secondary school teachers, in all subjects, were asked about their knowledge of sustainable development and ESD in schools (Seybold & Rieß, 2006; Rieß & Mischo, 2008). Both studies revealed a lack of knowledge, especially in the field of ESD. The second study showed, additionally, that acquired knowledge about the projects developed for the UN-Decade of Education for Sustainable Development (UNESCO, 2005b) remained quite minimal. Despite these deficits, the teachers demonstrated quite positive attitudes towards sustainable development and considered ESD to be an important issue. These findings are in line with other studies. For example, Zachariou and Kadji-Beltran (2009) questioned Cypriot school principals regarding their personal understanding of sustainability and revealed that even principals under-emphasize the economical and social aspects of the question. Definitions of sustainable development were "rather theoretical, based on their experiences with environmental education, linked to the environmental dimension of sustainable development and limited to the protection and conservation of the environment. Social and economic aspects of the environment were not mentioned" (p. 323). A study in Greece also reached similar conclusions. Spiropoulou, Antonakaki, Kontaxakaki and Bouras (2007) showed that Greek in-service-teachers "referred only to environmental aspects of sustainable development, […], without mentioning the economic and social ones" (p. 446) when asked for their personal understanding of sustainability

Almost no research evidence exists concerning PCK and attitudes towards ESD teaching in chemistry. This holds true for both the international scene and in the German context. However, some insights might be gleaned from studies of related groups of persons or topical areas. In 1998, Cross interviewed six teachers from Scotland and the USA, who came from different domains of science teaching, about their opinions about sustainable development. The finding was:

> … that they have very real concerns for the direction of human interactions with the planet and a desire to participate in reforming the public's views about the direction of social progress. On the other hand, these teachers were generally unaware of underlying theoretical issues surrounding the 'sustainable development' movement; they took the concept at face value. (Cross, 1998, p. 50)

Summers, Corney and Childs (2003) also conducted teacher education on ESD for primary science teachers. They found that teachers perceived teaching ESD as something new, exciting and immensely valuable, although they had a lack of knowledge and problems in developing their own teaching practices at first. Kagawa (2007) found similar results in an online survey of 1865 students at the University of Plymouth from all subject areas, including students in educational subjects. The students viewed sustainability as 'a good thing', but their positive responses were not particularly correlated with their degree of familiarity with the concepts of sustainable development or sustainability. The students again strongly associated the concepts of sustainable development and sustainability directly with the environment, rather than linking sustainability also to economic and social aspects.

One can also learn a lesson from related topics by comparing teachers' knowledge and their attitudes about them. Feierabend, Jokmin and Eilks (2011) described German chemistry teachers' attitudes and PCK towards teaching climate change. They found very positive attitudes with respect to implementing the topic of climate change in teaching. The teachers had many intuitive ideas of how to perform this. However, there were many deficiencies in their SMK and very little coherent or theory-based PCK among the participants when specifically dealing with implementation of this topic into chemistry classes. These results are similar to other studies in biology and environmental education. Pe'er, Goldman & Yavetz (2007) revealed a lack of knowledge and missing conceptualization for environmental education among Israeli student teachers, even though the educators' attitudes towards the subject were quite positive. In the case of biology, Esa (2010) confirmed a high level of SMK among pre-service teachers from Malaysia. She emphasized student teachers' readiness to implement the goal of integrating ESD into biology education. She also described a persistent need to provide teachers with both a better understanding of the curriculum and the necessary pedagogies for achieving this, although explicit research of the participants' PCK was not provided by her study. Said, Ahmadun, Paim and Masud (2003) also researched the environmental concerns, knowledge and practices among Malaysian teachers. They found that most teachers do not have the explicit knowledge or an understanding of the necessary practices of environmentally-responsible behavior, which would coincide with their level of concern. The same is true for the research conducted by Tuncer et al. (2009) in Turkey. They found that "despite their low levels of environmental knowledge, respondents (student teachers) expressed positive attitudes toward the environment as well as a high degree of concern about environmental problems" (p. 433). Kennelly, Taylor and Maxwell (2008) developed and evaluated a course on environmental education for undergraduate student teachers in Australia. They wanted to achieve a shift towards more positive attitudes concerning environmental education. However, all participants already held favorable attitudes towards the environment and a strong desire to use it as a focus for their teaching. Therefore, there was no significant improvement noticeable. Despite these findings, the researchers stated, about their subjects, that:

> … their confidence in their ability to teach EE effectively was limited and this seemed to be linked to weak pedagogical and content knowledge in this area. In post instruction, the majority of students indicated that the unit had provided them with a better conceptual understanding of environmental issues, as well as important pedagogical skills, ideas and resources to get these concepts across to their own students. (p. 150)

Overall, pre-service teachers often have very positive attitudes towards implementing issues in their classes taken from environmental education or ESD. However, there is often a deficit in sufficient knowledge, both in SMK and PCK. It seems that PCK represents the domain of knowledge with the largest deficits. Nevertheless, no corresponding study researching this question among German secondary school chemistry (student) teachers has been carried out to date. This paper therefore aims to provide some data in this area. The current study explores the knowledge base of German chemistry teachers and teacher trainees with respect to their SMK, PCK and their attitudes concerning sustainability and ESD in the context of secondary school chemistry education.

METHOD AND SAMPLE

Questionnaire

The study is based on a written questionnaire combining open, closed and Likert-based items. The questionnaire was developed by the research group, then pre-tested and re-negotiated on the basis of initial feedback in the questionnaire. It consists of four parts.

a) The first part collects general information on the participants' age, field of study and formal level of education.
b) This comprises several open questions enquiring into the participants' knowledge and understanding of the technical terms 'sustainability', 'sustainable development' and 'education for sustainable development (ESD),' including their opinion on connections between the above mentioned concepts within the range of school subjects.
c) This section begins by providing an explanation of sustainable development and ESD, which conforms to modern theory. It uses closed-answer questions asking whether and how the participants have previously come into contact with any of these concepts, whether in their teacher education program or elsewhere.
d) The final part of the questionnaire focuses on the participants' PCK concerning sustainability issues and ESD. This part is again based on open questions concerning the subjects' a priori knowledge about secondary school students, the issues and contexts considered to be suitable for implementing ESD in chemistry education, and pedagogies presumed to be proper for ESD-type chemistry education. This last part of the questionnaire asks the participants about their attitudes towards ESD. They are required to rate their opinion of the importance of ESD in general and of chemistry education in particular on a scale ranging from 0 to 10. They also answer three Likert-type questions which ask if the participants consider ESD important enough that it should be taught in lower secondary classes. Respectively they are asked additionally if they consider ESD too difficult to be introduced in levels lower than upper secondary education, and if they could imagine implementing ESD in their own lessons.

The instrument underwent an expert validation within the research group and communicative validation with a sample of participants of a pilot study was conducted.

Participants

The study collected data from pre-service teachers at two levels of teacher training. One sample is comprised of student teachers during their university teacher preparation program. In Germany, every student teacher must obtain a Bachelor's and Master's degree. Both programs contain courses in subject matter, domain specific pedagogy, and general education. The combination of both programs represent the German approach towards one teacher education program from the beginning. Every student teacher studies two school subjects and takes courses in both education and psychology, as well as participating in school internships to gain initial teaching experience. The second sample, the trainee teachers, stems from a compulsory, in-service preparatory program. After completing their university teacher training program, prospective teachers in Germany attend eighteen months of in-service training (the 'Referendariat') before becoming fully certified secondary school teachers. During that time, they need to teach approximately 10 hours per week on their own, join their mentors during their lessons and attend seminars and lectures. The sample in the pilot study consisted of 31 student teachers from one university and 19 trainee teachers in the trainee program ('Referendariat') of one of the German States ('Länder'). In the main study, 87 student teachers from three different universities in the North of Germany took part and 97 trainee teachers from four of the 16 German states. Additional details about the participants are given in Table 1.

Table 1. Overview on the sample

Student teachers (N = 87)					
Area of studies		Age		Second Subject	
Lower secondary level	8	<25	57	Biology	33
Upper secondary level	25	25-30	19	Physics	8
Both levels	48	31-35	4	Mathematics	17
Other	1	>35	4	Other	29
No answer	5	No answer	3	No answer	0
Teacher trainees (N = 97)					
Area of studies	No.	Age	No.	Second Subject	No.
Lower secondary level	16	<25	4	Biology	32
Upper secondary level	12	25-30	64	Physics	16
Both levels	56	31-35	15	Mathematics	20
Other	12	>35	10	Other	29
No answer	1	No answer	4	No answer	0

Data analyses

The closed and Likert questions were analyzed statistically. Qualitative Content Analysis (QCA) was used to evaluate the open questions (Mayring, 2000). QCA categories were developed from the material gathered in the pilot study and the theoretical framework, and were communicatively validated by discussing the interpretation back with single participants of the study and within the research group. Concerning the associations with the term "sustainability" the analysis started with categories derived from the literature that were then refined with respect to the data material. Concerning the understanding of Sustainability and ESD there were no categories found in the literature. Thus the categories were developed directly from the material. Finally the material was coded and the number of mentions in each category was counted. The resulting categories describe different the types of understanding of the terms 'sustainability and sustainable development' and the understanding of the term 'ESD'. They proved themselves to provide a high saturated coverage of the data and were applied to the whole sample by two independent raters. Reliability of the rating was high. For the student teachers Cohen's kappa was 0.73 for their understanding of sustainability and 0.78 for their understanding of ESD. For the teacher trainees, Cohen's kappa was 0.77 for sustainability and 0.73 for ESD. In cases of disagreement a joint rerating was performed by the raters to enrich the data in the sense of a search for inter-subjective agreement (Swanborn, 1996). A different approach was applied to describe the participants' PCK. The four indicators for PCK were:

- Knowledge about students' prior knowledge
- Knowledge about the curriculum and potential contexts for ESD in chemistry education.
- Knowledge about domain-specific instructional strategies for operating ESD in chemistry education, and
- Knowledge about justifications and attitudes for implementing ESD and respective topics into chemistry lessons.

Without applying a pre-structured theoretical framework, the two raters analyzed the open questions about PCK independently using Qualitative Content analysis (Mayring, 2000). Both raters described different subcategories concerning students' potential prior knowledge, suitable curriculum contexts, instructional strategies and attitudes which were jointly negotiated and refined using a cyclical approach using Swanborn's method (1996). Then the number of mentions in each subcategory was counted. The relationship between both kinds of data was researched to find any potential for triangulation (Thurmond, 2001).

FINDINGS AND DISCUSSION

Associations with 'Sustainability'

When asked for the context of this term, the participants associated 'sustainability' with six main categories (Figure 1). The domain mentioned most often when participants were asked about the term sustainability dealt with ecological contexts, such as environmental problems, pollution, exhaustion of resources, climate change and renewable energy. In this category, all student teachers together named different ecological contexts 116 times, the teacher trainees mentioned varying ecological contexts 162 times. 16 student teachers and 19 trainees referred only to environmental contexts. The most popular ideas were: preventing environmental pollution, saving resources, and developing renewable energies. The issue of climate change was mentioned twelve times, which is quite surprising as climate change is one of the most often discussed issues of sustainable development in the media in Germany in recent years.

The second largest domain mentioned is concerned with social issues, such as health, lifestyle, social injustice, politics, or society. It was mentioned approximately the same number of times as economical issues, such as a circular economy, industry and production processes. Only rarely did the participants mention typical issues taken from the political debate on sustainability which combines ecological, economical or social impacts, for example globalization, consumerist behavior, fair-trade, mobility, or global development. Only 4 student teachers and 9 trainee teachers named contexts combining ecological, economic and social perspectives, a view which represent the heart of all modern concepts of sustainability (Burmeister et al., 2012).

Aside from these domains, many participants associated the term sustainability with 'sustainable learning', meaning sustainable learning achievement. The most prominent association in this respect was that 'sustainability' means keeping knowledge in mind even after school is finished. 16 student teachers and 13 trainee teachers mentioned only the educational context when writing down their associations with sustainability.

Other context that were only mentioned by single participants touched upon e.g. 'philosophy', 'research', 'revolution', 'sense of responsibility', 'in every condition of life', 'in every situation concerning change' and others. 2 student teachers and 5 trainee teacher did not answer the question.

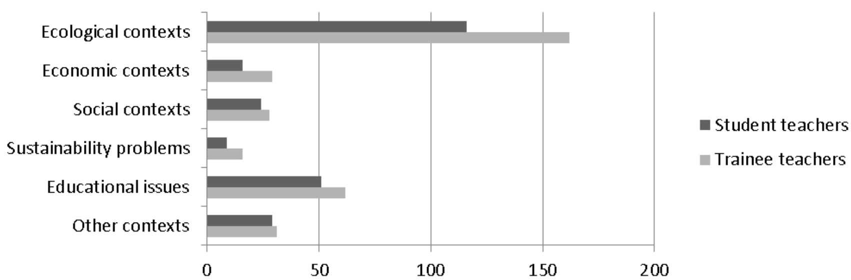

Figure 1. Total number of associations with 'sustainability' mentioned by the participants

Understanding 'Sustainability'

Seven categories were found for the understanding of sustainability (Table 2). Only a small fraction of the participants (student teachers 2.3%, trainee teachers 3.1%) was categorized as having no meaningful idea about what the term 'sustainability' means at all (category 1). This was the case for answers like 'I don't know' or when answers didn't make any sense. Another group of participants sidestepped the word sustainability by explaining the meaning of the word in a very abstract fashion (category 2). This was the case for about 6.7% of the student teachers and 10.3% of the teacher trainees. These participants explained sustainability and sustainable development as something permanent and long-lasting. Typical answers were e.g. "long-term instead of short-term" or "something lasts for a longer period of time". In these answers sustainability was not explained as a holistic concept but rather as an attribute or characteristic of things or actions in any domain. This is sound reasoning, because in the German language the adjective or adverb sustainable ('nachhaltig') is indeed used for pointing out long-lasting effects in any possible domain. Issues such as the economy or flora and fauna can be 'sustainably damaged' ('nachhaltig beschädigt') which means permanently damaged. This understanding is also related to any use of the German word in the domain of education (category 3). This domain was used exclusively by about 16.1% and 12.4% of the student teachers and trainee teachers, respectively, to explain the concept of sustainability. In these answers, sustainability was explained using the example of sustainable learning. Sustainable learning means that knowledge 'sticks' in your head, even after school is over and the exam has already been written.

Table 2. Student teachers and teacher trainees' understanding of 'sustainability'

No	Category	Student teachers	Trainee teachers
1	No understanding	2.3 %	3.1 %
2	Abstract understanding	6.7 %	10.3 %
3	Educational interpretation	16.1 %	12.4 %
4	Single right idea	40.2 %	39.2 %
5	Basically right idea	10.3 %	19.6 %
6	Good understanding	6.7 %	9.3 %
7	Confusion of concepts	13.8 %	5.2 %
	No answer	3.4 %	1 %

The 'educational' understanding of sustainability reported above varies with the results of other studies on the same topic (e.g. Summers & Childs, 2007). One reason for this might be the fact that the data were collected in chemistry education courses both at the university and within the in-service program. After filling out the questionnaire, some of the participants confirmed that they had thought that the study was about education and school, only realizing later that it was not just about sustainability in education. Another reason may be the frequent use of the adjective 'sustainable' in the German language in connection with appropriate learning and teaching methods. Some of the students said that their replies would have been different, if they had known that the questionnaire was not solely about education. This is of course one limitation of questionnaires, because researchers can only analyze what is actually written down. Misunderstandings cannot be corrected after the fact.

Aside from the more semantic concepts or the concepts connected to the domain of educational effectiveness, nearly 60% of student teachers and nearly 70% of trainees explained sustainability in connection with ideas taken from the concept of sustainable development in today's world and society. This big group is split into the categories 4, 5 and 6. About 40% of both student teachers and trainees based their explanations on a single correct idea borrowed from this domain (category 4). The answers either represented one of the three pillars of modern sustainability concepts (ecological, economic, and societal sustainability) or they referred to the idea of inter-generational equitability. These answers can be considered correct intuitively, but had no fully-developed or well-reasoned theoretical concept behind them. Three major ideas were dominant within this type of answers (all quotes from the questionnaires): "Doing things that are good for the future," "saving and not exhausting resources" and "leaving a nice world for the future generation." About 10.3% and 19.6% of the student teachers and trainees, respectively, elaborated more fully by combining aspects of at least two dimensions from the three-pillars-concept of sustainability - or the idea of inter-generational justice - in a meaningful way (category 5). One example was "for the coming world, the future, continuing chances. For example, every tree I cut I will replace with a new one, so that my children will also be able to use the resource wood." However, a complete and theoretically sound explanation remains missing in these answers. Only between 6.7-9.3% of the participants from both student teachers and trainees showed a fully elaborated understanding of sustainability (category 6). They regarded all three dimensions of a world- and society-oriented understanding of sustainability in a meaningful way:

Companies, processes or projects are sustainable, if they operate profitably over the long-run with respect to ecological, social and economic aspects. Sustainable development leads to a situation where coming generations will not be disadvantaged by the fact that today's society is following its own best interests.

About 13.8% and 5.2% of both groups, respectively, had different ideas about the term sustainability (category 7). They either gave several possible definitions, or combined explanations from the educational domain with ideas fitting to the three pillars model of sustainability, or gave a semantic explanation of the word. 3.1% of the students and 1% of the trainee teachers didn't answer the test. A Chi-Square-Test did not show any significant differences between both groups.

Understanding ESD

Concerning their understanding of ESD, 27.5% of student teachers and 19.6% of teacher trainees revealed that they had no idea about, or a sound understanding of, what ESD means (Table 3, category 1). 5.7% and 8.2%, respectively, mentioned a few ideas in the right direction, such as education for 'ecological awareness.' However, they were far away from any elaborated idea or definition (category 2). About 49.4% of the student teachers and 41.2% of the trainee teachers were able to outline at least one complete idea that was in accordance with the aims and pedagogy of ESD (category 3). But they still did not express the main idea of ESD, which deals with enabling students to take personal action for a sustainable future. Typical answers were "taking sustainability into account in school lessons," or "school education should enable the students to cope critically with environmental issues in their life which might be presented to them in media." Only 8% of the student teachers and 19.6% of the trainee teachers were able to give a good explanation for the meaning of ESD (category 4). However, they did not employ technical terms or explicit theoretical ideas associated with the pedagogy of ESD. A typical answer was: "Our children should learn to think with foresight. Knowledge obtained from school lessons should be available and applied to students' future lives (protection of the environment, assuring the existence of future generations)." A theoretically elaborated understanding in accordance with the terminology of ESD was only given by one single student teacher and none of the trainee teachers (category 5). For the Chi-Square-Test, categories 4 and 5 were combined to form a single category, as category 5 included only one single participant. Participants that didn't answer the test (8% students and 11.3% trainee teachers) were omitted. Again no significant differences between both groups were observed.

Table 3. Student teachers and trainee teachers' understanding of ESD

No	**Category**	**Student teachers (%)**	**Teacher trainees (%)**
1	No understanding	27.5	19.6
2	Single notes	5.7	8.2
3	Idea into right direction	49.4	41.2
4	Right idea	8	19.6
5	Elaborated understanding	1.1	0
	No answer	8	11.3

Sources of Knowledge about Sustainability and ESD

The results from the open questions show that most of the participants concentrate on single ideas about sustainable development and ESD, which are roughly correct. However, they are generally unfamiliar with the underlying theoretical concepts of such ideas. This finding can be explained by the participants' own reflections on their learning. Only about 20% of the participants remembered having any contact with the theoretical concepts behind the modern understanding of sustainability, or the pedagogy of ESD. This included their normal courses at university and their pedagogical-didactic courses during their teacher education (Figure 2 and 3). The vast majority from both groups mentioned that these ideas and concepts did not play any role in the teacher education courses in which they had taken part. 23 student teachers and 30 trainees had never heard of any of these concepts during their entire teacher education (or they were unsure about them). Out of these, 14, in both subgroups, had heard of at least one of the concepts in the media, however, 9 student teachers and 16 teacher trainees had never come into contact with any of the concepts. When comparing sustainability to ESD, ESD remains the less well-known known factor. And if participants knew about these concepts at all, the most often mentioned sources of information were sources outside of the teacher education program, such as the mass media.

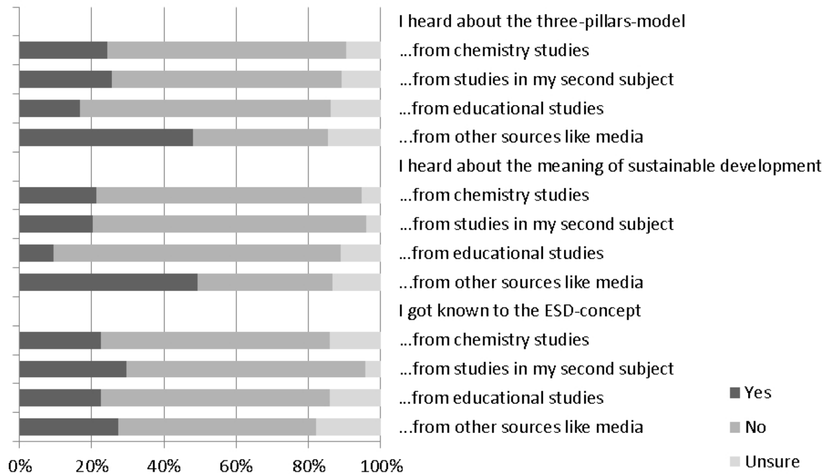

Figure 2. Student teachers' sources of knowledge about 'sustainability' and ESD

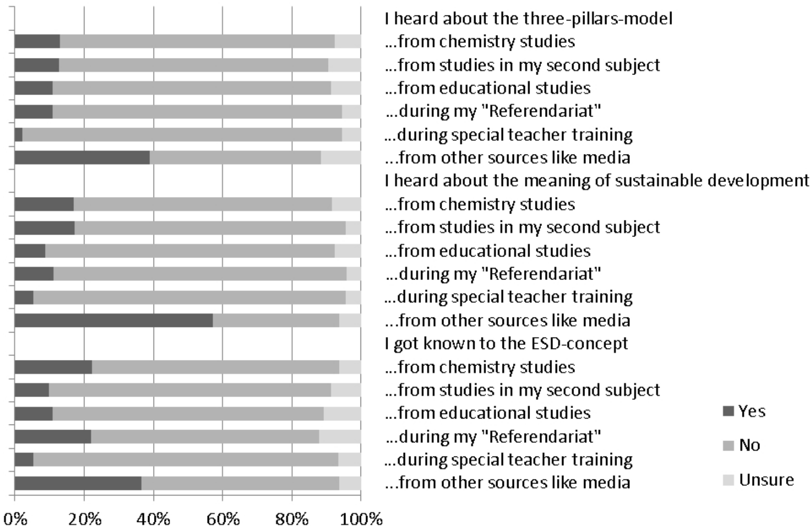

Figure 3. Trainee teachers' sources of knowledge about 'sustainability' and ESD

Overall, the results show that there is a major lack in the participants' Subject Matter Knowledge concerning concepts of sustainability and ESD. The next sections discusses the participants' attitudes towards implementing ESD into Chemistry education and their Pedagogical Content Knowledge.

Attitudes dealing with Sustainability and ESD in Chemistry Classes

By turning over the questionnaire, the participants received a short theoretical introduction to the definition of sustainability and the concept of ESD. Then the participants were asked if ESD should be implemented in either lower or upper secondary classes. They were also asked if they could imagine implementing ESD in their own future teaching. The results are shown in Figure 4. More than 85% of the participants expressed positive attitudes towards implementing ESD into their own chemistry lessons. Almost 80% considered ESD to be important enough that it should be treated in lower secondary education. T-tests for all three questions did not show significant differences between both groups.

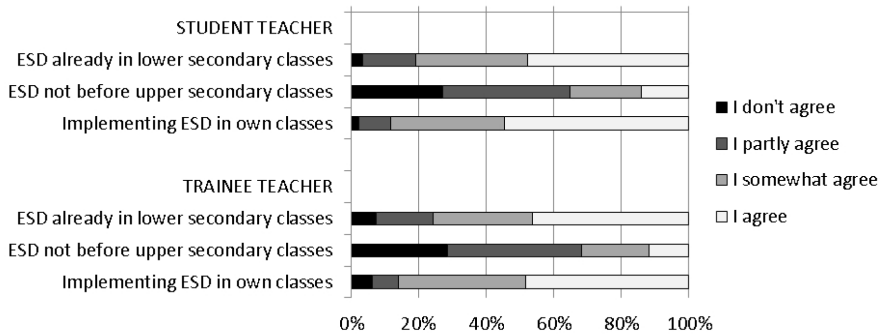

Figure 4. Student teachers and trainee teachers' attitude to implementing ESD in chemistry classes

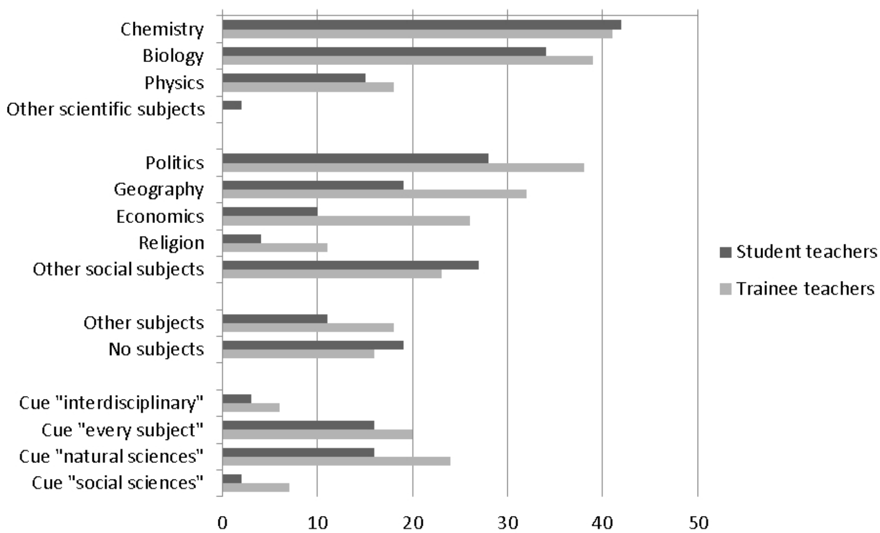

Figure 5. Preferred allocation of ESD among the school subjects (number of times topics mentioned by the participants)

When asked which school subjects might be best for promoting ESD, the participants acknowledged the important role of both science in general and chemistry education in particular. Chemistry, biology, politics and economics were the most frequently mentioned subjects. Another finding was that, although chemistry and biology were mentioned often, physics was not, even though it is directly connected to questions of sustainable energy supply. Seven student teachers and eight trainee teachers mentioned exclusively natural sciences. The remaining (two and four) participants stated only the social sciences in their answers. This means that the majority of the participants acknowledged the interdisciplinary approach necessary for implementing ESD, including the fact that ESD required support from many different school subjects. Some participants did not even name specific subjects, but said that ESD needed support from all school subjects (Figure 5).

When asked to rate the importance of ESD in both general and chemistry education on a scale from 0 to 10, both groups showed high levels of support (general education mean = 8.6 in both groups; chemistry education mean 7.4 and 7.5 for student teachers and trainee teachers, respectively). T-tests for both questions did not show significant differences between both groups.

Potential Contexts and 'Pedagogies for ESD in Chemistry Education

Knowledge about the curriculum is an essential part of PCK. Ideas about where to connect ESD related issues with students' potential prior knowledge and the chemistry curriculum thus allow insights into whether the participant have knowledge, but also imagination of ESD driven curricula in the case of Chemistry education.

The participants were asked about the most suitable contexts for ESD within the chemistry curriculum. When asked where ESD might start based on students' prior knowledge and potential interest 26% student teachers and 25% trainee teacher explicitly stated that there might be no adequate prior knowledge on which to build. About half the student teachers and trainee teachers from this category just stayed with this comment. The other half gave this statement but additionally mentioned one or two potential topics where students' might have some prior knowledge e.g. about air pollution, renewable energies, or saving water, electricity, or fuels. Together, with participants simply mentioning such topics and contexts, about 40% of the participants were able to mention ideas for any potential prior knowledge of students. In cases where associations of students' prior ideas were mentioned, the most often mentioned topics were environmental issues, issues connected to dealing with and saving natural resources, and questions of waste disposal (Table 4). Another 18% of the both groups explicitly stated that they did not know, or could not assume any prior knowledge or interest being connected with sustainable development, e.g. by reasons that they did not have any experience in the topic and had never thought about it. Another about 20% participants in both groups did not answer this particular question.

The most often mentioned suggestion, when the participants were directly asked how to connect ESD and the chemistry curriculum, were the topics of fossil and renewable fuels. This is a typical topic in nearly every German chemistry curriculum and textbook. Topics mentioned less often were connected with waste and recycling, water, metals, climate change or plastics, or more general environmental problems and saving natural resources (Figure 6). Single topics mentioned by only few participants included daily life or societal issues, such as pesticides, batteries, health and nutrition and were coded as "other contexts." A context purely derived from the inner systematics of chemistry theory was coded as a "systemic context." 17 of the student teachers and 12 of the trainees did not mention even one potential topic from the chemistry curriculum to be considered as a good starting point for ESD. Overall, the teacher trainees mentioned more (on average 3.45 ideas per participant) ideas than the student teachers (on average 2.64 ideas per participant), despite the fact that the area of the mentioned topics in both cases was not very broad and was limited only to the topics of climate change and environmental pollution.

Table 4. Estimation of elements in students' prior knowledge to be used for ESD-type chemistry education (number of topics mentioned by the participants)

Field	Student teachers	Teacher trainees
Saving water, electricity, fuel	10	20
Waste-disposal and recycling	14	20
Resources	14	16
Environmental issues	49	24
Other issues	13	10

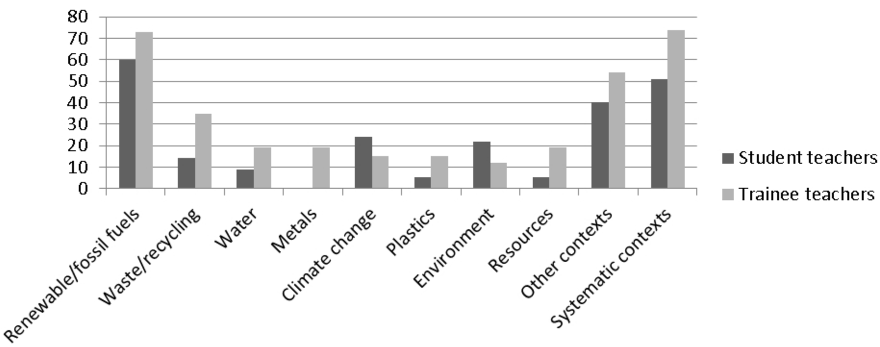

Figure 6. Potential topics from the chemistry curriculum for ESD in chemistry education (number of topics mentioned by the participants)

The last questions asked about knowledge and a choice of suitable pedagogies for implementing ESD into chemistry education. All participants most often named teaching methods, but sometimes they mentioned curriculum designs or media as well. Nearly half of the student teachers were able to make suggestions, but 23% of the trainees were not able to imagine even one suitable instructional idea. Project-based teaching, cooperative learning, presentation techniques, and techniques promoting exchange and discussion were mentioned among the teaching methods suggested (Table 5). Yet, only some of these methods seem to be specifically suited to the context of ESD. Methods especially attuned to mimicking societal debates, decision-making processes or relating chemistry to society were rarely mentioned. One exception to this rule was the quite frequent mention of role-playing exercises and panel discussions.

Table 5. Potential pedagogies for ESD in chemistry education (number of pedagogical elements mentioned by the participants)

Category	Student teachers	Trainee teachers
Curriculum approaches		
Context-based science education	1	5
Socio-scientific issues based science education	5	3
Other curriculum approaches	8	0
Teaching methods		
Cooperative learning	0	12
Working in projects	13	12
Jigsaw classroom	2	5
Learning at stations	3	12
Performing experiments	16	8
Methods of presenting, e.g. mind mapping, poster, oral presentation, etc.	8	28
Methods of self-directed learning, e.g. online search, Webquests, inquiry-based learning	4	14
Methods of discussion, e.g. role-playing, panel-show	16	29
Extra-curricular activities, e.g. excursions, inviting outside experts	13	13
Other methods e.g. placemate	21	38
Media		
Videos	5	5
Everyday media, e.g. newspaper, magazines, advertisements	4	6
Other media	0	1
Did not answer the question	45 %	23 %

CONCLUSIONS AND IMPLICATIONS

The results of this study show that many of the chemistry student teachers and trainee teachers in this sample have a positive attitude towards the idea of sustainability and sustainable development. This is particularly true for educational contexts. Yet, very few participants in both groups were able to underpin such positive attitudes with theory-based knowledge. Most associations to sustainability stemmed from environmentally related topics; the interplay between ecological, economic and societal dimensions, which is prevalent in every modern concept of sustainability, was only rarely mentioned. These findings are similar to related studies in other countries, including those analyzing teachers and student teachers from other domains, e.g. the United Kingdom, Greece, or Cyprus (Summers & Childs, 2007; Spiropoulou et al., 2007; Zachariou & Kadij-Beltran, 2009).

In comparing both groups no major differences were found. It seemed that neither the subject matter courses in teacher education in chemistry, nor the courses in education and general science education, attended by the participants, offered any theory-based insights into modern concepts of sustainability. This finding might not be a problem in the case of student teachers, since they still had several years of teacher education before becoming an in-service teacher. But teacher trainees were in the final phase of teacher training. They faced no compulsory professional development courses after they qualified. It seemed clear that their teacher education had neglected teaching them about concepts of sustainability and modern, theory-based concepts of sustainable development. This held true for both the prospective teachers' university studies and the practicing teachers' in-service professional development program. More crucially, most participants stated that any knowledge that they had obtained was generally not during their teacher training, but rather information from mass media and the Internet.

The same discussion is true for the participants' knowledge about ESD. Here the situation becomes even worse. Despite some intuitive associations, most of the participants from both groups lack any theory-based knowledge about ESD whatsoever. They are unsure of any related pedagogies which may give aid in connecting ESD to chemistry education. There is no major difference between both groups in this area, either. Teacher trainees do seem to possess somewhat higher levels of ideas in the right direction. The reason for this may come from a better knowledge of the school syllabus, curriculum and available textbooks, due to their experience of actually working in a school. But the conclusion remains the same. Neither the pre-service university program, nor in-service professional development seems to offer any substantial examination of the didactics of ESD, including related pedagogies of how to cope with ESD in chemistry education. Another indication for this claim is that the high percentage of participants not answering in the part of the survey covering their knowledge and ideas about potential contexts and pedagogies (see Table 5).

Despite participants' lack of knowledge, there are also some promising results. Both groups show positive attitudes towards ESD and acknowledge the importance of ESD for chemistry education. After hearing an explanation of ESD, many of the participants were able to suggest at least some meaningful topics, contexts and pedagogies for ESD in chemistry education. Here teacher trainees fare better than student teachers, most probably because they have more first-hand knowledge and practical experience in planning and conducting chemistry lessons.

Since the attitudes measured in this study were positive and the importance of ESD acknowledged by teachers, educational research and policy papers, a more thorough examination of sustainability and ESD in chemistry teacher education seems to be in order, at least in the German context. This claim concerns both learning about the subject matter and theoretical constructs behind modern concepts of sustainability, including the theory and pedagogies of ESD (UNESCO, 2005b). Burmeister et al. (2012) suggest that both issues take a more prominent role in educating future chemistry teachers due the importance that chemistry has for sustainable development. Such an approach can also contribute to discovering the full potential that chemistry education has for promoting more general educational skills, including students' future ability to take part in society (Hofstein et al., 2011). Two approaches can be useful when answering this challenge. The first is to make learning about sustainability and ESD an independent topic in chemistry teacher education as recently suggested by Burmeister and Eilks (2013). The second is to continuously connect subject matter and domain-specific educational courses to issues of sustainability and ESD. In all probability, a combination of both may prove to be best.

What has also become clear is that most in-service teachers in Germany may not possess highly-developed knowledge about the topics of sustainability and ESD. As this study shows, learning about sustainability and promoting ESD seems to be of low priority in current chemistry teacher education in Germany, with the situation being even worse in the past. One indicator of this is that none of the participants mentioned learning about these ideas and concepts during their school education prior to university. This indicates that investment in in-service professional development in Germany is needed in order to increase teachers' subject matter and theoretical knowledge about modern concepts of sustainability and about ESD. Such inspiration may be possible if coursework from pre-service chemistry teacher programs is used as a starting point (Burmeister & Eilks, 2013).

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