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ORIGINAL ARTICLE

Science Teachers' Beliefs on Science Teaching and Learning for Implementing in STEM Education

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ABSTRACT

STEM, STEAM education is important for building a better future, and teachers have a key role in attracting students to the field of STEM. However, when teachers need to shift from traditional disciplinary-based education to integrated STEM education, they often find this transition challenging. This difficulty arises because their beliefs about science teaching and learning are deeply rooted in traditional disciplinary-based approaches. Beliefs have a profound influence on their teaching practises as well as their professional development, even though teachers are often not conscious of their own beliefs. To address this issue, we employed a phenomenological approach to investigate the phenomena when their beliefs espoused by asking formative episodes that influenced their development as science teachers. This study aimed at exploring the current subject-specific beliefs of in-service science teachers. This told us how best to guide teachers through this process of the transition from traditional disciplinary-based education to STEM education. Our findings revealed that teachers' beliefs showed that curiosity and/or interest towards science to be the most important factors in student learning. This indicates that while teachers' core beliefs are not entirely disciplinary-oriented, they are more open. It would reduce their anxiety and low self-efficacy in conveying STEM education.

KEY WORDS: Beliefs; professional development; STEAM; STEM

INTRODUCTION

Stroud and Baines (2019) explained that before the STEM term came in, educational practices were distinct and separated into domains. After STEM, it is argued that the importance of affiliating the fields of science, technology, engineering, and mathematics education. At that time, "STEM education emphasized theoretical understandings of solutions to real-world problems" (Stroud and Baines, 2019, 1). This may sound too obvious; however, people in the field of STEM education face the issues of attracting more children into the field of STEM. Potvin and Hasni (2014) used the education resources information center database to analyze 252 papers discussing about Science and Technology (S&T) and "interest/motivation/attitude (I/M/A)," and found out that the issues on S&T education are not about teaching quality itself, but mainly on I/M/A of learners. They summarized that "Indeed, S&T exists for the exact purpose of explaining the world and increasing well-being. It might, therefore, appear paradoxical to remind teachers of the importance of rebuilding links between S&T and reality. Nevertheless, this recommendation is judged to be important to repeat. It also suggests that studying the reasons why (and how) science is getting distorted when taught in elementary and secondary classes might be most insightful." It means that currently STEM fields are not attracting children as much as they want, neither they nor their teachers realised S&T are related to their everyday lives. STEM education is to change from separated individual STEM subjects learning to an integrated teaching and learning across subjects as well as reflecting and applying to real world problems.

Yakman (2010) explained STE@M pyramid, "Science and Technology interpreted through Engineering and the Arts, all based in Mathematical elements" for "A Framework for Teaching Across the Disciplines". There are many barriers when they try to apply those teaching and learning happens at school across the disciplines. One of the important factors to solve the barrier is teachers who play a central role in students learning as well as curriculum practices. It is shown that teacher's practices reflected by their beliefs and their beliefs are often hard to change. It means that if teachers cannot establish beliefs about what STEM, STEAM learning is, they find extremely difficult to put STEM STEAM education into practices.

Teacher beliefs have been a central focus area of science education research for a number of years and quite a number of teacher belief studies have been conducted so far (Jones and Leagon, 2014). Our understanding of teacher beliefs is not succeeded in the consensus with regard to a definition of beliefs (Hutner and Markman, 2016). From the literature review, Pajares (1992) identified six different types of teachers' educational beliefs: Beliefs about teacher efficacy, epistemological beliefs, beliefs about "causes of teachers' or students' performance," beliefs about self-concept or self-esteem, self-efficacy beliefs, and finally beliefs about "specific subjects or disciplines (reading instruction, the nature of reading, and whole language)." The latter type of belief has later been referred to as subject-specific belief (SSB), meaning what teachers believe about how children learn specific subjects. SSBs have only rarely been investigated in depth so far despite previous research demonstrating that subject specificity is important for teachers' beliefs. In one empirical study, a teacher's belief system was analyzed as she developed her professional knowledge about science teaching and learning (Bryan, 2003). It was shown that the teacher's foundational beliefs about the value, nature, and goals of science education had a profound influence on her teaching and development. However, understanding teachers' beliefs is not straightforward and more exploratory research on teachers' beliefs is needed. The research presented here tried to achieve this by conducting a phenomenological study on the SSB of Danish in-service science teachers.

METHODS

Research Approach

According to Pajares (1992): "All teachers hold beliefs, however, defined and labeled, about their work, their students, their subject matter, and their roles and responsibilities." However, such beliefs may not be consciously accessible to the teacher – let alone the researcher. There are several methods that have been used to explore teachers' beliefs; however, in this study, we tried to penetrate the teachers' espoused beliefs using a phenomenological approach. Espoused beliefs are "self-reported claims about the way things are or should be" (Bryan, 2012) even if they may not necessarily be something that teachers are conscious of. This resonates well with the phenomenological idea that "man can only speak of that which appears to someone's stream of consciousness or experience" (Giorgi and Aanstoos, 1985, p.84). Using a phenomenological approach, it is possible to identify phenomena such as teachers' beliefs through careful examination of formative episodes in the life of the teachers as they perceived them. In our case, teachers were asked to provide examples of episodes in their life that had an influence on their development as science teachers. Episodes included situations that had a significant impact on how they became teachers, situations where other people influenced them, students reacted strongly to their teaching, or when they developed the reasoning behind what they did in relation to teaching science. By using a phenomenological approach, it is possible to describe what kind of perceptions the participants have on their episodes about PD (Posnanski 2002). This study followed a phenomenological approach in line with previous research (Willis 1991, Luft, Roehrig, & Patterson, 2003; Minor, Onwuegbuzie, Witcher, & James, 2002; Lumpe, 2007; Lumpe et al., 2012). We followed Giorgi's descriptive phenomenological analysis procedure (Charmaz &McMullen, 2011; Giorgi & Aanstoos, 1985) by segregating data into meaning units based on categorisation of teachers' SSB. Each process has been taken as following; 1) read the transcribed manuscript of data holistically, 2) identifying the separated section called "meaning units" that present a change in meaning within an episodes, 3) restricting each meaning units into the third person sentences in order to segregate a perception of a researcher who analyse the data. 4) integrates and condense meaning units into a consistent statement called "core statements" (Leigh-Osroosh, 2021).

Limitations

It is important to note that this study seeks to explore a small sample of Danish science teachers to contribute to the qualitative understanding of SSB. The results are not representative of Danish science teachers. The study is also limited by the methodological focus on teachers' espoused beliefs and lack of observations of actual teaching practices. Although the correlation between teachers' beliefs and teaching practices has been investigated for a long time, there may not be a clear line of causality between them (Hutner and Markman, 2016). Therefore, how the teachers' SSB relate to their actual teaching practices would need to be investigated further.

Participants and Analysis

Interviews were conducted with 6 in-service science teachers working in Danish public schools. Danish public schools offer mandatory teaching from grades 0 to 9. The teachers chosen for this study were all selected for teaching science grade 7–9, because, in the Danish education system, grade 7–9 science tends to be taught by teachers who have a more comprehensive knowledge of science. The assumption behind this selection was that such teachers would be better able to describe their SSB than teachers teaching general science at lower grade levels where science is taught as an integrated subject. In total, six teachers agreed to be part of the study. Semi-structured individual interviews lasting an hour were conducted with each of the six science teachers. The interviews were mainly conducted in English, but also in Danish when teachers found it necessary to communicate clearly. The translation of Danish passages of the transcripts was later checked by a native Danish speaker. All interviews were audio-recorded and transcribed for analysis. In the following quotes, minor grammatical corrections have been made to the teachers' English to enhance the ease of reading and to better represent the teachers' statements as the Danish teacher was not able to communicate fluently in English. Pseudonyms have been assigned to each respondent for the sake of anonymity.

FINDINGS

The phenomenological analysis of the interview data resulted in core statements from each of the six science teachers. Core statements do not express the full scope of the teachers' beliefs, but rather represent the "essence" of each science teacher's SSB, which allowed us to examine commonalities and differences. Below is a short summary of each science teacher's SSB based on the phenomenological analysis to introduce the reader to each of them followed by a summarized list of the teachers' core statements.

Mette

Mette was a novice teacher who was highly motivated and willing to share and collaborate with the other teachers. She was not particularly interested in science when she attended school and she did not pursue science in her work after her first formal education. After several years of working as an artisan, she started a second education to change her line of work. She explained when she studied mathematics as a part of her teacher education, she found that she had an "intuitive understanding" of mathematics and science. Her intuitive understanding allowed her to become good at mathematics, chemistry, and physics. Mette explained that her newfound interest and abilities in mathematics and science motivated her to teach science to students who were not necessary motivated in school. Part of Mette's SSB was that she believed felt that, as a science teacher, you need to keep up with current science. This was evident from statements such as: "Science (as a field of research) is the only discipline that is a subject in schools and that is constantly changing… I want that aspect to be a part of school science as well." She believed that the knowledge taught in science in schools should reflect that scientific knowledge and practices are constantly evolving. Consequently, it was not meaningful for her to provide students with school science alone. She believed that it was important for students to learn how to build on the knowledge they acquired in school to make their own investigations and apply their knowledge to real-world challenges. This belief was echoed in her approach to her own professional development where she strove to keep up with current science research. She said that by teaching science, she was motivated to learn more as a teacher, because in science there are no clear answers about the world: "You cannot get answers, but very interesting questions. That motivates me. It is a great way to see the world around me and I want kids to see the world around them through science."

Mikkel

Unlike Mette, Mikkel liked science in school. His family moved to Denmark when he was 9 years old. The move caused language problems for him, but science appealed to him because it was based on numbers. His innate interest in observing and reflecting on how things work brought him to realize early on in his life that it was important to make students aware that science is part of everyday life. He said that it was not difficult for him to find ways of engaging his students in scientific topics – including the students who were not interested in science. He believed that learning science was about more than students learning the curriculum: "Of course, learning science is a lot of things they have to learn – that is what curriculum is about – but I am not interested in that. I am more interested that they always seek the truth – have curiosity about science. That is very important. […] As long as they are curious about science, they will want to find the answers. […] The main thing is making science interesting for students." He liked teaching because it enabled him to experience the students' growth and development. As an example, he mentioned a student who was not engaged in school, to begin with, but after becoming interested in science, she "transformed" into a student who ended up scoring high marks on the examinations. Mikkel said that such transformations were the reasons, he liked teaching.

Ida

Ida also had very positive feelings toward science from her early childhood. She always enjoyed learning science – especially learning about life. She was driven to teach children because she wanted them to experience the same joy of science that she had. She said "…I would rather be a teacher in primary and secondary school […]. I wanted to be a part of laying the foundation for [my students'] motivation and interests." She believed that primary and lower secondary school was the time when students developed their curiosity toward science and she wanted to be involved in that process. She believed that it was important that there were two legs to stand on as a professional science teacher: Knowledge of science and knowledge of didactics. She enjoyed doing experiments in her class that could pose ongoing challenges for her students because she believed that curiosity was the most important aspect of science. To maintain her students' curiosity, she encouraged them never to "settle" with a given answer but to keep asking questions and finding more answers. As she explained: "So it's actually a way of learning instead of specific topics [to be learned]." In addition, she expressed that "Joy is very important for curiosity that is to want to acquire and to maintain the childish joy of science that I still have it." This illustrated her belief that joy and curiosity ought to be a central part of science teaching.

Laura

Laura emphasized the word "curiosity" when talking about her teaching. She believed that the main goal of science education in schools was to stimulate and nourish students' curiosity. Her definition of curiosity was the interest and willingness to investigate something. By sustaining the students' curiosity in science, she believed that they would naturally get a good basic understanding of science that would serve them well in their future. She believed that people learn when they were active, and that science as a subject unique in the way that it allowed students to combine theories in books with opportunities for hands-on work. She believed that the most important competencies that her students should gain from her classes were the abilities to investigate, communicate, and see things from different perspectives to be able to solve problems in any situation. Laura believed that the goal of science education was not about getting students to become scientists, but rather for them "to have science in their hearts." In the interview, she explained that "I think my aim or goal is to make my students become motivated for science in many kinds of ways." She elaborated by saying: "When we talk about "Science for all," we are talking about competencies. You have to be able to do something with your knowledge, and that is all (about) the competencies." She believed that she could reach students with different needs by exposing them to different ways of using science to "investigate and want to find out stuff, which is a big part of our subject."

Emil

Emil had been interested in nature since he was a child. His personal interest in nature drove him to want to teach. He wanted students to experience and feel nature and make observations. He believed that it was very important for students to go on field trips into nature to appreciate the natural world around them. According to Emil, his students learned best when he was able to help them link what they were working on in science classes with what they had worked on previously. He therefore tried consciously to help them construct their understanding of science in small steps. If a student had difficulty in understanding science, he would use a variety of approaches including hands-on activities to help the students make the necessary connections to understand. Emil also believed that it was important for science teachers to explain the mechanisms of how things work and how scientists made discoveries to their students.

Victor

Victor also wanted to be a teacher, but initially, he did not consider becoming a science teacher. After finishing his education, one of the first things Victor learned as a teacher was that he had to develop his teaching on an ongoing basis to accommodate his students. Victor believed that teaching was all about creating "hooks" through experiences that the students could relate to. "By giving them different experiences, you can use the experiences as a hook (…) that I can hang knowledge and theory on. Moreover, by doing practical things, kids that are not that much interested, get interested." He believed that science teachers should try to connect students' hands-on experiences with the theories from textbooks to engage students otherwise not interested in science or able to understand science. He also believed that teachers should aspire to relate scientific phenomena to the student's everyday world to prevent students becoming intimidated by doing science. He believed that if he could spark curiosity toward the world around the students, they would carry this curiosity with them even after they graduated. Victor believed that the specific scientific knowledge students gained in school would not be nearly as important for the students after they graduated as the curiosity he hoped to inspire in them and he expected that such curiosity would be lasting. Consequently, he believed that curiosity would make students want to understand scientific issues and make informed decision about them.

Core Statements

Table 1 shows core statements of each science teachers.

Table 1: List of core statements

Teacher	Core statement
Mette	Science evolves all the time and therefore teachers have to develop to be able to use different ways of teaching to retain students' interest in science and to help them see connections between different phenomena.
Mikkel	Science teachers need to be able to apply different approaches to teaching science to stimulate students' curiosity, which is what science is all about.
Ida	Curiosity is the most important outcome of science lessons because it drives students to continue to ask questions and find answers – even after graduation.
Laura	The goal of science education is to make students curious about and motivated for science for them to develop the competencies to discover, investigate, draw conclusions, and discuss all kinds of issues in the future.
Emil	It is important for students to learn what scientists have discovered, how natural phenomena interact with each other, and discuss such connections in school as well as outside school.
Victor	Teachers need to support students' interest in science as well as to help them understand and use science by linking their everyday world to the world of science so that students are able to relate to science in the future.

The six core statements of science teachers revealed that students' "curiosity" and/or "interest" seemed to play an important role in the teachers' SSB. We therefore examined each teacher's data again to explore all so-called "natural units" in the analysis where the words curiosity or interest appeared. What follows here is a discussion of the way the teachers expressed their beliefs regarding student curiosity and interest.

DISCUSSION

Curiosity and Interest as a Common Theme

Ida, Laura, Mikkel, and Victor used the word "curiosity" to describe what they believed to be the most important thing for students to learn through science. Ida emphasized the word curiosity throughout the interview and explained that curiosity meant not to "settle" for a given answer but to keep asking questions and pursuing further answers. Ida explained that being curious was a part of what made people enjoy science. Furthermore, by nourishing a continuous curiosity for the world around them, they could acquire a good basic understanding of science that would serve them well in their future. Similar to Ida, Laura explained that she believed curiosity to be what drove people to investigate the world and make discoveries. She said that it was important for her, that her students were curious when they started in her science classes because this enabled them to acquire key competencies such as being able to conduct investigations and experiments, problem-solving, drawing informed conclusions, and being able to discuss further steps in an investigation. Mikkel described curiosity as the quality that made people want to find answers, get new perspectives, and make a difference and he wanted his students to pursue truth through science. For him, the job as a science teacher was all about stimulating the students' curiosity and making science interesting for them. This coincides with Loewenstein's (1994) review on psychological research about curiosity. He explained that "curiosity arises from the landscape of an individual's pre-existing interests." Victor described that he believed that science teachers needed to be curious themselves to be able to create "hooks" (by this he meant references to issues or phenomena from their everyday life) that could help students link pre-existing interests with the science being taught. The first thing Victor learned as a science teacher was that every student is different and that he therefore needed many different "hooks" to engage them all in science. Mette (and to some extent Mikkel) used the word "interest" rather than curiosity to explain what she believed to be an important factor for students learning science. Emil was the only teacher who did not talk about curiosity or interest in the interviews. For him, the most important aspect of teaching science was to help the students connect their life experiences and with what was taught in science. In this way, Emil's beliefs were similar to Victor's in that they both believed that students need to be able to relate to what was taught in science to learn science.

Curiosity and Interest and Learning Science

A belief shared by five of the six teachers in the study was that curiosity and interest were some of the most important factors in motivating students to learn science. They consequently expressed how they tried to stimulate student interest and curiosity through their teaching. In doing so, the teachers used the words curiosity and interest more or less interchangeably, but these concepts are treated differently in the literature. For example, curiosity has been shown to be a situational phenomenon that plays an important role in establishing interest (Spektor-Levy et al., 2011), and Krapp and Prenzel (2011) argue that interest is a stable motivational state necessary for effective learning in science. Krapp and Prenzel (ibid.) distinguish between various forms of interest and one particular form of interest is content-specific interest which they say can enrich one's scientific knowledge and help people to "acquire and implement inquiry skills" and might "contribute to the development of positive attitude toward science." This concept resonates with what the teachers expressed in this study. Some of the teachers (Mette, Mikkel, Laura, and Ida) believed that the most important thing in science was to acquire curiosity and interest – even more important than gaining specific scientific knowledge. They believed that as long as their students had an interest in science, they would also develop competencies that would allow them to continue learning science. Loewenstein's study from 1994 seems to give merits to these beliefs: "Because curiosity is more likely to occur and will tend to be stronger as information is accumulated, interest, in effect, primes the pump of curiosity." Similarly, Silvia (2008) has explained that interest is part of what she calls "knowledge emotion." His summary of previous publications concluded that "as a source of intrinsic motivation, interest plays a powerful role in the growth of knowledge and expertise." In this sense, the teachers' belief that prioritizing that students acquire an interest in science over specific scientific knowledge and skills seems justified as all the teachers seem more focused on providing more general and life-long education in science rather than preparing their students for a career in science.

Beliefs about the Development of Curiosity and Interest

The data showed an interesting difference between the teachers' SSB with regard to whether they believed that curiosity and interest could be developed by the teachers through good teaching or whether it was something that had to be intrinsic to the students. Mette and Mikkel believed that students' interest toward science could be developed through good teaching. Mette used herself as an example and explained that she was not interested in science in school. However, when she was studying to become a teacher, she found mathematics and science to be interesting and acquired an "intuitive understanding" for it. Subsequently, she became interested in science. Based on her own experience, she believed that the students could learn to appreciate science as long as they could be brought to believe in their own abilities. Therefore, she tried continuously to work with the students in her class that were not interested in science. Mikkel was also motivated to teach science because he enjoyed seeing students' interests toward science grow. Contrary to Mette, Mikkel was good at science when he was a child. After he became a science teacher, he had a student who told him that he hated science. This motivated Mikkel to try different ways to engage the student and in the end, he saw the student "transformed" into someone who was good at science and enjoyed learning science. Unlike Mette, who established her belief that teachers could change students' attitudes based on her personal experience before becoming a science teacher, Mikkel got motivated to help students develop an interest in science after he became a science teacher. Both Mette and Mikkel believed that teachers could help students become interested in science.

In contrast, Laura believed that such interest (or curiosity as it were) needed to be developed earlier. She said that younger students in grade 5 or 6 were often more curious than the older students. This led her to believe that if she could help nurture curiosity from grade 5 and up, it could lead to better student learning as well. She also explained that in her experience, it was much more difficult to teach students science if they did not already have an innate curiosity that she received from the students in grade 7. Like Mette and Mikkel, Laura believed that interest or curiosity could be developed through good teaching, but at the same time she believed that it was much harder to develop once the students reached 7th grade. Similarly, Ida believed that primary school was where students' interests were developed, but she believed that it was possible to inspire curiosity in the older students as well. In fact, that was one of the reasons why she chose to become a science teacher. However, Ida explained that a few months before her interview, she had had to give up on a student who had a negative attitude toward science no matter how she had tried to engage the student. Ida explained that her motivation toward teaching science was to share her joy of learning science, but based on her recent experience, she now believed that some students simply could not be helped.

Helping students make connections or links to increase curiosity and interest also seemed to be an important part of several of the teachers' SSB. These teachers believed that making connections was important – especially for students who were not that interested in science. With such students, the teachers made special efforts to put scientific knowledge into perspective for the students. For example, Mikkel used examples from students' everyday lives and related them to scientific knowledge in his science teaching. By helping students realize that science was a part of their everyday life, he hoped that students would become interested in science. Victor also talked about the importance of making connections between the textbooks that he used and hands-on activities to create hooks for his students. Emil believed that it was important to help students make connections between what the students have learned previously and what they are learning in the current classes because the students rarely were able to make such connections themselves.

CONCLUSION

In the preceding, we have described the SSB of 6 Danish science teachers using a phenomenological approach. These science teachers studied showed surprising commonalities in their SSB regarding the importance of curiosity and interest. While the teachers had differing opinions regarding the nature and development of students' interest or curiosity, most of them seemed to agree that interest and curiosity were the most important factors in getting students to learn science.

This result raises the question of how we might adapt these SSBs for integrated STEM education. The challenge with SSBs in the context of STEM education is not just about overcoming disciplinary boundaries but about cultivating science teachers' core beliefs that align naturally with STEM principles. Research by Kelly et al. (2020) showed that teachers often feel less confident when teaching outside their subject expertise. To address this, they suggest creating a collaborative community of practice to enhance teachers' self-efficacy in integrated STEM teaching.

Stohlmann et al. (2012) argue that integrated STEM activities enable teachers to focus on big ideas that integrate subjects. This study highlights the potential of leveraging existing SSBs to facilitate a smoother transition towards integrated STEM education, rather than solely focusing on changing or re-educating science teachers. By fostering awareness of SSBs and providing a collaborative community of practice, we can more effectively develop teachers professionally.

Since teachers come from diverse backgrounds, it is crucial for schools to offer support and time for collaborative efforts. While interdisciplinary perspectives are essential for STEM education, it is important to align these with teachers' existing beliefs about student learning. By starting with teachers' current practices and showing how these can integrate into STEM frameworks, we make the transition more relevant and impactful.

For further implication for future research, it is necessary to offer collaborative training programs that allow teachers to reflect on their current beliefs and explore how these can evolve to support STEM education. Establishing a strong foundation in teachers' beliefs about STEM education will ultimately lead to more effective and meaningful integration of these concepts into their STEM teaching practices. Research on such practises as well as its evaluation is expected in the future.

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