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Norwegian Teacher Educators' Reflections on Inquiry-Based Teaching and Learning in Science Teacher Education

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ABSTRACT

Inquiry-based science education (IBSE) has been a key element in science education for the past decade and should therefore be a key element of pre-service teacher (PST) education as well. This study aims to explore how IBSE is implemented in teacher education for primary and lower secondary levels (years 1–10) to prepare PSTs for their professional practice as science teachers. This is explored through an interview study conducted at seven teacher education institutions in Norway. The results reveal that teacher educators implement IBSE in different ways and to different extents. In the interviews, they discuss the use of various scaffolding models and describe specific examples of teaching activities and how they included literature and mandatory work in addition to reflections on the opportunities and challenges related to IBSE in teacher education. Based on these results, we examine three issues related to the implementation of IBSE: 1) how IBSE is implemented (whether science teacher educators prioritize giving PSTs experience in inquiry-based methods in the learner role or the teacher role), 2) how often IBSE is implemented (whether educators focus on single examples or have a plan for progression), and 3) the intention of IBSE implementation (whether IBSE is taught as a product or a process). Based on these issues, we provide recommendations for how IBSE can be implemented in science teacher education.

KEYWORDS

Inquiry-based science education; pre-service teachers; science teacher educators; teacher education

Introduction

Inquiry-based science education (IBSE) is promoted in official policy and curriculum documents and in science education research literature (Crawford, 2014; National Research Council, 1996, 2001; Rocard et al., 2007; Rönnebeck et al., 2016). This is also the case in the Norwegian context, in which IBSE has a prominent role in the newest curriculum (Norwegian Directorate for Education and Training, 2019). IBSE emphasizes students' own interests and stimulates active learning by enabling them to conduct their own investigations. It is a recommended approach for school science teaching because it can provide students with key knowledge and skills in science and contribute to motivation (Crawford, 2014).

Previous studies have highlighted the importance of sufficient teacher guidance when students conduct inquiry (Bjønness & Kolstø, 2015; Furtak et al., 2012; Hmelo-Silver et al., 2006). However, studies have reported that teachers lack experience in and knowledge of

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how to conduct it (Asay & Orgill, 2010); therefore, inquiry should be part of teacher education. Crawford and Capps (2018, p. 29) give the following recommendations on how IBSE should be implemented in teacher education:

> We need to provide teachers (both prospective and practicing teachers) with rich, integrated, and authentic science experiences; in which to engage as learners. In addition, we need to scaffold teachers in how to reflect on these experiences, through which teachers can more fully develop their cognition for engaging students in scientific practices.

Thus, pre-service teachers (PSTs) need to learn through IBSE to experience it themselves and learn how to teach it in their future profession. This is in accordance with our recommendation in a systematic review of how IBSE is used in PST education (Strat et al., 2022). In this review, we recommend designing an entire teacher education program with a focus on leading PSTs through a progression from learning through inquiry-based activities to teaching through inquiry.

Research has shown that teachers and PSTs tend to teach the way they are taught (Britzman, 2003; Weld & Funk, 2005); therefore, modeling is emphasized (Lunenberg et al., 2007). When teacher educators model research-based teaching approaches, PSTs are offered a chance to learn science the same way that their students are expected to learn it and be introduced to activities that they can use in their teaching (Lunenberg et al., 2007; Rojas et al., 2021). Many PSTs enter teacher education without having experienced IBSE (Windschitl, 2003). Therefore, teacher educators need to model IBSE for PSTs to experience it.

The knowledge base of science teacher educators' perspectives on how IBSE is implemented in teacher education is limited. In Australia, Fitzgerald et al. (2021) explore primary science teacher educators' practices and perspectives on IBSE and emphasize that PSTs should be involved in IBSE as both learners and teachers. Nevertheless, there is still a lack of empirical studies from other countries. Therefore, by attempting to address this gap in the literature, the present study examines how IBSE is implemented in Norwegian teacher education to prepare PSTs for their professional practice as science teachers. This is explored through an interview study with teacher educators for primary and lower secondary levels (years 1–10). We pose the following research questions: 1) How do science teacher educators describe their use of IBSE in teacher education programs? 2) What opportunities and challenges related to IBSE are highlighted by teacher educators?

Theoretical background

IBSE is grounded on the ideas of Dewey (1938), who founded the concept of inquiry in experience: doing and then reflecting on what happened. In the 1990s, IBSE returned to prominence through the National Science Education Standards in the United States (National Research Council, 1996, 2001, 2012). Currently, it is the recommended approach to teaching science in school (Aditomo & Klieme, 2020; Adler et al., 2018; Crawford, 2014).

Crawford (2014, p. 515) defines IBSE as a process that

> involves engaging students in using critical thinking skills, which includes asking questions, designing and carrying out investigations, interpreting data as evidence, creating arguments, building models, and communicating findings in the pursuit of deepening [one's] understanding by using logic and evidence about the natural world.

This definition refers to a learning process in which students are actively engaged in understanding scientific concepts, processes, and the nature of science (NOS), and that is in accordance with scientific practices. The National Research Council (2012) has identified eight scientific practices of the inquiry process: 1) asking questions, 2) developing and using models, 3) planning and carrying out investigations, 4) analyzing and interpreting data, 5) using mathematics and computational thinking, 6) constructing explanations, 7) engaging in argument for evidence, and 8) obtaining, evaluating, and communicating information. Scientific practices have become prevalent and are often used synonymously with IBSE (Crawford, 2014; National Research Council, 2012; Rönnebeck et al., 2016). However, according to Gericke et al. (2022), scientific practices keep the focus on students engaging in "real science," whereas IBSE is related more to a pedagogical approach. In the following section, we present the use intentions for the approaches to IBSE in teacher education and previous research on IBSE in teacher education.

Intentions for including IBSE in teacher education

Bybee (2000) highlights three intentions for including inquiry in education. The first intention infers that learners should increase their understanding of the inquiry process by focusing on conceptual and procedural knowledge (Bybee, 2000). Conceptual knowledge involves learning about scientific phenomena and how science is created, while procedural knowledge focuses on letting learners study how to conduct inquiry as a process (Furtak et al., 2012).

The second intention describes how learners develop certain cognitive abilities while conducting inquiry (Bybee, 2000). These abilities are known as 21st-century skills (OECD, 2018), examples of which are system thinking, problem solving, creativity, critical thinking, and collaboration skills. These skills are not new, but learners need to acquire them to be able to handle the complexity of modern societies (Haug & Mork, 2021).

The third intention considers inquiry to be a pedagogical strategy (Bybee (2000), Constantinou et al. (2018), and Rocard et al. (2007) describe IBSE as an inductive approach and teachers as those who give learners space and structure for observation, experimentation, and construction of knowledge. Learners play an active role in building knowledge rather than passively receiving lectures from educators (Crawford, 2014).

Approaches to IBSE in teacher education

There are different approaches to implementing IBSE in science teacher education at different levels. At the macro level, Anderson (2002) differentiates between scientific inquiry, inquiry learning, and inquiry teaching. *Scientific inquiry* refers to researchers applying scientific methods to conduct research on natural science. *Inquiry learning* (hereafter inquiry-based learning [IBL]) describes the process in which learners work with inquiry-based methods to understand scientific concepts and processes and the NOS. *Inquiry teaching* (hereafter inquiry-based teaching [IBT]) describes the variety of ways teachers or teacher educators use inquiry as a pedagogical tool (Anderson, 2002).

On a more detailed level, an inquiry-based activity can be organized with different degrees of freedom and guidance for learners in the inquiry process (Banchi & Bell, 2008). "Degrees of freedom" distinguishes between whether learners derive questions and design and carry out investigations on unknown results and whether the questions, procedures, and/or results are known by the educator. Trna et al. (2012) recommend that PSTs should experience inquiry-based activities with all degrees of freedom during their time in teacher education.

Other approaches to IBSE are the various scaffolding models for teachers, such as the 5E model (Bybee et al., 2006) and Seeds of Science/Roots of Reading (Barber et al., 2007). The 5E model is a framework for conducting IBL through five phases: engage, explore, explain, elaborate, and evaluate. Bybee et al. (2006) argue that, by using this approach, "individuals redefine, reorganize, elaborate, and change their initial concepts through interaction with their environment, other individuals, or both" (p. 11). Seeds of Science/Roots of Reading, is a model developed in the United States that has been adapted to the Norwegian context (Ødegaard et al., 2015). This model can be summed up by four slogans—Do it, Talk it, Read it, and Write it—, and it engages learners in learning science concepts in depth while explicitly teaching them to read, write, and discuss as scientists do (Barber et al., 2007).

Regardless of approach, PSTs need to gain experience in IBSE during teacher education (Crawford & Capps, 2018), relate IBSE to their future classrooms (Syer et al., 2013), and reflect on educational choices related to degrees of freedom and models—where they are appropriate and why (Duncan et al., 2010; Trna et al., 2012). To do so, sufficient teaching time is required, as the process of advancing from the initial views of learning to more complex conceptions of teaching is a slow and demanding process (Rivero et al., 2011).

Previous research on IBSE in teacher education

There has been increased interest in how IBSE is conducted in science teacher education over the past 20 years (Strat et al., 2022), and studies have highlighted the importance of PSTs gaining ownership of IBSE (Baxter et al., 2004; Syer et al., 2013; Varma et al., 2009). A common suggestion is for PSTs to experience IBSE as learners before practicing it in the teacher role (Crawford & Capps, 2018; Stuchlikova et al., 2013; Trna et al., 2012). Several studies have focused on IBL and the different perspectives on its implementation in teacher education (Strat et al., 2022). Some studies have examined how the use of IBL can lead to an increase in PSTs' conceptual knowledge (Nugent et al., 2012) and how inquiry-based activities can improve procedural skills, such as asking scientifically oriented questions (Cruz-Guzman et al., 2017). The pattern of these studies is that they refer to positive results related to conceptual understanding, science attitudes, inquiry skills, and self-efficacy.

Studies have also emphasized the importance of PSTs conducting IBT (Baxter et al., 2004; Syer et al., 2013; Varma et al., 2009). A suggested way to experience IBT is through microteaching. Zhou and Xu (2017) applied a microteaching study of IBSE in a methods course that allowed PSTs to implement inquiry teaching with their peers and reflect on this experience and their understanding of inquiry. They concluded that microteaching was a promising way to develop PSTs' understanding of inquiry and IBT skills (Zhou & Xu, 2017).

Another way for PSTs to conduct IBT is to implement it in school placement (Binns & Popp, 2013; Britner & Finson, 2005; Yoon et al., 2012). However, PSTs encounter challenges in connecting the theoretical perspectives they learn at university with the science teaching they experience in school placement (Del Greco et al., 2018; Fazio et al., 2010; Soprano & Yang, 2013). In Binns and Popp's (2013) study, PSTs had positive views of IBSE before school placement, but they found it difficult to implement because of a disconnection between what they had learned on campus and that in school placement. Therefore, it is important for teacher educators to bridge this gap (Fitzgerald, 2020; Herbert & Hobbs, 2018). Studies have attempted to address the theory–practice divide through co-learning (Gunckel & Wood, 2016) and co-teaching (Eick & Dias, 2005), in which the mentor teachers are involved in the learning process together with the PSTs. Another recommendation for managing the transition between IBL and IBT is to include reflection sessions after conducting IBL for PSTs to develop individually as inquiry-based teachers (Baxter et al., 2004; Duncan et al., 2010) and to make connections between the campus-based and school placement experiences of their education (Morrison, 2008). Regardless of the approach, it is recommended to make an integrated progression from conducting IBL to planning IBT (Baxter et al., 2004; Duncan et al., 2010). When PSTs experience such progression, they gain mastery and build up their ownership of and self-efficacy in IBT (e.g., Soprano & Yang, 2013).

Among the studies on the role of teacher educators in IBSE, the Australian study of Fitzgerald et al. (2021) explored primary science teacher educators' practices and perspectives on IBSE. They identified the following themes: 1) developing scientific skills and practices, 2) reigniting positive attitudes toward learning science, 3) modeling IBSE, 4) experiencing hands-on inquiry, and 5) using real-life questions and challenges as a context for IBSE. These themes have been identified to provide a meaningful approach to IBSE in teacher education, and they will be compared to our results in the Discussion section.

Method

This qualitative study explores how Norwegian science teacher educators working in teacher education for primary and lower secondary levels (years 1–10) report on their implementation of IBSE. In the following sections, we describe the context of the study, the participants, the data collection, and how the data were analyzed.

Context of the study and participants

The Norwegian teacher education programs for primary and lower secondary levels became master's-based in 2017 (Norwegian Ministry of Education and Research, 2017). There are 13 institutions offering science teacher education at the primary and lower secondary levels, and seven of them offer a master's specialization in science education (Advisory Panel for Teacher Education, 2020). The programs comprise on-campus courses in subjects, subject education and pedagogy, and teaching practice in schools. PSTs can choose three (i.e., lower secondary levels) or four (i.e., primary levels) subjects, and prior knowledge is not required. Thus, some PSTs have no education in science after the age of 16, while others have one or two years of specialization in chemistry, biology, and/or physics from high school.

In Norway, science is taught as a separate interdisciplinary subject (including chemistry, physics, biology, technology, and parts of geosciences) in years 1–11 and follows the curriculum given by the Norwegian Directorate for Education and Training (2019). The curriculum emphasizes both inquiry and scientific practices, and it is quite open, giving teachers flexibility in terms of planning. However, the number of hours devoted to the science subject in years 1–10 is quite low from an international perspective (Nilsen et al., 2021). In primary school, especially years 1–4, science is typically taught by the class teacher. Therefore, teachers' competence in science varies, with some having no formal education in science (Nilsen et al., 2021). In lower secondary school (years 8–10), science is taught by teachers who have specialized in science, either through the current program or through a master's degree in a science discipline and one year of pedagogical education.

Science teacher educators working in Norwegian teacher education institutions have diverse educational backgrounds. Some of them have a degree in science education, while most have a background in a specific subject discipline (e.g., physics or biology) and possess a master's degree and perhaps a Ph.D. in this subject (Jegstad et al., 2022). Therefore, they have different research backgrounds and foundations for teaching science education. Furthermore, the curricula for these programs are open and thus provide a large degree of freedom on how to include science content knowledge and science education.

The seven Norwegian institutions that offer a master's specialization in science education were selected for this study. The selection criterion for the individuals participating in the interviews was at least one year of work experience in teacher education. In total, 29 science teacher educators participated (14 males and 15 females). Two of the interviews had two and three participants, respectively, while the rest had four to six participants, all from the same institution. Before the actual interviews, the participants completed a questionnaire with background information. Figure 1(a–d) presents the background information of the participants, illustrating a spread in their subject background (although a predominance of biologists), teaching experience from teacher education, and teaching positions. Regarding

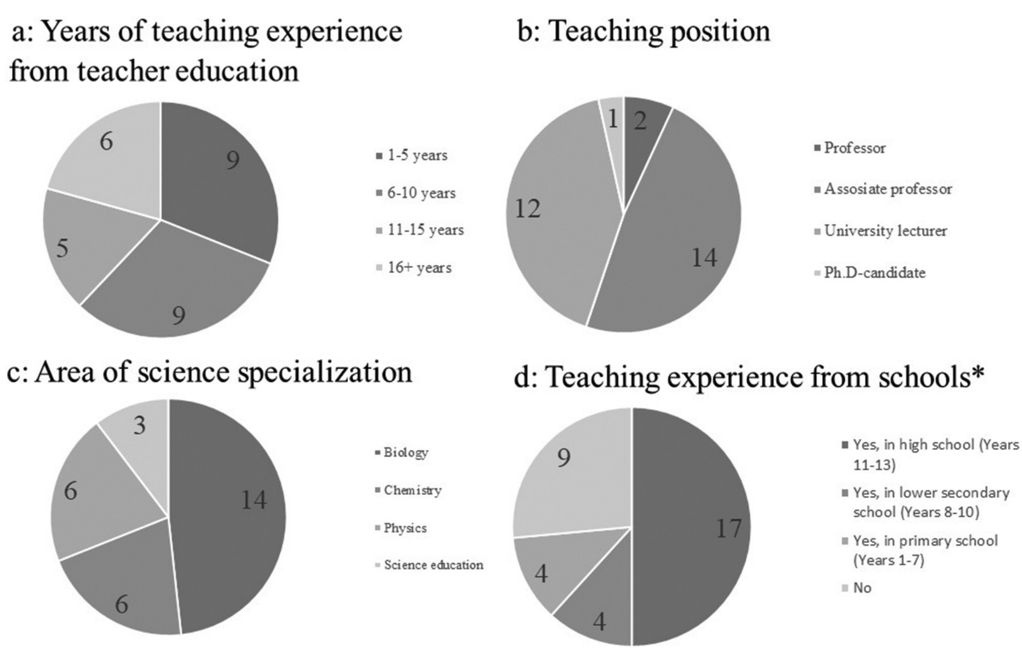

Figure 1. The three themes with their respective codes related to how the science teacher educators describe their use of IBSE in the teacher education programs.

their teaching experience in schools, half of the participants had experience in high schools, while about a quarter of them had experience in primary or lower secondary levels.

This study is part of a larger research project focusing on IBSE in science teacher education. Two of the institutions included in the data material are involved in this project, and the authors are employed as science teacher educators at one of the institutions. The study followed the general ethical standards approved by the Norwegian National Research Ethics Committees (approval number 924453). All participants signed an informed consent form, and the data material was anonymized in the process of transcription. The informants were given pseudonyms, starting with the letters A–G, related to institutions A–G (i.e., all informants from one institution starting with the same letter). To maintain the anonymity of the informants, all informants from one institution were given the same gender.

Data collection

Data were collected through focus group interviews (Cohen et al., 2018; Krueger & Casey, 2009). The teacher educators were recruited by sending e-mails to the leaders of the science education sections who forwarded the invitation to the teacher educators. The interviews were conducted from August 2020 to September 2021. Each interview lasted approximately 45 minutes and was recorded. Two of the interviews were conducted physically, while the rest were conducted digitally through Zoom due to COVID-19 restrictions.

The semi-structured focus group interviews were conducted in Norwegian by the first author and framed around the question of how science teacher educators implement IBSE. Specifically, the questions covered three topics: how they understand IBSE, in what ways they include it in their science teacher education programs and what they see as the benefits and challenges of IBSE in teacher education. The interview guide was piloted in two institutions. There was no need to adjust the interview guide after the pilot interviews because it was broad enough to understand how IBSE was implemented at the institutions. The two pilot interviews have therefore been included in the study.

Analysis

The interviews were transcribed and analyzed using the six phases of thematic analysis (Braun & Clarke, 2006, p. 87; Nowell et al., 2017). Table 1 presents these phases, along with specific examples from one of the themes.

Results

The results are presented in two sections according to the research questions. The first section addresses the first research question on how teacher educators describe their use of IBSE. The second section addresses the opportunities and challenges related to IBSE highlighted by the teacher educators in accordance with the second research question.

Table 1. Description of the phases in the thematic analysis (Braun & Clarke, 2006) with specific examples from one of the themes.

Phase 1 *Familiarizing yourself with your data*	The interviews were transcribed in Norwegian by the authors. During the transcription, small words and stuttering were excluded from the data material because they were not considered necessary to maintain the content of the phrases. Both authors read and double-checked the transcripts before coding.
Phase 2 *Generating initial codes*	To ensure consistency, the transcripts were coded jointly by the two authors, with open discussions on the content of the initial codes. This open-coding procedure resulted in the first draft of a coding book. Although coding was performed inductively, the theory of IBSE (both theoretical and methodological) helped label the codes. Two examples of initial codes are "open inquiry" and "5E."
Phase 3 *Searching for themes*	The authors discussed the codes and agreed on preliminary themes related to each research question. The initial code "open inquiry" was categorized under the preliminary theme "degrees of freedom," while "5E" was categorized under "scaffolding models."
Phase 4 *Reviewing the themes*	The preliminary themes and initial codes were revised to work in relation to each other. Some codes were grouped together, while others were moved to other/separate themes. The themes were checked in terms of the coded extracts, and a revision and specification of the themes were carried out. Preliminary themes, such as "degree of freedom" and "scaffolding models," became codes and part of the theme of "teaching methods."
Phase 5 *Defining and naming the themes*	The themes were clearly defined, named, and related to one of the research questions. For example, the theme "teaching methods" was defined as "the teacher educators' descriptions of how they introduce/use different IBSE approaches in their teaching" and related to the first research question (i.e., how science teacher educators describe their use of IBSE in their programs).
Phase 6 *Producing the report*	In the results section, the data were presented according to the research questions, including overviews of the themes and related codes (see Figures 2 and 3). As the goal was to provide an overview of how teacher educators implement IBSE in teacher education, the results were jointly presented from all interviews. Authentic excerpts from the interviews were translated from Norwegian into English in a way that preserved the original intention and ensured the trustworthiness of the study (Elo et al., 2014). The translation was conducted jointly and double-checked to ensure quality.

Descriptions of how IBSE is used in science teacher education

When the teacher educators described their use of IBSE, three themes were identified: *pedagogical approaches to IBSE in teacher education programs, examples from the subject disciplines*, and *curriculum and assessment practices in teacher education programs*. Figure 2 presents an overview of the themes and their codes, which are explained in the following.

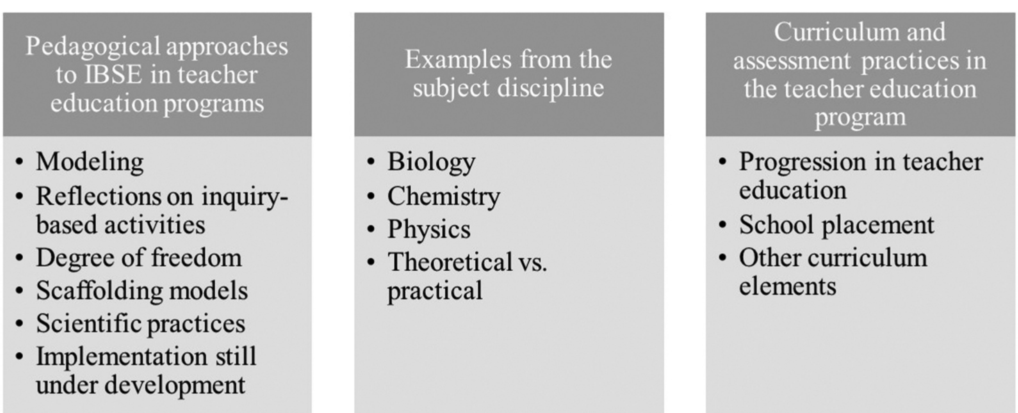

Figure 2. The four themes and codes according to what opportunities and challenges are highlighted by the teacher educators.

Pedagogical approaches to IBSE in teacher education programs

The first theme—the pedagogical approaches to IBSE in teacher education programs—concerns the descriptions of how the teacher educators introduced and used IBSE in their teaching. The interviews revealed that all the teacher educators included IBSE in their teaching, but the extent to which and the approaches to how IBSE was used differed between the institutions and the individual teacher educators. According to the teacher educators, they included inquiry-based activities in which the PSTs assumed the student role and the teacher educators *modeled* IBSE. Charlotte argued that the PTSs gained concept knowledge during such teaching, and she reflected on how these experiences could affect how and to what extent PSTs use inquiry-based methods as teachers. Danielle highlighted how modeling could exemplify how educators should guide learners during an inquiry-based activity: "[We need to] show them how to do it (. . .) not just talking about [it], but actually do it."

Teacher educators from some of the institutions considered the *reflections on inquiry-based activities* to support PSTs in how activities could be adapted to their future classroom. Elizabeth shared some of the questions she would ask her PSTs after conducting inquiry-based activities: "Let's now take a step back. Was this [activity] inquiry-based? In what ways? To what extent? What could have been done differently to make it (even more) inquiry-based?" The goal of these sessions was to increase PSTs' reflections on how to use and improve inquiry-based activities in their teaching. However, other teacher educators argued that such reflection sessions were seldom conducted. According to Frankie:

> But there is something different about trying to have a discussion about what the difference is between a closed [inquiry-based] activity and a more open activity. We have probably not had those discussions and have not talked about how we do this in school.

Others argued that they did not explicitly reflect on the activities together with the PSTs but rather assumed that they made this transition themselves when they entered the classroom.

The teacher educators also discussed the different aspects of IBSE. They stated that the PSTs were given experience in different *degrees of freedom* during their courses. Emma specifically described an activity in which the PSTs received the same equipment but different assignment texts with different degrees of freedom. She explained how the PSTs reflected on the activity afterward through teacher-led questions:

> What was the benefit of the first assignment, which was perhaps not inquiry-based at all? What was the benefit of the second assignment [that was inquiry-based]? What does that do to you as a student? (. . .) This often gives some good discussions.

Various *scaffolding models* were emphasized in the teaching methods. The 5E model and the models from Seeds of Science/Roots of Reading were some of the examples that the participants brought forward. Betty explained, "I think it is important to present different (. . .) models for IBSE, and that they reflect on the models, (. . .) and when they are appropriate."

The teacher educators pointed out the relationship between inquiry-based activities and *scientific practices*. They suggested that, during an inquiry-based activity, the PSTs could work with specific parts of the scientific working methods, such as forming a hypothesis, making an argument, or increasing trustworthiness.

Despite the efforts to include IBSE, some of the teacher educators emphasized that their *implementation was still under development*. According to Eleanor:

> We conduct parts of it. We do not necessarily do the whole process from the questions (. . .), but we make the parts inquiry-based by adding specific structures. So, we try, and I (. . .) think we are more aware of IBSE than we were five years ago, but it is still a learning process for us as well. What works with our PSTs? What doesn't work? (. . .) But being confident that the PSTs get the academic outcome through modeling is challenging.

Here, Eleanor pointed to the development that had taken place in science teacher education in Norway, in which the latest reform in teacher education programs and a more conscious focus on the education part of science education had led to the development of teaching in the programs. However, she also stressed the aspects of whether the PSTs learn enough content knowledge from working inquiry-based. This is an issue that we will touch on when discussing the portion on challenges in "challenges and opportunities related to IBSE."

Examples from the subject disciplines

The second theme—examples from the subject disciplines—includes examples of how teacher educators use IBSE in their programs. All examples were practical inquiry-based activities, and most were from biology or chemistry. Examples from *biology* included inquiring into ecosystems, exploring human senses and the nervous system, and animals' adaptions related to mammals' feet or birds' beaks. Gary described how they had made the task of dissecting a pig's heart more open:

> The PSTs get to handle a pig's heart with initially no tools. They need to touch, feel, smell, and use their senses. (. . .) They have to make a drawing of the heart, and preferably the circulatory system, before they compare [the drawings] in pairs, (. . .) pose one or more questions about things they are wondering about. (. . .) Furthermore, they discuss, "What are we going to find out here?" "How are we going to try to find an explanation for . . . " (. . .) before they can collect data. Then, we ask, "Did we discover any of it? And what conclusions can we draw from what we have done?"

This kind of inquiry was also described by educators from other institutions performing similar activities using the head of a caribou or an earthworm.

In *chemistry*, the examples included exploring the properties of liquids, the factors influencing the formation of rust, and precipitation reactions. Aaron described an inquiry-based activity focusing on precipitation and degrees of freedom:

> PSTs often struggle with precipitation reactions. Therefore, (. . .) I go to the fjord to fetch some seawater and ask them to find a precipitation reaction they can use to detect ions. (. . .) Actually, now I see that this is a great way to use degrees of freedom, (. . .) and they can comment on the activity (. . .) and how they should adapt it to their students.

For *physics*, only one specific example was given in two interviews: mathematical modeling by studying falling muffin cups. Experiments with Ohm's law were mentioned in two interviews, but no specifications were given.

Overall, the examples given in the interviews revealed that the PSTs mainly gained experience in IBSE in the student role by performing *practical activities*. They experienced practical activities in which they collected data, often with the aim of learning content knowledge. However, there were no examples showing how PSTs could perform inquiry-based work through *theoretical activities* to emphasize IBSE as a pedagogical approach in which learners are active in their knowledge construction outside practical activities. The teacher educators also gave few examples of how the PSTs used IBSE in the teacher role.

Curriculum and assessment practices in teacher education programs

The third theme—curriculum and assessment practices in teacher education programs—is related to how IBSE is implemented in teacher education from a more structural perspective, including school placement, literature on IBSE, mandatory work, and written assignments. In some institutions, the participants discussed a collective plan for how IBSE should be implemented to ensure conscious *progression*. According to Camilla, a participant in Institution C, "In course no. 1, we have a session with IBSE in which we focus on the 5E model and teach different descriptions of the term inquiry with some examples." Charlotte elaborated on how IBSE was included in later courses:

> In course no. 2, we have dedicated lessons with some literature on IBSE. Some of the lessons are not just "these are the tools you need" but also "how can you make this [inquiry-based activity] more inquiry-based?" (. . .) In course no. 5 (. . .) [the PSTs] make a teaching plan that they try out with their fellow PSTs, reflect on, and hopefully try out during their school placement.

This is an example of how IBSE was connected to a progression in which the PSTs first experienced IBSE in the learner role and thereafter conducted it in the teacher role during school placement. Conversely, teaching in other institutions was characterized by more individual practices, in which some emphasized IBSE, whereas others did not. The teacher educators in these institutions typically knew little about what was taught in other courses.

Some teacher educators explained that the PSTs were encouraged to implement IBSE during *school placement* as a part of their progression. However, at Institution D, they argued that IBSE was implemented to a lesser extent during school placement due to challenges in the mentor teachers' knowledge. Danielle expressed her concern: "The mentor teachers may not really know what IBSE is." Daphne remarked that in some of their courses, there was collaboration between schools and teacher education to deal with this challenge, but she did not describe how the collaboration was carried out.

As part of the progression, *other curricular elements* were highlighted by the teacher educators. They described elements such as literature on IBSE as a part of the required reading and mandatory work and IBSE as part of the summative assessment in teacher education programs. For most of the teacher educators, assessment practices were the most important way for the PSTs to experience IBSE in the teacher role. One of the educators stated that they had a mandatory task in which the PSTs made their own inquiry-based activities. These activities were collected in a booklet. In the next semester, the PSTs conducted these teaching activities for each other in groups. Some teacher educators also mentioned that many PSTs wrote their bachelor's and master's theses on IBSE.

Challenges and opportunities related to IBSE

Through the research question on the challenges and opportunities related to IBSE, four themes were identified: *understanding the concept of IBSE, learning outcomes from IBSE, structures*, and *roles*. Figure 3 provides an overview of the themes and codes related to them.

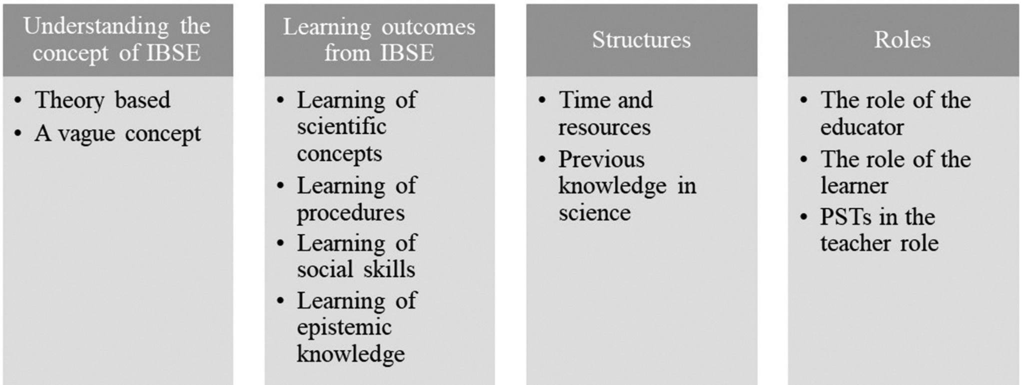

Figure 3. a-d: Background information of the participants. (*Some teacher educators have teaching experience from several school levels).

Understanding the concept of IBSE

This theme is related to the understandings of IBSE that emerged from the interviews. All interviews contributed a *theoretically based* definition of the concept that lays the foundation for the teaching methods. Several of these definitions were inspired by John Dewey. According to the teacher educators, IBSE is about "minds on, not just hands on" (Erica), and it is important to have " . . . the brain in activity" (Aaron). IBSE can be characterized by three essential aspects: asking questions, collecting data, and knowledge building. IBSE is "a light variant of research" (Danielle). However, some argued that IBSE is a complex concept that could be difficult to conceptualize. Some further described it as a *vague concept*. The teacher educators who described it as vague pointed to the challenge that many teachers equate practical work with IBSE. Danielle expounded on this viewpoint:

> If you ask schoolteachers who have worked for a few years, many will relate it [IBSE] to practical activities. They believe that to do something practical is to work inquiry-based, and this is not what we're trying to teach our PSTs.

The teacher educators also expressed uncertainty about whether non-practical work, such as a literature search, could be labeled IBSE. Some emphasized that reading only textbooks and conducting online queries were not necessarily inquiry-based, but if there were secondary data that PSTs could use to learn to discuss, argue, and reflect on, it would be IBSE.

Learning outcomes from IBSE

This theme covers the opportunities and challenges in the learning outcomes from IBSE. Regarding learning as an opportunity, the teacher educators emphasized the *learning of content knowledge* and the PSTs being "active in their own learning process" (Daphne) and "getting more ownership of the knowledge you receive than just having it served to you" (Elaine). They argued that increased ownership of learning gained through inquiry-based activities would increase engagement, curiosity, and motivation among the PSTs. The teacher educators also highlighted IBSE as important for other types of learning, such as *learning of procedures* and *learning of social skills* (e.g., collaboration). In some interviews, IBSE was related to the *learning of epistemic knowledge* and NOS. Felix argued, "They [PSTs] should learn about scientific practice and work on 'how do we achieve knowledge of the NOS.'"

However, some teacher educators were hesitant as to what extent PSTs should learn subject knowledge when conducting IBSE. Demi shared the following:

> I'm not convinced that they [the PSTs] learn more subject knowledge by working inquiry-based. (. . .) I think that they learn about NOS, the distinctiveness of science, to be active in their own learning process (. . .) [and] collaboration. I think that inquiry creates deep engagement, and engagement is central when it comes to learning. In this way, you can say that it facilitates learning. (. . .) So, they learn a lot, but when it comes to content knowledge, I'm skeptical, both from research and from my own experience.

Here, Demi considers IBSE to facilitate learning but not necessarily learning of content knowledge. This implies the use of IBSE to teach deductively, not as an inductive pedagogical strategy.

Structures

This theme discusses issues of *time and resources*. In all interviews, IBSE was referred to as a time-consuming method, especially in teacher education, with limited time allocated to teaching and with the need to teach both content knowledge and science education methods during this teaching time. According to Donna, "The reality is that IBSE is very resource-intensive, also when it comes to time. (. . .). It must occur within the given frames and resources, which is a big challenge." Aaron further pointed out, "We have a dilemma there. We know we should use it more, but in reality, there are a lot of traditional activities with detailed instructions." Therefore, the challenge caused by the time allocated to teaching affects the type of teaching and the teaching experiences that PSTs gain through their teacher education. The teacher educators discussed some solutions to how they could include IBSE without spending too much time, such as conducting simple rather than complicated experiments, focusing on different parts of an inquiry-based activity, or integrating flipped classrooms to provide time for more student-active learning methods.

Several teacher educators stressed the challenges related to the PSTs' *previous knowledge in science*. This is linked to the importance of PSTs being sufficiently confident in their content knowledge to include IBSE in their teaching, as well as the minimum knowledge needed to work inquiry-based as learners. Demi asserted the following:

> You often need some conceptual knowledge to be able to ask good questions. When they are completely blank about chemistry, it is difficult to work on asking good questions when they do not know what an atom, molecule, or element is. I think they must have some basic knowledge, at least to a certain extent, before they can start with more exciting inquiry-based activities.

This is consistent with Glenn's viewpoint that the limited background knowledge of the PSTs contributed to time pressure, as he needed to teach physics instead of physics education. "It's time consuming, but if all PSTs entered with physics knowledge from high school, I could spend my time working on physics education rather than rectilinear motion." Here, Glenn articulates the challenge that some PSTs have no science specialization from high school. This has implications for the teacher education program, as teaching has to start from scratch.

Roles

This theme refers to the *roles of both the educator and the learner*. George observed that being a tutor instead of a traditional knowledgeable teacher was difficult for science teachers.

> We see that it is difficult to deal with it as a teacher. Even experienced teachers find it difficult. Because it is a completely different teacher role than the one you usually have. (...) Other teachers who are not science teachers may be used to this kind of philosophical conversation, but for science teachers, this is usually a challenge.

The challenges related to the role of students were also discussed. The teacher educators elaborated on reports from teachers whose students were resistant to the method. Some of the teacher educators reported similar experiences with teacher education: the PSTs had been mostly exposed to traditional teaching and were more occupied with finding the correct answer than the process.

Another element specified in several of the interviews was the challenge in the PSTs' implementation of inquiry-based activities in *the teacher's role* during school placement. The participants emphasized that the PSTs did not dare to conduct IBSE as they would rather perform step-by-step experiments. Demi argued that this was due to difficulty: "I simply think it is a bit difficult for them. They are insecure professionally, so they may not dare try it out." These types of challenges led several of the participants to think of different solutions, such as mandatory work or including IBSE in the PSTs' school placement.

Discussion

This study aimed to explore how Norwegian science teacher educators implement IBSE in teacher education for primary and lower secondary levels to prepare PSTs for their professional practice as science teachers. Overall, the results revealed that the teacher educators included IBSE in their teaching but in different ways and to different extents. The teacher educators discussed various scaffolding models and gave specific examples of teaching activities and how they included literature and mandatory work related to IBSE.

Although the teacher educators considered IBSE an important teaching strategy and highlighted opportunities such as increased ownership of learning and engagement, curiosity, and motivation among the PSTs, they admitted that IBSE was given less priority than desired. They expressed concerns about IBSE being a time-consuming method, especially in teacher education with limited time allocated to teaching. They also pointed out the challenges related to the science backgrounds of PSTs and whether they learned subject knowledge through IBSE. Based on these findings, three issues were identified that could explain why IBSE is implemented less than desired: how IBSE is implemented, how often IBSE is implemented, and the intention of IBSE implementation. In what follows, the results from the study are discussed in relation to these three issues, followed by a discussion of our results compared to a similar study by Fitzgerald et al. (2021) and the limitations of our study.

First, regarding *how IBSE is implemented in science teacher education*, the teacher educators considered IBSE a major topic in science education, and some of them focused on how IBSE was included in their lessons. Most of the teacher educators provided the PSTs with experience in inquiry-based methods in the learner role (i.e., IBL (Anderson (2002)), but this is different from whether the PSTs gained experience in the teacher role (i.e., IBT

(Anderson (2002)). The inquiry-based activities exemplified were typically practical activities in which the PSTs themselves participated in IBL to learn scientific methods. These learning outcomes are related to scientific practices, which are important for gaining an understanding of how science is conducted (Crawford, 2014). IBL is also important from a modeling perspective, given that teachers tend to teach the way they themselves are taught (Britzman, 2003; Weld & Funk, 2005). However, PSTs need to connect their own experiences with IBL to facilitate IBT for students (Baxter et al., 2004; Varma et al., 2009). Studies have shown that PSTs struggle with this transfer (Baxter et al., 2004; Gunckel & Wood, 2016; Kang et al., 2013). One way to manage this transition more easily is to include reflection sessions after IBL (Baxter et al., 2004; Morrison, 2008). Some teacher educators discussed how they included such sessions after IBL, whereas others did not. Some assumed that the PSTs could perform this transfer themselves.

PSTs must also gain experience in IBT (Binns & Popp, 2013; Britner & Finson, 2005; Yerrick et al., 2008; Yoon et al., 2012). In the interviews, great variations were observed in the extent to which the teacher educators gave the PSTs experience in conducting IBT. Some teacher educators included IBT, such as allowing the PSTs to try out or make their own inquiry-based activities, which they conducted with each other in groups on campus. This is consistent with microteaching, which is a recommended method to provide PSTs experience in IBT (Zhou & Xu, 2017). Other teacher educators stated that IBT was part of the PSTs' school placement, which is a recommended way to empower PSTs to teach science (Fitzgerald, 2020) as long as they are given the opportunity (Fitzgerald et al., 2021). The inclusion of IBT during school placement also presents some challenges. The teacher educators expressed concern that the mentor teachers supervising the PSTs in school placement had little experience with IBSE. Studies have shown different ways of meeting these challenges, such as co-learning (Gunckel & Wood, 2016) and co-teaching (Eick & Dias, 2005). These approaches promote different strategies to obtain coherence among the different parts of the teacher education program.

Second, the issue of *how often IBSE is implemented* was based on the teacher educators' descriptions of the amount and progression of IBSE in their courses. Some institutions seemed to have individual IBSE practices, and the teacher educators typically focused on small, single IBL examples without conscious progression. They highlighted that IBSE is a time-consuming method, and that this, combined with the PSTs' lack of background knowledge in science, often resulted in lessons being based more on traditional teaching methods. According to the teacher educators, IBL was implemented to a lesser extent than they preferred, and they did not prioritize IBT. As mentioned above, some also assumed that the PSTs themselves made the transfer from IBL on campus to IBT in schools when they entered the classroom. However, changing PSTs' ideas and practices is a slow and demanding process (Rivero et al., 2011). Therefore, teacher educators should make a progression plan on how IBSE should be implemented effectively in specific and consecutive courses. This was implemented in some of the institutions, such as Institution C, where they had a conscious progression on how IBSE was implemented throughout the program to provide the PSTs varied experiences in IBL and IBT, consistent with the literature (Baxter et al., 2004; Duncan et al., 2010; Strat et al., 2022).

Third, the issue of *the intention of IBSE implementation* refers to whether inquiry is taught as a product or as a process. Inquiry taught as a product relates to PSTs receiving diverse opportunities to develop their procedural skills and understanding of science through the use of inquiry-based activities (Bybee, 2000). This can be related to Bybee's (2000) first two intentions for including inquiry in education, aiming for the development of conceptual or procedural knowledge (intention 1) and 21st-century skills (intention 2). Inquiry taught as a process, in the context of teacher education, refers to Bybee (2000) third intention: inquiry is used as a pedagogical approach in which learners have an inquiring attitude toward subject knowledge regardless of subject discipline (Bybee, 2000; Constantinou et al., 2018). When inquiry is used as a pedagogical approach, it also facilitates the development of 21st-century skills, consistent with intention 2.

Our results reveal that IBSE is mainly taught as a product. The examples from the subject disciplines, combined with the teacher educators' ideas about learning outcomes, indicate that IBSE is included in specific topics when the goal for inquiry-based activities is to gain experience in scientific practices or conceptual content. Teaching IBSE as a product is important because PSTs need to gain these experiences and take ownership of the IBSE approach to be sufficiently confident in using it in their future classroom (Stuchlikova et al., 2013). However, as a process, IBSE is also important, given that learners in inquiry-based lessons are actively engaged in constructing their own understanding (Furtak et al., 2012). The teacher educators' descriptions of how they strived to give PSTs a sufficient theoretical and practical foundation of the science concepts in their subjects, arguing that the PSTs lacked content knowledge and therefore could not work inquiry-based, indicate that the teacher educators emphasized scientific practices and deductive teaching and did not recognize IBSE as an inductive pedagogical approach (Gericke et al., 2022). This trend is slightly concerning, as IBSE does not necessarily require students to have content knowledge but rather to have an inquiry-based attitude to the topic (Crawford, 2014).

When comparing these three issues to the study of Fitzgerald et al. (2021), the findings in their study mainly emphasize our first and third issues. The participants in both studies asserted that teacher educators should model IBSE and that PSTs should experience hands-on inquiry to develop their motivation and scientific knowledge and skills. However, Fitzgerald et al. (2021) also stressed the use of real-life questions as a context for IBSE, an element that was not highlighted in our results. Other researchers have recommended context-based activities to achieve more effective education (Herranen et al., 2019), indicating that this aspect should also be considered in Norwegian teacher education.

This study has three limitations. The first limitation is the various topics addressed in the interviews. Although a semi-structured interview guide was prepared in advance, the conversations took different directions according to the participants' interests and viewpoints. However, Cohen et al. (2018) and Krueger and Casey (2009) argue that these viewpoints are necessary because they contribute broader perspectives on the themes. Nevertheless, this can make it difficult to capture the full range of how IBSE is implemented in the participants' teacher education within our time limit of 45 minutes. The second limitation is the group size in the interviews. We aimed for groups of four to six participants, as this size is recommended if the complexity of the topic and the participants' level of experience and passion about the topic are high (Krueger & Casey, 2009). However, two of the interviews had only two and three participants, respectively. This reduced the interactions between the participants, made the conversations more comparable to an in-depth interview (Cohen et al., 2018), and gave fewer perspectives on the topic. This is linked to the third limitation, which is teacher educators' decision to participate. Most teacher educators from smaller institutions tended to participate in interviews, which enabled them to describe how IBSE was implemented at the bachelor's and master's levels. Conversely, those from larger institutions seemed more arbitrarily selected, resulting in a lack of educators with teaching experience in all courses and subject disciplines. This might have led to a lack of perspectives on how IBSE was carried out in a particular teacher education. However, according to Krueger and Casey (2009), the intention of a focus group interview is to achieve saturation in the data, and three to four focus groups are usually enough to gain this saturation. Therefore, as our study conducted seven interviews, we could be considered to have attained saturation for our purposes.

Conclusion

IBSE has been promoted in school curricula worldwide (Crawford, 2014), and PSTs must be prepared for inquiry-based teaching through their teacher education (Fitzgerald et al., 2021). In this study, we explored how IBSE was implemented in Norwegian science teacher education at the primary and lower secondary levels. The interview results revealed that the implementation of IBSE is a complex process, and that different teacher education institutions and teacher educators implement IBSE in different ways and to different extents.

The teacher educators considered that IBSE is an important teaching strategy but also admitted that IBSE is given less priority than desired due to the challenges of limited teaching time and limited background knowledge of many PSTs. Based on this finding, three issues that could explain why IBSE is implemented in teacher education less than desired were identified and discussed. Accordingly, we present some recommendations. First, in accordance with other studies (e.g., Fitzgerald et al., 2021; Strat et al., 2022), *IBSE should be implemented with a dual focus* on PSTs as both learners and future teachers. To ensure this dual focus, there is a *need for longitudinal progression plans* for how IBSE can be introduced, exemplified, and reflected on in their programs to ensure that it is a recurring topic within the science teacher education program. There should also be a *balanced focus* between IBSE implemented as a product and that as a process, allowing PSTs to be active in their development of both knowledge and 21st-century skills.

The findings of our study contribute to the knowledge base on science teacher educators' perspectives on the implementation of IBSE in teacher education, thus supplementing the study conducted in the Australian context by Fitzgerald et al. (2021). However, as revealed by the teacher educators, the implementation of IBSE is still under development, and they are still in the learning process of how to implement it. Therefore, we also recommend that science teacher educators have platforms, both within an institution and between different institutions, on which they can discuss and develop their understanding of IBSE and how it can be implemented in teacher education.

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