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Mind the Gap Between Chemistry and Outdoor Education: Primary and Lower Secondary Preservice Teachers' Beliefs During an Outdoor-Based Introduction to Chemistry in Science Education

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ABSTRACT

Outdoor education is rarely used to teach chemistry, despite its potential benefits for students. This paper investigates preservice teachers' (PSTs) beliefs about the domain of chemistry in science education. Sixteen primary and lower secondary PSTs were asked to draw their perception of chemistry in science education and mind maps about outdoor education before being exposed to a novel, student-active approach. This approach introduced chemistry outside the classroom, demonstrating how outdoor environments can be used with students to learn about basic chemical concepts. Six participants were selected for in-depth interviews after the introduction. An abductive approach was applied to analyze the data. Results indicate that prior beliefs about teacher-centered laboratory activities dominate, with few links to everyday or natural phenomena. The interviews showed that these beliefs stem from secondary school experiences, often associated with challenges such as difficulties in remembering the content of experiments. Some PSTs had prior teaching experiences and wished to include the outdoor environment in their future teaching practice. These unique and diverse beliefs influenced direct encounters with chemical phenomena outdoors. Activities that created visible links between familiar phenomena and chemistry were embraced, especially if they solved prior challenges from school. Nevertheless, the diversity of outdoor phenomena led some PSTs to question their prior chemistry knowledge. This challenge may hinder future integration of outdoor activities unless these questions are addressed. The findings suggest that regularly incorporating chemistry related outdoor activities in teacher education may prove beneficial. However, reflecting on emerging challenges is essential.

KEYWORDS

Beliefs; chemical phenomena; chemistry education; outdoor education; science teacher education

Introduction

Research on outdoor education often shows positive effects from a student perspective, including learners' motivation, engagement, social skills, and learning (Becker et al., 2017; James & Williams, 2017; Larsen et al., 2017; Stevenson et al., 2021). Outdoor education in this context comprises formal, curriculum-based activities in school or higher education, which uses alternative learning arenas to the classroom, both nature and other local,

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informal environments like schoolyards (Waite, 2020). This approach is comparable to *science-oriented place-based education*, which emphasizes the use of relevant local contexts on the school ground and nearby surroundings (Buxton & Provenzo, 2011; Semken & Freeman, 2008). However, as place-based education may be associated with a strong focus on cultural, social, or political aspects (Yemini et al., 2023), this paper employs the more neutral term *outdoor education*, related to the Scandinavian term *uteskole* (Barfod et al., 2021).

Meanwhile, from the teacher's perspective, many challenges related to outdoor education appear, often hindering the teacher to carry out outdoor activities. Time, organization, lack of competence, and classroom management are the most prominent perceived challenges (Ayotte-Beaudet et al., 2017; Scott et al., 2015; Killengreen et al., 2023). Additionally, Buxton and Provenzo (2011) are concerned that science education in recent years is shifting toward generic laboratory science, neglecting local contexts, due to focus on standardized, international, and nationwide test-regimes.

Lack of integrated outdoor education has consequences for teacher education as well, with Subramaniam et al. (2018) finding beliefs among preservice science teachers (PSTs) that disconnect science content in outdoor settings from in-school science. In this context, Azam and Menon (2021) argue that teacher education needs to actively intervene, as mounting evidence suggests that science method courses emphasizing student-centered approaches and inquiry-based learning can change PSTs' beliefs from teacher-centered to student-centered views. This includes outdoor education, as visible in PSTs drawings about themselves as science teachers (Azam & Menon, 2021; Markic & Eilks, 2015). However, while biology and geology traditionally include fieldwork, this is not the case for chemistry (Poë, 2015).

Chemistry education is traditionally situated in the laboratory or classroom, often focused on teaching the declarative knowledge of the discipline (Freire et al., 2019; Hofstein & Kind, 2012). Consequently, outdoor education as an alternative method is not even mentioned in reviews about recent trends in chemistry education (Erduran & Akış, 2023; Teo et al., 2014). Likewise, chemistry is rarely discussed in outdoor science education reviews (Ayotte-Beaudet et al., 2017; Schilhab, 2021). However, modern science standards use chemistry more integrated as one of the central sciences to understand phenomena in nature and our everyday lives (NGSS, 2013; OECD, 2023). The Norwegian school system exemplifies this point. Here, all compulsory science education is integrated from grades one through eleven. Students can only choose specialized subjects like chemistry or biology during their final two years of high school if desired (Kunnskapsdepartementet, 2019).

As the notion of chemistry surrounding us everywhere is a critical perspective that potentially creates relevant school chemistry (Freire et al., 2019), no compelling reason exists why chemistry education should stay in the laboratory. The diversity of chemistry outdoors has been described as school relevant (Borrows, 2019; Forest & Rayne, 2009; Richards, 1968), which shows that, in principle, nothing stands in the way of integrating outdoor phenomena. However, many teachers remain skeptical to integrate outdoor chemistry into the standard science curriculum, perceiving it as a time-consuming additional activity (Sciortino & Mifsud, 2024). This corresponds to PSTs specializing in chemistry and physics that tend to hold more conservative views on science education compared to PSTs in biology or primary science (Markic & Eilks, 2015).

In higher education, Forest and Rayne (2009) found that course-related field trips fostered interest and motivation among chemistry students, while Höper and Köller (2018) and Jegstad et al. (2022) implemented outdoor chemistry activities in secondary teacher education, which both motivated PSTs and triggered chemistry-related talk outdoors. However, PSTs sometimes showed discrepancies when transferring such experiences to future teaching practices. These include considering challenges outdoors as valuable for their own chemistry learning but not appropriate for students or denying the suitability of the urban environment for outdoor education in general (Remmen et al., 2020).

Two gaps can be deduced from the presented literature that motivate the research questions below. First, existing research on beliefs in science education often focuses on overall course outcomes, not on beliefs specifically toward the domain of chemistry in science education. Additionally, studies on outdoor chemistry rarely delve into PSTs' beliefs. Second, teacher training programs traditionally introduce chemistry through lab work. While outdoor activities might be added later, they are rarely the foundation.

This study aims to bridge these gaps by investigating both PSTs' existing beliefs about chemistry in science education and their perceptions of learning basic chemistry through outdoor experiences. Therefore, an innovative teaching unit was developed, which departs from traditional approaches by commencing with student-centered outdoor activities. These introduce chemistry as an integral component of our everyday environment and aim at giving PSTs firsthand experience in how to teach chemistry in grades 1–7 across learning arenas, before continuing with theoretical knowledge in digital teaching units. PSTs beliefs are investigated by drawings and mind maps before, as well as in-depth interviews after the intervention. The following research questions are posed.

(1) Which beliefs toward chemistry in science education do PSTs express before having experienced an outdoor-based introduction to chemistry?
(2) How do PSTs explain their drawings of chemistry education and mind-maps on outdoor education after the introductory teaching unit?
(3) How do PSTs experience outdoor chemistry activities in light of their prior beliefs?

Theoretical framework

Alongside introductory literature on outdoor education, this study draws on the following theoretical underpinnings to inform the abductive analysis, especially of the drawings.

Preservice science teachers' beliefs

Belief is a broad term that includes both conscious and unconscious elements, such as long-term worldview, motivation, self-efficacy, interpretation of information, and prior personal experiences concerning a topic (Jones & Park, 2023). As beliefs are expressed through communication, action, and evaluation, different ways exist for approaching these. A frequently applied technique is the use of drawings, as these provide rich opportunities for analysis and make it easier to visualize unconscious elements (Minogue, 2010). This study utilizes and further develops the "Draw-a-science-teacher-test" (DASTT-C), one of the few validated instruments for measuring beliefs through drawings (Jones & Park, 2023; Thomas et al., 2001). In the original test, PSTs are asked to draw themselves as science

Table 1. DASTT-C categories, test-procedure and scoring results in this study ($N = 16$).

When analyzing a drawing following the principles of DASTT-C (Thomas et al., 2001), three different angles are in focus. The teacher, the students, and the learning arena itself. These are divided into 13 different categories, see below. For every category, a point is given if it depicts the teacher-centered view, but not if it shows a student-centered view instead.

Examples for teacher-centered situations: if the teacher is drawn centrally located ahead of the class, instead of advising individual students, a point is given. Likewise, several desks drawn in rows, facing in one direction indicate a teacher-centered view, see also Figure 1.

Examples for student-centered situations: Students sitting around tables with the teacher in the background indicates a student-centered view and does not give a point; likewise, perspectives that focus on students' faces, or the teacher supporting students in understanding (Minogue, 2010); see also Figure 2.

Angle		*13 Categories (shortly described by their teacher-centered view)*	*Number of drawings that scored teacher-centered in this study (N = 16)*
Teacher	Activity	Demonstrating experiments or activities	7
		Lecturing or giving directions	6
		Using visual aids like the blackboard, PSE …	6
	Position	Centrally located (head of class)	11
		Erect posture (not sitting or bending down)	11
Students	Activity	Watching and listening	4
		Responding to teacher or text questions	0
	Position	Seated (or suggested by seats)	6
"Environment"	The items, typically found inside the classroom	Desks in rows	7
		teacher's desk in front	7
		lab organization (Equipment on teacher's desk)	7
		symbols of teaching (Blackboard …)	10
		Symbols of science knowledge (PSE, equipment, lab instruments)	14

teachers, with additional prompts like: "What is the teacher doing? What are the students doing?" (Alkış Küçükaydın & Gökbulut, 2020; Azam & Menon, 2021; Minogue, 2010). The test's elements and analysis are described in detail in Table 1.

DASTT-C studies consistently show that PSTs often start with teacher-centered views and shift toward more student-centered beliefs during their first science methods courses (Buldur, 2017; Minogue, 2010). Larger shifts occur among those that have experienced strong teacher-centered science education in school, compared to those with student-centered experiences (Azam & Menon, 2021). Longitudinal studies suggest that these beliefs may not necessarily develop further during their second course (Ambusaidi & Al-Balushi, 2012). Furthermore, Markic and Eilks (2015) found PSTs in chemistry hold the most student-centered beliefs midways, while at the end of their studies, they were depicting more blended views. As the analysis in this paper targets chemistry within science education, it is necessary to clarify what distinguishes chemistry from science education in general (Taber, 2019).

Chemistry in science education

A central concept, unique for chemistry related education, is *the chemist's triplet* (Talanquer, 2022). It highlights the distinction between the macroscopic properties of substances and the submicroscopic particulate nature of matter and their various symbolic representations (Taber, 2019). However, a challenge for school chemistry has been identified as too much focus on disciplinary knowledge of submicro and symbolic details while neglecting the connection to macroscopic phenomena (Freire et al., 2019). This difficulty becomes especially relevant when engaging with real-life problems outside the classroom, where nothing is labeled (Poë, 2015). As the first years in school focus more on outdoor education than higher grades (Barfod et al., 2021; Waite, 2020), especially teachers in primary and lower secondary schools up to seventh grade should be able to understand basic chemistry in various learning arenas and explain these. Appropriate explanations in grade 1–7 include the macroscopic dimension and simple particle models (Kunnskapsdepartementet, 2019). However, Jegstad et al. (2022) found that only PSTs with extensive background knowledge in chemistry would link phenomena outdoors to submicro explanations without relying on authoritative sources as the textbook or teacher.

The challenge of linking phenomena to meaningful explanations poses a dilemma especially for primary and lower secondary school PSTs. Their formal background knowledge in Norway is typically limited to their own integrated science classes from school. Therefore, they often face a gap between the content knowledge they learn in teacher education, including the periodical table and Bohr's atomic model, and the simple representations they can use when teaching. Additionally, in the age of the Internet and social media, students and the PSTs themselves will meet a variety of chemical representations that are neither quality-checked nor adjusted to their understanding (Gilbert & Afonso, 2015).

Therefore, this complexity of symbols and models, should be discriminated in a greater detail, than the chemist's triplet provides (Taber, 2019). Water molecules, for instance, may be depicted as a pure symbol "H_2O," as an iconic stick-ball-model, which seek to model an actual natural property, or a formula that combines symbolic letters with iconic lines, representing electron-pair bonds, a quality that Talanquer (2022) calls the degree of *iconicity*. Since PSTs' drawings often include diverse symbols and icons for substances (Markic & Eilks, 2015), and selecting appropriate representations is crucial for their future teaching practice (Talanquer, 2022), this aspect will be included in the drawing analysis.

Additionally, as PSTs will teach across various grades, it's important to distinguish the level of detail in representations or their *granularity*. This refers to whether they depict macroscopic features, undifferentiated particles, or molecular details (Talanquer, 2022). The considerations in this section will guide the abductive approach toward the drawings.

Methods

Before presenting the teaching unit, participants, data collection and analysis, some information about the research context is provided to offer an understanding of the study's setting. This study is part of a larger project on a 5-year integrated master's program for PSTs qualifying them to teach in primary and lower-secondary schools (grades 1–7 in the US). Norwegian, math, and primary education dominate this curriculum, while two science courses are given during the first two years. This program addresses teacher shortages in rural Norway and utilizes a blended format, combining remote studies with digital and limited physical in-person meetings with focus on dialogue-based learning (e.g. Dysthe, 2002).

Epistemological grounding

As a socio-constructivist approach underpins the program, this study is situated within the interpretivist research paradigm (Treagust & Won, 2023). Being the sole researcher from science education, I played an active role throughout the research process, from the initial research idea to the final report, acknowledging that my own experiences influence the choice and interpretation of data. The results are therefore understood not as absolute truth but as "a sensible interpretation of the situation" (Treagust & Won, 2023). Here, my year-long experience as the participants' teacher prior to the study is considered beneficial, fostering a trusting collaboration during data collection. Equally relevant is my experience collaborating with other researchers in the field, utilizing similar data (e.g., Höper & Köller, 2018; Jegstad et al., 2022; Killengreen et al., 2023).

To mitigate potential researcher bias, two main steps were taken. First, triangulation and an abductive strategy to answer the research questions (Timmermans & Tavory, 2012), changing between theoretically guided deductive steps and inductive analyses. Transparency is provided by showing original drawings, the detailed method, context description, and various excerpts. Second, crucial steps in the analysis were discussed collaboratively. Given the study's and author's foothold in two different research groups, three researchers in the chemistry in science education group read an early draft of the analysis, while three colleagues from the blended learning group provided feedback on a late draft of the manuscript. Additionally, coding of the drawings was discussed with a colleague to avoid misinterpretations as discussed in Azam and Menon (2021). Similarly, categories for the mind maps were discussed together with the first author of Killengreen et al. (2023).

The teaching unit in its context

Science education in this program consists of two courses, spread across the first two years (2×15 ETCS credit points). In Norway, these courses encompass both an introduction to the disciplinary knowledge of science and the corresponding pedagogical content knowledge for teaching integrated science. Basic concepts of biology and geology were introduced during the first year, while chemistry and physics are central perspectives during the second. Outdoor activities are prioritized throughout the courses, incorporating place-based elements both at the campus and PSTs' hometowns, which aligns with the importance of such activities in blended learning programs (Korson, 2023). Table 2 describes the teaching unit developed for this study, which was placed at the beginning of year two in a physical meeting. The location adjacent to the shoreline is typical for many schools and universities in Scandinavia. Data collection occurred before, during and after the teaching unit, as depicted in Table 2.

Data collection and analysis

A triangulation of methods was chosen to increase the validity of the results.

Drawing chemistry in science education before the teaching unit

Inspired by the DASTT-C test (Thomas et al., 2001), a drawing assignment was given without guiding prompts to reduce leading clues. The intense focus on student-centered

Table 2. The student-active teaching unit in its context, including data collection.

First year Science course

Introduction to biology, geology, sustainable development, and their pedagogies/didactics, with a focus on outdoor education/place-based education

Second year science course

Introduction to chemistry and physics and their pedagogies/didactics, continued focus on outdoor education

Introductory teaching unit to chemistry at the beginning of year two:
Overarching learning objective: Chemistry as a domain of science to explain natural phenomena by focusing on the substances themselves and their properties; Pedagogical methods: Student-centered outdoor activities, concerning basic chemical concepts in the nearby outdoor environment.

Preparations in PSTs digital learning management system	Learning objectives	Data collection
1. Reflective assignment: Drawings	Reflection about prior beliefs	**Drawings**
2. Read introductory chapter in their chemistry education textbook + being prepared for outdoor learning: Remember to bring suitable clothing to the physical meeting	Chemistry around us, Chemistry in science education, Chemistry triplett; Basic concepts: pure substances vs. mixtures.	

Physical meeting on campus, located in an urban area adjacent to the shoreline.

	Time appr.	Content and PSTs main practical activities [double purpose: PSTs own learning and student-active model activity]	Learning arena Classroom	Learning arena outdoors	Learning objectives	Data collection
1	20 min.	Individual assignment: Mind-mapping potential outdoor science topics	X		Reflecting on outdoor education possibilities in science education in general	**Mind-maps**
2	30 min.	Chemistry—the magical science, rooted in nature: Teacher presents stiff clubmoss (Lycopodium annotinum, known from fieldwork in first year course) PST experiment: Lycopodium powder explosions; safety goggles		Campus outside the building	Substances can be harmless or dangerous, depending on their level of dispersion. Introduction to Health and safety measures	
3	40 min.	Introduction to risk-assessments Hazard symbols game: "Who am I?" PSTs get a hazard sticker on their forehead and guess in small groups	X	(x)	Health and safety: School-relevant hazard symbols on everyday chemicals in and around the classroom	
Break						
4	30 min.	PSTs in small groups observe and describe properties of 3 self-chosen substances around them on campus. Plenary discussion and summary in the classroom	X	Campus	The world around us consists of substances with different properties.	

(*Continued*)

Table 2. (Continued).

5	30 min.	The hunt for mixtures outdoors: A reflective, cognitive group activity outdoors. plenary presentation and discussion of selected substances outdoors		Campus; adjacent seaside pro-menade	Substances can be either pure or blended
Break					
6	60 min.	Inquiry-based Group-work: "Is water a pure substance?" –Hypotheses and planning of which equipment to transport and use outdoors –Collecting different water samples (rain, sea- and drinking water), –vaporizing samples outdoors on camping stoves, – observations		adjacent seaside pro-menade and shoreline;	- a reminder about inquiry-based strategies – Introduction to separation techniques – Health and safety instructions for gas burners/camping stoves
Break					
7	30 min.	-Short summary of the experiment groupwise; class dialogue –Teacher lecture: The chemistry triplett: macroscopic phenomena explained by the invisible submicro-level	X		A simple particle model for phases and phase-transitions
8	20 min.	Role-play—the whole class as particles in different phases		Campus-hall	Visualizing a simple particle model with different methods
Break					
9	60 min.	What is air and wind? Observations with all senses Student experiment with portable scales and syringes;	X	Campus	– Air consists of particles. – measuring air mass and comparing to vacuum

All activities include a short reflection about the chemistry content and perceived challenges for PSTs own learning, but the larger reflective session on how to transfer these to future teaching practices was postponed until the next digital meeting after the research interviews

After the physical meeting in PSTs digital learning management system:
Assignment: Document five mixtures and pure substances at home,
Chapter 2 and 3: health and safety, Particle models and their limitations,

Digital zoom-meeting	Data collection
Reflecting about the outdoor activities and prior beliefs toward chemistry in science education	**Individual research interviews**

education throughout PSTs' first year of study in all subjects could have been taken as a hint to draw what they expected to be the "right" picture. Without guidance, the PST had to choose the content and pedagogical focus independently. The following assignment was given prior to the teaching unit in their digital learning management system:

> We will begin the second-year science course by exploring the substances and materials around us, which belongs to the domain of chemistry. Please reflect about this topic by drawing what you associate with chemistry education. Explain your drawing on a separate sheet.

After initial screening and familiarizing with the drawings, DASTT-C-protocol (Thomas et al., 2001) was enacted, according to Table 1 in the theoretical framework. Additionally, the category "symbols of science" was differentiated, and chemistry related representations coded due to (Talanquer, 2022). To gain a more comprehensive understanding of the PSTs' beliefs beyond the perspective of chemistry in science education, the study collected additional data that explored their perspectives on outdoor education.

Drawing mind maps on outdoor education during the teaching unit

Before starting the outdoor activities, PSTs were asked to create mind maps about possible outdoor education activities, encompassing all fields of science education. In comparison to the drawing assignment, this language-based method asked for specific content. Considering the PSTs' exposure to outdoor education theory and practice in their first year, a language-based method was well-suited to delve into their current beliefs, as mind maps are powerful visualization tools supporting the development of creative associations between ideas toward a topic (Shi et al., 2023).

Mind maps were coded following the categorization in Killengreen et al. (2023). All distinct items were counted and assigned to either scientific disciplines, sustainable development (for instance, recycling activities), or other interdisciplinary topics. An item was interpreted as a topic or keyword, separated by either circles, spaces, lines, or arrows from each other.

Interview after the outdoor-focused introduction to chemistry

In addition to the initial data collection methods, six individual in-depth interviews were conducted to explore the origins of the PSTs' prior beliefs and their experiences with the teaching unit. The selection by the author was based on the distinction of drawings into three groups. It aimed to capture the range of perspectives evident in the drawings, similar to Markic and Eilks (2015) in their study of chemistry teachers' beliefs and included:

- Four from the large group of mainly teacher-centered drawings, including two strictly classroom-based drawings (Anne, Beatrix), one that depicted an alternative learning arena (Celine), and one that stood out by depicting extraordinarily many representations and various topics (Doris)
- The only student-centered drawing (Evelyn)
- One focused strongly on "symbols of science," omitting people and furniture (Felicity)

The interviews were semi-structured, happened some weeks after the teaching unit and lasted between 20–40 minutes, resulting in more than 2.5 hours of audio data. These interviews used stimulated recall, PSTs' own data, to trigger reflections about their beliefs (Barton, 2015):

(1) While looking at the drawing, the following central question were posed:
   - Explain exactly why you chose to draw these elements.

- Explain your experience of the introduction to chemistry.
- Prompts about the experienced outdoor activities if not spontaneously discussed.

(2) While reviewing the mind map: Explain your mind map and reflect on potential changes due to the introduction to chemistry.

The interviews were analyzed based on a guide for abductive thematic analysis (Thompson, 2022) as described in detail in Table 3.

Participants and research ethics

All enrolled PSTs in this course were female. Sixteen out of 18 agreed to participate in this study. Their formal background knowledge and experiences toward the domain of chemistry consists of integrated science education in school as part of the compulsory curriculum from grades 1–11. None of the PSTs had chosen to specialize in science subjects such as chemistry, biology or physics during their high school education or afterward. Below is a summary of the teaching experience and relative age of the six interviewed participants:

- Anne: No prior teaching experience, enrolled directly after high school.
- Beatrix: Substitute teaching in a 1-7 grade school while enrolled in the program, enrolled directly after high school.
- Celine: Substitute teacher in a 1-7 grade school while enrolled in the program, enrolled with a few years of prior teaching experience in that school.
- Doris: No prior teaching experience, enrolled directly after high school.
- Evelyn: No prior teaching experience, paused her education for a few years after high school before enrolling.
- Felicity: Former experience teaching grades 5-7 as a substitute teacher, paused some years before enrolling.

Names are fictional to maintain their anonymity. All participants consented individually to all data collection. The data collection was designed to disturb the PSTs' learning process only minimally and instead contribute to reflection activities. These steps were taken because this study is part of the larger project, designed to develop blended teacher education, in which the PSTs were asked to contribute as well. The study followed the strict ethical standards by the Norwegian National Research Ethics Committees (2022), approval nr. (SIKT Reg. nr. 245234).

Results

In this section, research questions one and two about the PSTs' prior beliefs toward chemistry in science education will be addressed by Findings 1–3. Findings 4 and 5 will provide insights about the third research question, regarding PSTs' perception of the outdoor activities.

Table 3. Description of how the abductive thematic analysis was performed, based on the eight steps in Thompson (2022).

Step 1	Transcription and familiarization	I transcribed the interviews verbatim, staying true to the actual speech, including non-verbal elements like pausing or sighing, thereby becoming familiar with the data. Parts of the interviews that were not related to the research questions were excluded, for example small talk, and organizational aspects. Thompson (2022) was chosen due to providing a more transparent abductive procedure, which seemed more feasible for avoiding researcher bias in this study, instead of the more open form of reflective thematic analysis of Braun et al. (2022).
Step 2	coding	For coding, the same abductive strategy was used as for the drawings. In the first round, I tried to apply relevant codes used in DASTT-C. These did not fathom the diversity of extensive, student-centered descriptions. Therefore, in the second round, inductive codes were added, remaining close to the raw data. As this resulted in more than 70 codes, these were partly merged, in comparison to both the research questions and research literature. Coding of selected excerpts was discussed with a colleague, which resulted in revised description and merging of codes.
Step 3	codebook	A codebook was compiled and revised after testing on parts of the data, resulting in 30 codes. Distinct comments about when to use and when not, to avoid overlap between codes were added, and all interviews were re-coded according to the codebook, as advised by Thompson (2022), for example: Code: *positive transfer of PST experiences to future practice* When to code: *If PST comments positively and explicitly link an outdoor activity from teacher education to possible future practice* When not to code: *If reservations are made; if unclear about which activity or other than teacher education; if not an explicit link, but only the activity is explained;* Example: *00:04:24 Beatrix: I liked the boiling of water. I thought that was nice. I think you can do that together with the students on a day trip to the shore and the like.*
Step 4	Development of themes	Themes were developed based on grouping the codes. Different themes were tried and dismissed if no consistent patterns were found. For example, no general connections between teacher- or student-centered perspectives vs. experiencing specific activities were found. Instead, in comparison to the research questions, the themes shown in Figure 7 in the results section were found. To ensure rigor and clarity in the analysis, an early draft of the manuscript was shared with three chemistry education colleagues. Following a research group discussion of the presented analysis, including code groupings and emergent themes, the manuscript was revised. This resulted in a more consistent application of the coding scheme and a clearer presentation of the identified themes.
Step 5 + 6	Theorizing and comparison of datasets	These themes were then discussed toward the aim of this paper, integrating the theoretical perspectives with prior beliefs (as expressed in drawings, mind maps and interviews), and PSTs' anticipation of the outdoor chemistry activities which resulted in a changed order of presentation.
Step 7	Data display	Following the advice of Thompson (2022), Figure 7 displays the thematic network analysis, showing three separate themes, confirming and extending the DASTT-C-based results, and showing the perception and potential transfer of outdoor activities as perceived by the PSTs. The main themes at a glance: – *PSTs' beliefs originate primarily in secondary school science, including elements of their own teaching experiences and expectations.* – *Appreciation of outdoor activities if PSTs perceive a direct link between a phenomenon and chemistry.* – *Inconclusive transfer of outdoor activities to future teaching practices if the diversity outdoors challenges PSTs' beliefs.*
Step 8	Writing up	The three themes, hereafter called Findings 3–5, are presented through thick descriptions of representative excerpts. A late draft of the complete manuscript was then read by three colleagues and discussed with the research group in blended learning.

Finding 1: chemistry education is mainly drawn as a teacher-centered laboratory activity

An initial review of PSTs' drawings showed a dominance of traditional classroom elements, supporting the use of DASTT-C categories (Thomas et al., 2001). The drawings were sorted according to the DASTT-C gradient (13 points = strong teacher-centered, 0 points = strong student-centered), with each DASTT-C category drawn in a teacher-centered view corresponding to one point, Table 1. This resulted in three distinct groups.

The largest group (see Figure 1), eleven of 16 drawings, usually locate the teacher in front of the class and students sitting in rows of chairs either with (Beatrix) or without (Anne) students. These elements are backed up by a range of teacher-centered categories. These drawings encompassed between 6 and 12 of 13 possible points. Celine is one of only two students who depicted different learning arenas. At the same time, she did not draw any chemistry-related symbols at all. This depiction starkly contrasts with Doris's, who drew explicit links between mostly correct iconical and symbolic chemical representations and a range of phenomena. However, her classroom shows the same, teacher-centered situation as all the other drawings in this group.

Only one drawing (Evelyn) depicts a strong student-centered perspective (3 points, see Figure 2). The students' faces become visible in detail, and a teacher encourages them to explain an experiment. This drawing is the only one showing differentiated emotions, with an enthusiastic boy and a girl seeking help. An association with cooking indicates that the student activities were recipe-style experiments.

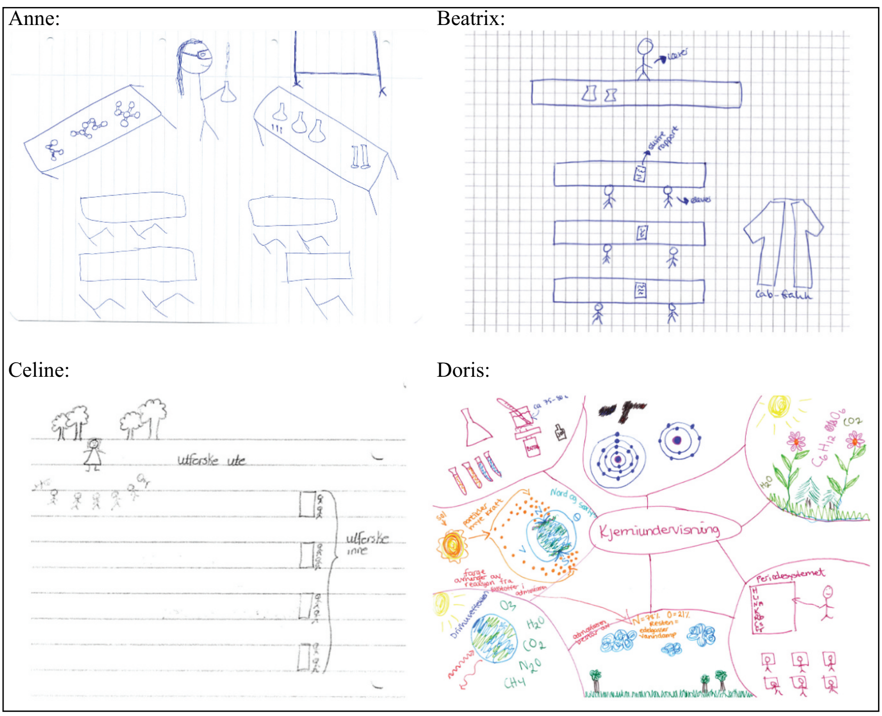

Figure 1. Four examples of teacher-centered drawings. Anne and Beatrix represent the majority of drawings among the participants in this study. Celine's drawing depicts to learning arenas. Doris depicts a classroom in addition to a view of chemistry as a central science to explain a variety of phenomena in the natural world.

Figure 2. The student-centered drawing of Evelyn, with a teacher asking students about their opinion. Norwegian text translates as follows: Teacher: "so, why do you think this happens …" Boy: "Wow!" Girl: "help … ".

Four drawings remain indecisive following DASTT-C, as these students did not draw any persons, focusing solely on science and chemistry-related artifacts. However, three of these drawings resemble classroom situations, similar to teacher-centered drawings like Anna and Beatrix. Felicity's drawing depicts more detailed chemistry content and an inquiry-based student activity with everyday life context (corrosion), as shown in Figure 3.

Through analyzing the drawings with DASTT-C, most PST drawings clearly associate chemistry education with teacher-centered classroom activities. However, they also show limitations of this test. "Symbols of science" is the most frequently depicted category (see Table 1), but it does not differentiate the chemistry-related elements. Therefore, a content analysis was conducted. Figure 4 provides an overview of all depicted symbols of science.

Laboratory equipment unrelated to everyday life dominates the list, followed by health and safety aspects such as protective goggles, lab coats and the Periodic Table of Elements. Objects related to the world outside the science classroom are rarely depicted. Only two drawings reference everyday objects like a sandwich and nails, and three drawings depict natural contexts like landscapes and phenomena like northern lights, a single plant-leave, or water. Following the theoretical framework, two chemistry-specific aspects in this category, "molecule models" and "chemical representations," were further analyzed.

Focusing on the differentiation of granularity in chemical representations (Talanquer, 2022), all students depict macroscopic artifacts, followed by atomic representations, Table 4. Comparing the iconicity of these representations, symbolic formulas of substances (for example, H_2O in Figure 3) were often correct, while iconic representations rather showed "fantasy molecules," for example, Anne in Figure 1. In 11 of 16 drawings, unconnected representations at different levels were pictured side-by-side. Felicity is the only one who depicts an inquiry-based experiment with corrosion and draws related representations from differentiated atomic models to the macro-level (see Figure 3). Doris (Figure 1) is the only PST who shows causal relationships between phenomena and their sub-microscopic representations. To investigate potential connections between the PSTs' prior beliefs about chemistry and their beliefs about using outdoor education, mind maps were analyzed.

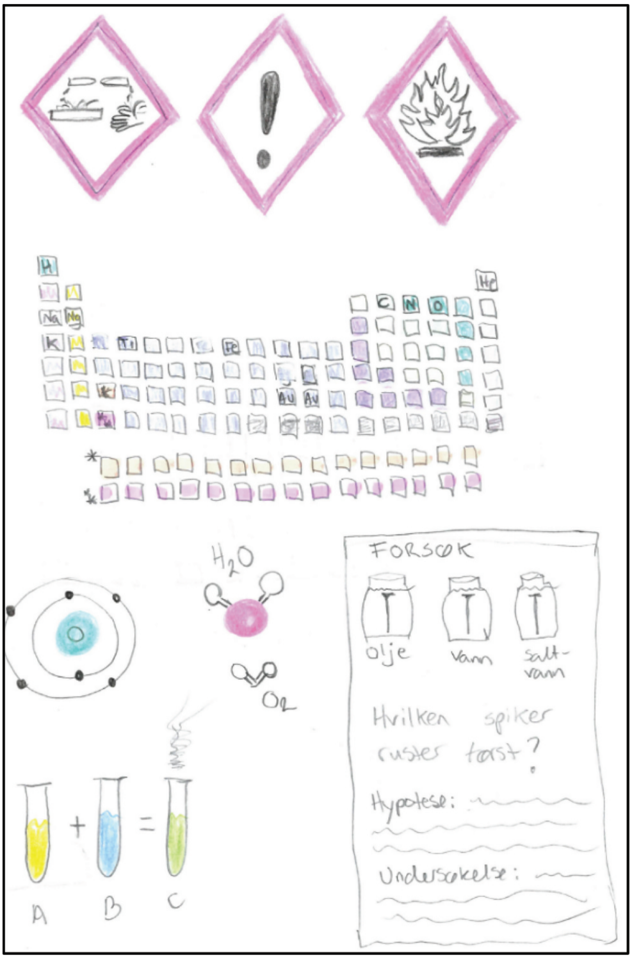

Figure 3. The "symbols of science"-centered drawing of Felicity; Norwegian text-elements: "experiment" "oil, water, saltwater" "which nail corrodes fastest?" different artifacts are depicted that all point to classroom-based chemistry, but without the classroom itself or people depicted.

Finding 2: chemistry is the least mentioned domain of science education in PSTs mind maps on outdoor education

The PSTs were asked to mind map all science topics they thought could be taught in an outdoor setting, see Beatrix's example in Figure 5. This reflective activity occurred while sitting in the classroom, with outdoor chemistry equipment within sight, informed about doing outdoor chemistry activities later. As expected, many mind map items aligned with the first-year focus on outdoor education. Most PSTs explicitly mapped various topics stemming from their own school experiences. All mind maps included biological aspects, as shown in Figure 6. A total of 190 distinct biology-related items were mentioned across all mind maps.

In contrast, chemistry is represented least, by eight items in five mind maps. These show a gradient from writing the word "chemistry" or "substance cycle" without

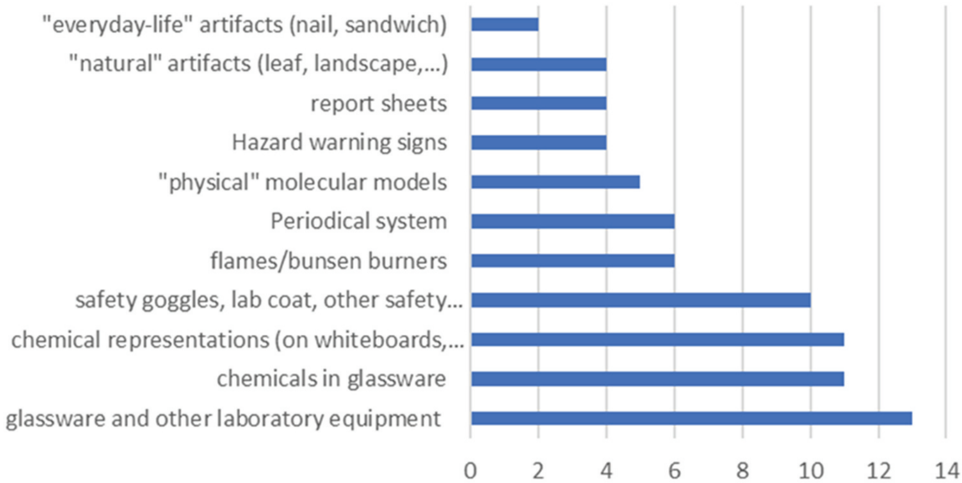

Figure 4. Content analysis of "symbols of science" and the number of drawings that include the respective classifications ($N = 16$). The artifacts were grouped in larger classes, for example physical objects like erlenmeyer flasks and beakers as glassware.

Table 4. Number of participants ($N = 16$ in total) that draw distinct chemical representations, categorized after relevant dimensions in Talanquer (2022).

Iconicity (to which degree show representations an artificial symbol (symbols), or try to model actual properties (icons)	
Icons (for example ball-stick models of molecules)	5
Blended symbol-icon (for example Lewis-formula)	1
Symbols (for example formulas like H_2O)	10
Granularity (how detailed the submicro level is expressed)	
Macro (observable artifacts representing chemistry, i.e. beakers with liquid)	16
Particulate (undifferentiated particles of substances, for example one circle for a particle which may be either a molecule, ion or atom)	1
Atomic (molecules, showing how atoms are connected by electron-pair bonds)	6
Electronic (atoms, showing details like electrons, protons, neutrons, for example in Bohr's atomic model)	4

further comment, keywords about experiments by Beatrix, to the outline of an experiment to analyze carbohydrates in nature by Doris as the most detailed comment on chemistry. The last one corresponds to her suggested laboratory experiment in her drawing (see Figure 1). Surprisingly, twice as many PSTs mention physics related activities about for instance gravity, or acceleration and speed, although this domain was not yet addressed.

Finding 3: PSTs' beliefs originate primarily in secondary school science, including elements of their own teaching experiences and expectations of university chemistry education

Throughout the interviews, the PST expressed beliefs about chemistry education, mostly confirming the elements in their drawings, but adding aspects that were previously hidden.

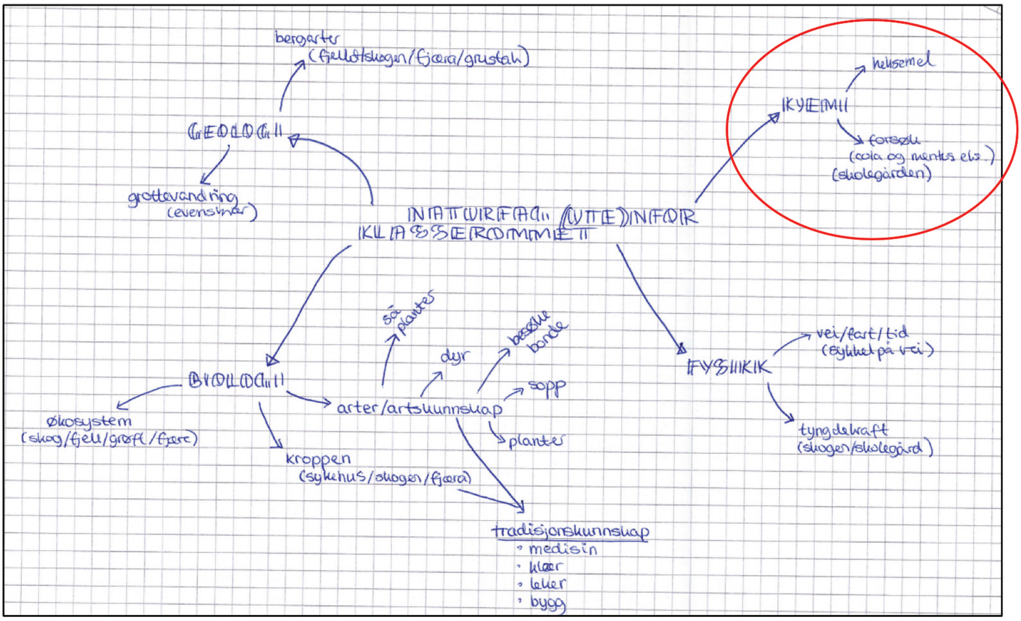

Figure 5. Beatrix's mind map about outdoor education in science. One of the comprehensive mind maps covering a wide variety of topics. The three chemistry items are encircled and translate as "chemistry," "witchflour" and "experiments (Coke and menthos exp.) (schoolyard)".

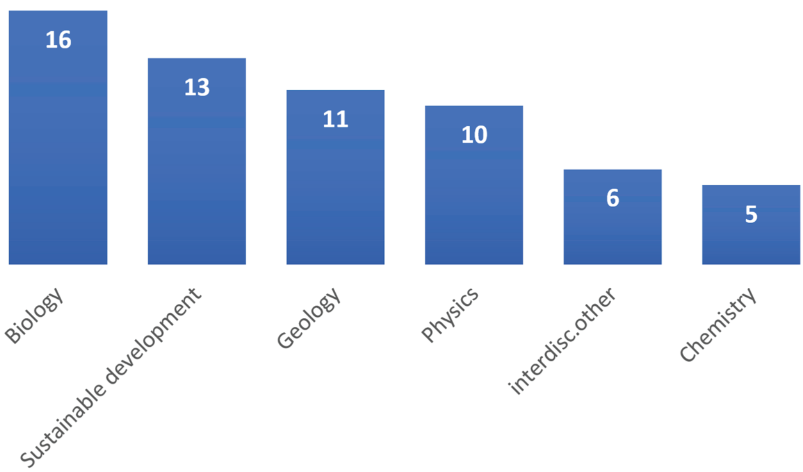

Figure 6. Number of mind-maps, containing items of the respective disciplinary categories. While biology, geology, physics, and chemistry represent classic science disciplines, sustainable development contains suggestions that are not clearly linked to one subject, but have a focus on sustainable development, such as collecting litter at the shoreline or sustainable energy sources. Other interdisciplinary topics contain suggestions like visiting the local history center.

The thematic network analysis of the interviews, which is the origin for Findings 3–5, is shown in Figure 7.

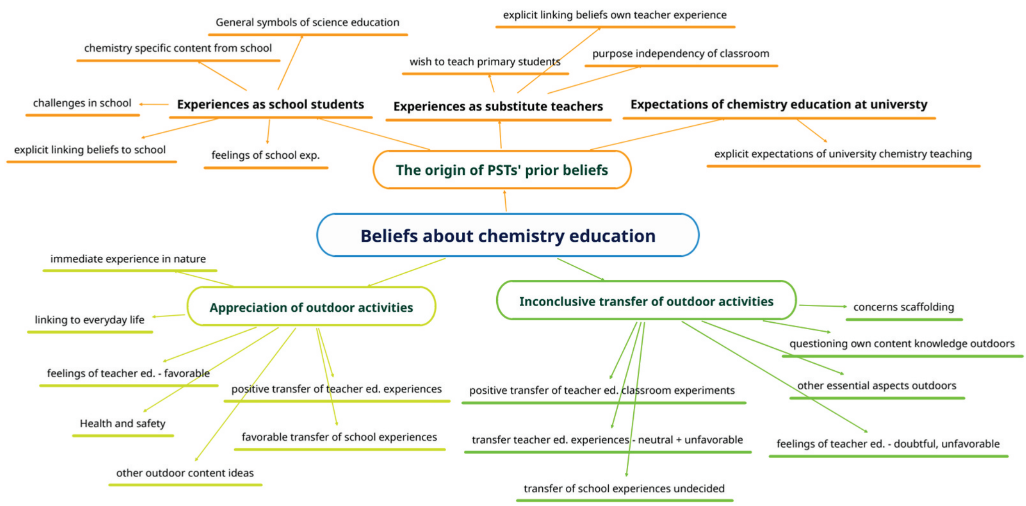

Figure 7. Thematic network analysis of the interviews. Codes responding to the research questions are displayed. Themes and sub-themes are marked bold.

School experiences depicted in the drawings

All PSTs identified student experiences in secondary school as central, specifically related to science courses in Grades 10 and 11 (which are given as integrated science in Norway).

> 00:01:01 Beatrix: What I associate with chemistry is, most of all, when we had science in grade 11. […] we did experiments, and we had to write reports, and that's sort of what we did. So, I don't have very good memories of chemistry, as what I remember was that we did so many experiments that were so similar. We made a salt bridge and lots of fun things, but I couldn't quite tell them apart.

The student perspective, largely absent from the initial drawings, became a central theme during the interviews. While hands-on activities were described by most PSTs, they were also directly linked to the perception of chemistry content as complex and difficult. This was particularly evident when PSTs attempted to connect their memories to specific concepts, as seen in the excerpt about the "salt bridge," a part of galvanic cells. Beatrix expressed difficulty because she perceived experiments as being similar, despite calling these "lots of fun things" in a resigned tone of voice. However, all PSTs reported slightly different challenges, occasionally accompanied by value-laden expressions as "I don't have very good memories," with Doris as an exception, who was satisfied with her school science education.

Experiences as substitute teachers depicted in the drawings

All three PSTs with teaching experience commented on their experiences and their wish to teach in primary school (grade 1–4) in the future. This desire included they would like to leave the classroom more often. While this aspect was not evident in Beatrix's drawing, Celine explained her teacher-centered drawing in Figure 1 in this way. She would like to go out related to chemistry but did not yet know how. Felicity explained that she did not draw a classroom in Figure 3 at all because she wanted to be independently of a specific setting. She added while looking at the rusty nail experiment in her drawing:

> 00:02:11 Felicity: Right, that was something we did in school that had to do with chemistry, and I remember it from when I taught fifth graders a few years ago. We made an experiment with nails, to see which one would rust the fastest. I don't recall if this happened in oil, water, or in salt. And then, we created some hypotheses.

Here, she links her drawing to her former teaching experience. This example extends beyond simply describing teacher or student activities, as most PSTs do. It indicates an inquiry-based activity, linking the corrosion phenomenon to beliefs about chemistry in science education.

Expectations of chemistry in science education at university

Some PST linked their experiences as students to their expectations of this introductory chemistry in their science course. This perspective was mainly expressed through teacher-centered classroom education, expecting traditional lectures. However, Celine links her expectation explicitly to first-year experiences:

> 00:02:53 Celine: I thought of chemistry as part of science education and that there would probably be a lot of exciting phenomena to see out in the forest and on the shore and everywhere, which I haven't really thought about; consequently, I could take out my students more if only I would gain a little more knowledge of chemistry.

Celine expressed this through an outdoor education situation in her drawing, Figure 1. Here, she explains why no chemistry-related elements were depicted. After mentioning her lack of subject-specific knowledge several times in the interview, she expressed her expectation of learning that would facilitate her linking these other areas to chemistry. This quote progresses to reflections on the outdoor activities the PSTs encountered during the introduction.

Finding 4: outdoor activities are appreciated when PSTs perceive a direct link between a phenomenon and chemistry

Throughout the interviews, different activities were positively commented on by PSTs. These comments often pointed out the advantage of first-hand experiences with phenomena.

> 00:09:20 Evelyn: I really liked the fact that we had to get that water ourselves from the sea by climbing down. Somehow it became cool. I fetched the water, we are going to boil it here and now, and suddenly salt appears. It was from that place, and we were the ones who fetched it. I was active in all the steps, instead of you [addressing directly the interviewer] would have come to the chemistry room with a bottle of saltwater.

Evelyn describes a positive feeling related to being involved in all steps of the experiment of vaporizing water. Direct presence at the place of the phenomenon and sampling the authentic substance are important to her. Furthermore, the temporal perspective, with all steps happening in sequence until a chemical substance is extracted, creates an authentic link from the phenomenon to chemistry education. She compares this situation with a hypothetical alternative of getting the substance presented in the classroom. This difference seems essential, as it was described by several PSTs similarly. They often compared this activity to concerns about their own student experiences highlighting the significance of the place itself.

Outdoor activities were also embraced, if PSTs perceived them as meaningful for better health and safety, or if they helped explaining a phenomenon on the submicro-level. In the following excerpt, Felicity refers to the drama activity, with the whole class of PSTs acting as particles after having observed phase-transitions outdoors.

> 00:18:35 Felicity: […] dramatizing how water particles move in the various phases or how they behave would be such a nice thing to do with students as well. Then you don't have to be in the classroom. You can be outside or in the gymnasium or, in whatever facilities you have, which is very different from school to school. This drama activity is very useful to understand: OK, the water particle is not gone when it's a gas. It's just about how the particle moves.

Felicity's statement highlights the contribution of this iconic representation, which for her intuitively explains the phase transitions observed while boiling water. Therefore, she is considering this distinct activity as worth trying out in school, and already reflects about how to perform this in yet unknown future schools. This is consistent with her explanation of not drawing a classroom, to be able to customize her teaching to suitable learning environments.

Finding 5: inconclusive transfer of outdoor activities to future teaching practices if the diversity outdoors challenges PSTs' beliefs

Even if Finding 4 provided examples in which PSTs embraced outdoor chemistry, the interviews also demonstrated tentativeness toward implementing outdoor activities in future teaching practice. Beatrix, for instance, who otherwise was very positive toward the activities, tentatively dismissed the quest for finding mixtures and pure substances outdoors.

> 00:08:53 Beatrix: I think it was very difficult for me. I still find it difficult to understand the difference between a mixed substance and a pure substance and how to know that it is a pure substance without thinking of it, like, "under a microscope." […] I read the chapter in the book, but I struggle to understand. So, before I were to have such an activity with my students, I would have to understand it properly by myself.

For Beatrix, it seemed crucial to understand chemical concepts correctly and how to explain this outdoors, before taking her class out of the classroom. She wished to know how a distinct phenomenon would be explained on a micro-level first. This relatively open activity, finding mixtures in the nearby outdoor environment, therefore, posed a challenge to her. Similarly, other contextual factors like weather conditions, classroom management, and timing are mentioned occasionally by different PSTs as manageable but possibly hindrances.

As a final example, a series of quotes might give an impression of how complex the individual decision-making toward outdoor chemistry is. Doris was the only PST who linked a variety of natural phenomena to chemistry in her drawings. At the same time, she drew a classic, teacher-centered classroom situation and was the only one who did not mention challenges originating from her time as a student. When asked to think about her drawing from the perspective of a future teacher, she spontaneously confirmed: "Yes, I think that I will teach chemistry exactly like this." As she did not mention any outdoor activities spontaneously, she was asked about how this relates to her recent PST experiences outdoors.

> 00:12:29 Doris: [pause for thought] I experienced that my brain started to think a lot. When we were going to find mixtures and pure substances, I started thinking: Are there invisible gases? Are they the pure substances? Because they are sort of alone? Are elements bound together when we see them? Like in water, there you have elements bound together, while we cannot see the noble gases, because they can be independent and alone. And then I thought: Is this a trick question?

The excerpt vividly portrays how the outdoor experience made her think, an aspect that she highlights throughout the interview as the most essential component of science education. At the same time, she suspected the teacher of giving "trick"-assignments outdoors when she was unsure how to link her theoretical knowledge to the situation. This became further visible when asked about the suggestion for an outdoor chemistry experiment on her mind map.

> 00:37:19 Doris: I think I would carry out what I have written here, yes, but I don't know if I really would have done it. I would have had to simplify based on whether it is the first grade or third grade or fifth or seventh.

Doris gradually started to argue with herself in her role as a future teacher, unsure if she would have enacted her own suggestions.

Discussion

This paper aimed to investigate PSTs' beliefs about chemistry in science education. The first section will synthesize Findings 1–3, focusing on the PSTs' prior beliefs. Then, the analysis will shift to explore PSTs' anticipation of the outdoor activities, based on Findings 4 & 5.

PSTs' prior beliefs rarely link chemistry with every-day phenomena and outdoor education

None of the PSTs reported prior experience with outdoor chemistry education during the interviews. Their drawings confirmed this, by primarily depicting a teacher-centered laboratory or classroom with instructors at the front and students seated in rows (Minogue, 2010). The limited number of drawings that contain everyday artifacts and alternative learning arenas further suggests that these PSTs rarely experienced connections to everyday life in their chemistry related education from school, a common challenge in Scandinavian countries (Broman et al., 2011). This is coherent with the traditional way chemistry is taught (Hofstein & Kind, 2012) and resembles findings about PSTs in science methods courses, which often lack experiences with student-centered approaches from school (Azam & Menon, 2021), despite these being advocated by current science education standards (OECD, 2023).

School related experiences posed challenges for the PSTs that, due to their interviews, often stemmed from practical activities, particularly those with outcomes that were difficult to understand or remember, a well-known issue in science education (Abrahams & Millar, 2008; Hofstein & Kind, 2012). The drawings support this argument by representations of common lab equipment with anonymous chemicals, along with submicroscopic representations that show a differing degree of granularity like molecules and single atoms. However, these elements are rarely linked with each other or the macroscopic elements. Additionally, iconic ball-stick models are sometimes technically wrong and do not illustrate realistic molecules but appear rather as generic "symbols of science" (Minogue, 2010), highlighting the difficulty for beginners to use these representations in a meaningful way (Talanquer, 2022). This aligns with arguments by Freire et al. (2019) and Buxton and Provenzo (2011) that science education overemphasizes scientific knowledge, neglecting connections to relevant, everyday phenomena.

While the drawings reflect rather traditional beliefs about chemistry education (Markic & Eilks, 2015), the mind maps on outdoor science education in general reveal a breadth of topics imagined by the PSTs (Finding 2). This aligns with research by Minogue (2010), Azam and Menon (2021) and Ambusaidi and Al-Balushi (2012), who have shown that beliefs often change significantly toward student-centered methods during the first science methods course. Thus, the mind maps, unlike the drawings focused on chemistry, reveal a much stronger anticipation of the first year's emphasis on student-centered outdoor education. However, consistent with research about outdoor education (Ayotte-Beaudet et al., 2017; Killengreen et al., 2023), most mind map topics are related to biology and sustainable development. This finding aligns with Subramaniam et al. (2018) who identified a lack of integration between outdoor education and in-school science beliefs, and ties this particularly to chemistry-related elements. It highlights the need for continued exposure to outdoor education across all science domains and throughout teacher education. Otherwise, PSTs may revert to their prior school-based beliefs in new contexts (Azam & Menon, 2021), as evidenced by most drawings in this study. Similarly, Markic and Eilks (2015) have shown that chemistry PSTs returned to more teacher-centered beliefs at the end of teacher training, compared to directly after a science course earlier in their studies, which focused on student-active methods.

A small number of drawings reveal interesting exceptions, which link chemistry to outdoor phenomena in their prior beliefs, while still showing a gap between chemistry and outdoor education. Doris's drawing depicts chemistry as a central science for explaining various natural phenomena, including a context-based experiment. However, she also drew a traditional, teacher-centered classroom, indicating that Doris holds different views of chemistry, simultaneously (Freire et al., 2019). Doris's drawing aligns with the notion that some students value chemistry's principal role in understanding scientific phenomena, finding greater motivation in intellectual challenges and abstract representations than in everyday contexts (Taber, 2015). Felicity, on the other hand, who previously worked as a substitute teacher, focused on these practical contexts and drew on her own teaching experiences. She deliberately omitted a classroom setting and would like to adapt future chemistry lessons to the local conditions and suitable learning environments, which aligns with the anticipation of place-based science education (Buxton & Provenzo, 2011). Celine's drawing further exemplifies this desire, as her drawing depicts an outdoor scene despite lacking explicit chemistry content. Her expressed hope to eventually understand the chemical aspects of outdoor phenomena aligns with Poë (2015) argument that connecting chemistry to outdoor contexts necessitates expert knowledge. The perception of the introductory teaching unit toward chemistry must be seen in light of these differing prior beliefs.

Outdoor chemistry is fostered if it provides direct links between chemistry and phenomena

The most prominent aspect in positive descriptions of the outdoor activities was a feeling of authenticity generated by understanding the significance of the nearby phenomenon for their own learning about water-chemistry (Finding 4). This is in line with literature toward other domains of outdoor education and the motivational aspects of outdoor environments as prerequisites for academic learning (Becker et al., 2017; James & Williams, 2017; Larsen et al., 2017; Semken & Freeman, 2008). It is comparable to how investigating carbohydrates outdoors motivated PSTs to learn more about chemistry and considering such activities for future teaching practice (Höper & Köller, 2018). However, sometimes PSTs chose outdoor places simply due to their practicability regarding health and safety, according to their interviews, which aligns with learning "in the place" rather than "from the place" (Yemini et al., 2023).

A wish to teach chemistry outdoors was often accompanied by a focus on future teaching in lower grades. This result aligns with the findings of Winje and Løndal (2021) and Scott et al. (2015) in biology education, as well as Barfod et al. (2021), who all found that outdoor education is more common in primary and lower secondary schools. However, these positive views were also related to prior unpleasant experiences from PSTs' own chemistry related science education in school. This aligns with Azam and Menon's (2021) findings using a pre-post test design of DASTT-C, where PSTs with negative experiences of traditional methods showed large shifts toward student-centered views.

The aspects above highlight the potential of outdoor chemistry if it manages to address and solve PSTs' concerns stemming from their own school chemistry experiences and creates visible links between ordinary phenomena and chemistry. However, this result applies only if the PSTs perceived that outdoor learning improved their understanding of chemistry or a specific phenomenon.

Contextual challenges may hinder future outdoor chemistry activities

Finding 5 indicates that the outdoor environment sometimes interfered with PSTs existing understanding of chemistry. Confronted with a larger and unfiltered diversity outdoors compared to the classroom (Poë, 2015), some PSTs perceived a lack of understanding when trying to answer the questions that the context provoked, consistent with findings about novices in context-based chemistry (Driel & Jong, 2015) and a general challenge for teachers regarding outdoor education (Ayotte-Beaudet et al., 2017). For example, the quest for finding pure substances or mixtures outside the classroom led Beatrix to dismiss the activity provisionally as possible to enact in her own teaching, due to uncertainties how to link the phenomena to not yet fully understood theoretical content. The situation, thus, created a learning need in line with Jegstad et al. (2022), and thereby supported reflections about content knowledge.

This self-critical transfer sheds light on discrepancies in PSTs' reflections about the potential of outdoor chemistry and the presumed link to beliefs (Remmen et al., 2020). In that study, some PSTs dismissed the possibility of integrating chemistry into outdoor education despite recently having experienced model activities as positive. Doris's interview resembles this finding. She linked chemical representations to natural phenomena in her drawing and suggested an outdoor experiment theoretically in her mind map. Yet she initially dismissed the possibility of teaching chemistry outdoors when asked about it in the interview, which corresponds to the teacher-centered classroom in her drawing. This highlights the findings of Broman et al. (2011) that secondary students appreciated teacher-centered chemistry education despite calling for more relevance to their lives. Doris's case aligns with Azam and Menon's (2021) findings about limited shifts toward more student-active beliefs among PSTs who were satisfied with their traditional school experiences. It also exemplifies why in-service teachers remain critical to enacting outdoor chemistry in secondary school (Sciortino & Mifsud, 2024). Outdoor chemistry faces several challenges simultaneously; the complexity of outdoor education (Ayotte-Beaudet et al., 2017) and the complexity and traditions of chemistry and its representations (Talanquer, 2022).

Additionally, some PSTs' expressed feelings suggest the influence of self-efficacy, a crucial factor for embracing or dismissing activities for future teaching (Jones & Park, 2023). Stevenson et al. (2021) have shown that female students' self-efficacy temporarily decreased despite increased science knowledge after outdoor science experiences. While their study focused on fifth graders, this gender-specific result may also be relevant here, as seen in Finding 5. Addressing this perceived lack of competence and reflecting on learning obtained through challenges in student-centered approaches is essential for promoting persistence (Stevenson et al., 2021). This aligns with Menon and Azam's (2021) findings of positive long-term effects for science self-efficacy in student-centered science methods courses.

Limitations

This paper is a first investigation of PSTs beliefs about chemistry in science education and how these might influence their perception of outdoor activities. Hence, this paper is limited to the main findings expressed by most participants. Other interesting individual aspects are only briefly discussed. As little was known about how the participants would express their beliefs beforehand, a triangulation based on three different data collection methods with open questions was used to validate the results and minimize potential bias.

The application of other methods, for example a pre-post test design, was discussed beforehand but not executed, as beliefs are long-lasting worldviews. The participants in this study may have perceived drawing again after the teaching unit as a strong hint to draw more nature-based, leading to biased pictures. However, following up with these PSTs in some years to determine whether the outdoor-based introduction may have contributed to lasting conceptual change will be interesting and valuable.

Conclusion

The analysis of PSTs' beliefs indicate that few connections exist between chemistry and outdoor education prior to the teaching unit, in line with research literature. Though, this gap may not necessarily hinder outdoor chemistry in science education. Instead, first-hand encounters with natural phenomena led PSTs to consider these for future teaching if they provide more meaningful access to understanding chemistry than prior school experiences.

However, the final decision to consider outdoor activities for future teaching practice seems complex, given that the same individuals dismissed some and endorsed other activities. These findings highlight the necessity of both introducing and reflecting on outdoor activities repeatedly throughout teacher education. These steps should parallel the progression through content knowledge so that initial challenges can be addressed and strategies to overcome these obstacles can be developed. Then, outdoor phenomena may emerge as valuable for PSTs, as indicated in their reflective interviews after the teaching unit.

The approach of starting with small outdoor activities focused on basic chemistry concepts could be a valuable strategy for other science educators as well, due to its feasibility. It addresses the time constraints faced by chemistry and science educators in schools and higher education, integrating outdoor learning seamlessly into existing curricula. Furthermore, it challenges the traditional focus on laboratory-based chemistry, promoting a more diverse and student-centered learning experience.

Suggestions for further research

Implications for further research concern how such an approach would be received in schools, in upper secondary teacher education and in gender-balanced groups. It is also necessary to investigate how outdoor activities could be integrated throughout a curriculum and to which degree PSTs in fully digitalized teacher education programs need scaffolding to experience such outdoor activities as meaningful. Furthermore, comparative studies should be conducted between countries where chemistry in secondary school is differentiated as a disciplinary subject versus chemistry in integrated science education.

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