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Qualifying the science experiences of young students through dialogue - A Norwegian lesson study

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Abstract: Practical and exploratory activities are an important part of science education. However, students' learning outcomes from such activities require more than just active participation; their experiences must be linked to scientific ideas. The purpose of this lesson study is to investigate the teacher–student dialogue after exploratory activities in a first-grade Norwegian classroom and examine how

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Eli Munkebye has completed her Ph.D. in science education and is an Associate Professor at the Norwegian University of Science and Technology, Department of Teacher Education. Her research focuses on sustainability education, critical thinking and student–teacher dialogue, with an emphasis on primary school. She teaches teacher education courses, at the master's level, about the nature of science, has co-authored textbooks in the subject of science for primary school and science for teacher education. For the last ten years, she has also been involved in a national education project for sustainability and has been a part of a project for primary schools on critical thinking in context of sustainable development for the last two years. The research reported in this paper relates to Munkebye's research interest that has a clear focus on the youngest children, i.e. the oldest pre-school children and pupils in primary and middle school, and their teachers and the teaching.

Ragnhild Lyngved Staberg has completed her Ph.D. in biology and science education and is an Associate Professor at Norwegian University of Science and Technology, Department of Teacher Education. Her research focuses on inquiry-based learning, teacher professional development, socio-scientific issues, critical thinking and education for sustainable development. She teaches teacher education courses mainly at the master's level and has co-authored textbooks in science, biology and biology education for primary school and teacher education. She has also been engaged in several science education projects at the regional, national and international levels over the last ten years, such as PRIMAS, Mascil, FaSMED, Inclusme, ENSITE, MOST and CriThiSE. The research reported in this paper relates to Stabergs' research group Scientific Literacy in School and Teacher Education.

PUBLIC INTEREST STATEMENT

Exploratory activities are considered important in science teaching in Norwegian schools, and based on the results of this paper, we claim that special consideration must be given to younger students during exploratory activities. When working with younger students, we suggest that teachers break the usual practice where the inquiry cycle's final phase is the consolidating phase. Promoting reflection related to the students' experiences while these are still fresh in their minds will make it easier for them to establish connections between the experiences and theory. Conducting shorter reflection phases closer to when the experiences are created might also help avoid losing time for the reflection phase.

teachers plan and facilitate this dialogue. Our conventional content analysis revealed that teachers' and researchers' objectives with regard to the reflection sequences were connected to students' dialogue, scientific dialogue, the content of the consolidation phases, the time given for reflection and the duration of the reflection. An analysis of the interactional factors that influence situation-related interest revealed a high level of social congruence among teachers but lower levels of cognitive congruence and subject-matter expertise. Through an initiative-response analysis, we found that the teachers have a strong dominance in the dialogue. To help young students grasp scientific ideas, we argue that reflective dialogues related to students' experiences and subject matter content need to take place immediately—almost at the same time as the experiences are created—instead of including consolidation as a separate final phase. Carrying out shorter reflection phases closer to the time when the experiences are created can help ensure that there is sufficient time for students' reflection.

Subjects: Primary/Elementary Education; Science; Thinking Skills; Teaching & Learning

Keywords: Primary education; science; experiences; dialogue; scaffolding; lesson study

1. Previous research

Practical and exploratory activities are an important component of science teaching in Norwegian schools and are characterised by the inclusion of exploratory elements such as exploring issues and collecting and consolidating data, in which questions are discussed in light of theory (Ministry of Education, 2020; Ødegaard et al., 2014; Olufsen et al., 2021). Practical and exploratory activities are also considered to strengthen students' learning in science (Abrahams & Millar, 2008; Hofstein, 2017). However, there is no agreement in the literature regarding whether exploratory activities yield better learning outcomes for students than more traditional teaching (e.g., Aktamis, Hiğde and Özden 2016; Jerrim et al., 2019). What we can establish is that for students to academically benefit from practical and exploratory activities requires more than just having active students (Abrahams & Millar, 2008; Osborne, 2015). Students must be guided (Hmelo-Silver et al., 2007) and challenged cognitively by promoting them to explain what is happening and helping them connect their observations to scientific ideas (Abrahams & Millar, 2008; Hofstein, 2017). Such consolidating phases of discussion and communication with others are often seen as a separate final phase of the inquiry cycle (Pedaste et al., 2015), which has also been confirmed by Norwegian studies (Ødegaard et al., 2014).

Norwegian studies show that practical activities in science are more prominent in primary schools than secondary schools (Karlsen et al., 2021; Klette, 2013; Ødegaard et al., 2014). Research has also revealed that surprisingly little time is set aside to support students' development of ideas during practical activities and that students' dialogue focuses mainly on the practical aspects of an activity (Abrahams & Millar, 2008). Further, Norwegian video studies show that the consolidating phases of discussion and communication are given little time, and the consolidation that is carried out is in the form of using data to draw conclusions rather than linking theory and practice (Karlsen et al., 2021; Kersting et al., 2021; Ødegaard et al., 2014).

Abrahams and Millar (2008) point out that practical work can be significantly improved by introducing scientific ideas during an activity and not just after (also see, Hofstein, 2017). According to Osborne (2015), to develop an understanding of an idea, one is required to talk, write and read about it and represent, draw or visualise it. Furthermore, results from various studies show that how one communicates with younger children is also of great importance for what learning opportunities and outcomes the child receives from the conversation (e.g., Gustavsson & Pramling, 2014).

An exploratory approach to learning in science emphasises the teacher's role as a facilitator, where the teacher, through dialogue, should guide students to construct their own knowledge (Furtak, 2006). On the other hand, Zhang and van Reet (2021), in their study on children between 5.5 to 7.5 years of age, found that a less restrained teacher role, where the teacher gave direct answers to students' questions, had a positive effect on the benefits students obtained from the practical activity. Only a limited number of studies have emphasised students' reflection in science inquiry learning (Runnel et al., 2013). In their systematic review, Akuma and Gaigher (2021) point to the necessity of future research to better support teachers with implementing inquiry-based practical work, and challenges associated with young children appear to be one of the factors that needs the most attention.

The purpose of this study is to investigate the teacher–student dialogue after exploratory activities for five-to-six-year-old students in a Norwegian classroom. We present the results from a lesson study cycle in which the theme was the sense of touch and the students completed two activities. The research questions were as follows:

(1) What characterises the teachers' and researchers' objectives for the reflection sequences?
(2) How do teachers support students' interest when students explore and reflect.
(3) What characterises the teacher–student dialogue in the reflection sequences that occur after exploratory activities?

2. Theoretical perspectives

The term "practical work" is used in different ways (Ferreira & Morais, 2020). In this study, we follow Millar's (2010) definition, which states that practical work includes any learning and teaching activity in which students work individually or in groups to observe or manipulate the objects or material they study. Practical work can be exploratory, which implies that students search for evidence to support their ideas and engage in critical and logical thinking (Ødegaard et al., 2014). Both of these can be a context for learning from which students gain experience and knowledge. Dewey (1938a) emphasises the continuity of experience, which he argues is linked to previous experiences and is important for future experiences; this gives the experience pedagogical value. Furthermore, Dewey (1938b) and Vygotsky and Cole (1978) highlight that learning does not take place solely within the individual, isolated from the outside world, but in an interplay between the learner and the social context in which the learning takes place, where language plays an important role. Here, the more competent other (often the teacher) plays an important role in scaffolding students through the use of language and other forms of communication. Dewey (1933) and Vygotsky and Cole (1978) emphasise, in particular, the role of the adult in children's learning.

2.1. Learning by doing and reflection

Dewey (1933) emphasises how important the learner's own activity is for learning and the responsibility of education to help students create vital experiences that require something beyond being handled by built-in habits. The handling of such vital experiences takes place through inquiry, where Dewey describes inquiry as an open and creative process as opposed to a series of steps (Lowery & Jenlink, 2019). The inquiry process involves reflective thinking, referred to by Dewey (1933, 3) as "the better way of thinking … that kind of thinking that consists in turning a subject over in the mind and giving it serious and consecutive consideration". Based on the work of Dewey, Rodgers (2002) emphasises the importance of reflection for understanding:

Reflection is a meaning-making process that moves a learner from one experience into the next with deeper understanding of its relationships with and connections to other experiences and ideas. It is the thread that makes continuity of learning possible, and ensures the progress of the individual and, ultimately, society. (Rodgers, 2002, 845).

We cannot expect that children, through exploration on their own, will be able to acquire the knowledge they need (Hatch, 2010).

2.2. Scaffolding

What support can the adult provide? With the intention of building a bridge between what students can do and what they are capable of doing (Vygotsky & Cole, 1978), Wertsch (1985) describes a starting point for communication between the learner and the more competent other at the interpsychological level. The communication requires intersubjectivity in the form of a shared understanding that is based on a common focus and the participants sharing some aspects of their definition of the situation. Wood et al. (1976) used the concept of scaffolding, a process through which an adult assists a child with a task that is outside of the child's capacity. The authors summarise this support in six points: (1) The adult must arouse the child's interest in the task and make them want to satisfy the requirements of the task. (2) The adult must reduce the degree of freedom. This means simplifying the task by reducing the number of operations required to perform the task. With such a reduction, the task becomes clearer for the child, who will then be able to more easily gauge if they have succeeded in meeting the task's requirements. The adult performs the operations that the child is unable to perform and allows the child to do what they are able to do. (3) The child's orientation towards the goal must be maintained. Disruptive factors may impede their interest in and motivation for the task. The adult must, therefore, guide the child in the right direction. Once the child has succeeded in something, they will not necessarily want to proceed with more complicated operations but, rather, continue with what has been mastered. Thus, there will be a need for the adult to be a driving force for the child. The adult's role will also be to facilitate children who either dare or find it worthwhile to take a risk and try out more complex operations. (4) The adult must, in various ways, direct the child's attention to critical factors in the task so that they become aware of any discrepancies between what has been done and what is considered correct. (5) The adult must control the child's frustration so that the problem solving is perceived as less stressful when supported by an adult. (6) The support must include the modelling of idealised solutions; this can include modelling parts of solutions or completing something that the child has started. Modelling implies an expectation that the child will imitate what has been modelled.

2.3. Factors in situated reflections

The students' and teachers' actions are situated in social practices, and our actions and understandings are part of the context, as they "include, create and recreate contexts" (Säljö, 2001, 38). Through Rotgans and Schmidt's (2011) three interactional factors, we see how teachers can influence the context to strengthen the students' interest, which, in turn, can promote their reflective processing of educative experiences.

Wood et al. (1976) report the students' interest as being decisive for their involvement in reflective dialogues. Dewey (1933) also considers the students' interest essential, as he claims that it is such interest that serves as the driving force for the processing of valuable vital experiences. Skalstad and Munkebye (2022) focused on students' interest in their video study of children (four to eight years old) as they examined adult support in different phases of exploratory activities in natural outdoor environments. The analysis used Rotgans and Schmidt's (2011) framework, which describes three interactional factors that influence situation-related interest in higher education: social congruence, cognitive congruence and subject-matter expertise.

Social congruence is an interactional quality of teachers in which they exhibit personal interest and care for their students and enable a good social climate and mutual respect between the students and themselves (Rotgans & Schmidt, 2011; Yew & Yong, 2014). This is also in line with the work of Loda et al. (2019), who found that social congruence is related to, for example, being interested in learners' academic workloads and daily lives. It has also been described as stimulating integration, interaction and individual accountability (Grave et al., 1998) and as respecting students' opinions, understanding their feelings and building good relationships with them (Kassab et al., 2006). Further, Xu et al. (2012) highlight the importance of having a caring and trusting atmosphere for promoting young students' interest in science.

Cognitive congruence refers to a teacher's ability to present content to students in terms with which they are familiar (Rotgans & Schmidt, 2011; Schmidt & Moust, 1995). Examples include breaking down concepts that they know are difficult, asking questions to guide students and giving students a structure that helping them structure their thoughts and the confidence that they can master it on their own. Schmidt and Moust (1995) claim that cognitive congruence allows a facilitator to recognise the difficulties that students may encounter while working through the subject matter content, while Grave et al. (1998) describe it as stimulating, elaborating and directing the learning process. Research suggests that teachers who lack cognitive congruence also lack strategies to scaffold students' learning and do not understand what students need (Yew & Yong, 2014). Rotgans and Schmidt (2011) found that cognitive congruence is the strongest and most significant predictor for situational interest.

Subject-matter expertise refers to the teacher's knowledge of specific content. According to, for instance, Schmidt and Moust (1995), the amount of knowledge a teacher holds has a positive effect on student achievement in an active-learning classroom. Although this research is based on higher education students, research from primary schools and preschools indicates that these interactional characteristics are relevant in studies involving younger children as well (Skalstad & Munkebye, 2022).

3. Methodology

3.1. Research participants and the context of the study

This study was conducted at a Norwegian primary school for Grade 1. Norwegian compulsory education is divided into two main levels: primary school (Grade 1–7) and lower secondary school (Grade 8–10). The compulsory education system is based on the principle of equitable education for all, and the education is free and primarily financed by the local authority. Only 3.5% of all primary/lower secondary students attend private schools. The minimum number of teaching hours at the primary level is 5,272 hours and that at the lower secondary level is 2,622 hours. At the primary level, the subjects Norwegian, Mathematics, Natural Science and Social Studies are allocated 26%, 17%, 7% and 7%, respectively, of the total number of teaching hours. Only 23% of pupils attend schools with 20 or more pupils per teacher in ordinary teaching situations, and only 5% of teachers do not hold the required qualifications for employment (Ministry of Education, 2016).

The study was conducted at a school with approximately 370 students that is located in Central Norway in a municipality with about 16,000 inhabitants. The participants of this study were two student groups consisting of 16 first-grade students each (five and six years old), their teachers (5) and a group of researchers (5), resulting in a total of 42 respondents. The participating students and teachers were recruited through opportunity sampling (Cohen et al., 2018) among schools that took part in a lesson study cooperation project with the Norwegian University of Science and Technology.

A lesson study is a systematic investigation of classroom pedagogy conducted collectively by a group of teachers, rather than by individuals, with the aim of improving the quality of teaching and learning (Tsui & Law, 2007). The investigation is conducted by examining a series of lessons, which are collectively designed by teachers, focus on particular content, explore alternative approaches to the content and address a specific weakness in student learning or a certain teaching difficulty faced by teachers. The collectively planned lesson is conducted by a teacher and is also observed and reflected on by the whole group. On the basis of the group's comments, the lesson will be revised, re-taught and reflected on again (Tsui & Law, 2007). As the term "lesson study" suggests, the focus of the investigation is the "lesson" and not the individual teacher. In the study reported in this paper, the lesson study involved not only practicing teachers (Ts) but also researchers (Rs). A lesson study approach was chosen because the municipality decided to involve all their primary schools in a lesson study project. They wanted to raise the teachers' competence by collaborating with researchers in their own classrooms. To build synergy between research and practices is in line with the work of Shimizu (2019). In our study, teachers and researchers developed a teaching sequence together; one teacher (T1) conducted the lesson for the first student group, while the others made observations. Following the evaluation and redesign of the teaching sequence, a second teacher (T2) implemented the lesson for the second student group. At the end, the teachers and researchers performed a final evaluation. Thus, the lesson study cycle consisted of the following phases: planning, first implementation, evaluation and redesign, second implementation and final evaluation. Each implementation included two reflection phases, referred to as T1.1 and T1.2 for the first implementation and T2.1 and T2.2 for the second implementation.

3.2. Data collection and analysis

We conducted a qualitative study, the data for which consisted of audio and video recordings of the teaching sequences and audio recordings of the planning and evaluation sessions. The sequences that were relevant to reflection were identified and transcribed.

The teachers' and researchers' planning and reflection sessions were analysed through conventional content analysis (Hsieh & Shannon, 2005), and the inductive approach described by Elo and Kyngäs (2008) was followed in this study. This approach was chosen because the existing theory and studies on teachers' planning of reflection sessions are limited. Similar to Hsieh and Shannon (2005), we define qualitative content analysis as a research method for the subjective interpretation of the content in text data (obtained here from audio recordings) through the systematic classification process of coding and identifying patterns. Content analysis is a well-suited method for analysing multifaceted and sensitive phenomena (Elo & Kyngäs, 2008). The unit of analysis used was one turn, which is a continuous period for which a speaker holds the floor (Linell, 1988). In total, 257 turns formed the basis for our content analysis.

The entire teaching sequence was analysed based on Rotgans and Schmidt's (2011) interest-creating factors of social and cognitive congruence and subject-matter expertise (see, Table 2 in Skalstad & Munkebye, 2022). The reflective sequences were also analysed using initiative-response analysis (Linell & Gustavsson, 1987), and, from this framework, the solicitation coefficient (S) and initiative-response difference (IRD) were used. S represents the proportion of the total number of turns that ask for an answer or demand a response. Hence, S is a strong indicator of questions. To obtain a measure of how much of the interaction space the parts in the dialogue use, the median of the degree of strength in each participant's turn is used as a starting point. Initiatives can be strong or weak depending on the degree of response. Strong initiatives are usually questions that require answers. However, such initiatives may simply be requests that require response. The difference between the medians, referred to as IRD, defines the participants' part of the interaction space in the dialogue. Taking the initiative reduces the other's opportunities to dominate. A high IRD indicates effective dominance, and dialogue dominated by the students results in a negative IRD; finally, an equal dialogue leads to an IRD value of zero.

The initiative-response analysis captures the dynamics, cohesion and dominance in dialogues. In an exploratory dialogue, both parties will work together to drive the dialogue forward; each turn (except the first) will be related to the previous contributor's turn, and it will have an initiative that leads to the next utterance. This differs from the triadic dialogue with initiative, response and evaluation (Nystrand et al., 1997), in which students do not have an initiative that drive the dialogue forward. The interaction space in this case is dominated by the teacher, who drives the dialogue forward and determines its direction. The initiative-response analysis considers the dialogue as a whole but still provides an opportunity to focus on individual participants. The unit of analysis is one turn, as it includes the utterance(s) that occur during the time the participant has the floor. Within a turn, therefore, there can be several independent units that can be composed of several words or just one word. Utterances are demarcated by a pause, intonation or change in content (Matre, 2000). In total, 82 teacher turns and 64 student turns formed the basis for the initiative-response analysis.

To ensure validity and reliability, the researchers repeated the analyses across time. For the content analysis, one of the researchers first analysed the transcriptions independently several times using open coding and an inductive approach. This initial coding was done until no new codes seemed to be needed. Subsequently, the authors discussed the initial codes and negotiated to arrive at a common interpretation. Then, the categories were jointly constructed. After creating the final set of categories, one researcher re-coded the dataset, and an intraindividual agreement of 88.7% was achieved. To measure the reliability of the initiative-response analysis, the dialogue sequences were reanalysed, and the coincidence between the categorisations was found to be 91%. It would have been more appropriate to look at the similarity of the same dialogue sequences between two different researchers, but this was not possible due to the lack of available expertise. Re-coding the dataset to ensure resilience is a technique that has been used in other studies that utilise initiative-response analysis (e.g., see, Jahoda et al., 2009, where agreement was 87%).

4. Results and discussion

Metz (1995) argues that primary school students are capable of grasping abstract ideas, especially if they receive strategic support from a more competent other. Through dialogue, students' experiences and ideas can be raised, and, with the teacher as a conversation partner, a common understanding that is in line with scientific ideas can be achieved (Wood et al., 1976). The abstract idea considered in this study was the sense of touch. The goal was for first-grade students to use the names of body parts and talk about the sense of touch, and the teachers and researchers wanted them to understand that we feel differently on different parts of the body.

After analysing the transcripts of the planning and reflection sessions using an inductive approach, we ended up with a set of 13 initial codes as well as five overarching categories (students' dialogue, scientific dialogue, content of consolidating phases, time for reflection and duration of reflection; Tables 1 and 2), which are the suggested key features of the transcripts. The planning and reflection sequences focused on the teaching process and not the individual teachers. Thus, when referring to quotes, we distinguish between T and R only and not between individuals. The categories were mutually non-exclusive, meaning that there were several possibilities for category combinations for each turn. Cohen et al. (2018) state that items can be assigned to more than one category and that this is desirable because it maintains the richness of the data.

4.1. Teachers' and researchers' objectives for the reflection sequences

During planning, the teachers and researchers spent much time discussing the best timing for summary and reflection. The first idea was to have a final summary at the end of the lesson, but alternatives such as conducting evaluations halfway through or the next day were also suggested, e.g., "I feel like having one at the end when we finish both [activities]" (T), "You could have taken … tomorrow in a way and relate to what we did yesterday" (T). Taking the age of the students into consideration, they decided to run two reflection sequences per session directly after each activity, as argued for by one of the researchers and a teacher: "I thought maybe it gives more and that it has a greater effect to have the summary right after the first [activity]" (R); "But I think it is important to take it today, while it is fresh" (T); "Try to get that reflection better then, as they are perhaps more receptive" (R). The total time spent was nine, ten, seven and eight minutes for reflection sequences T1.1, T1.2, T2.1 and T2.2, respectively (the whole session was 60 minutes).

Table 1. Overview of the initial codes and categories

Initial codes	Categories
Students' conversations Students' questioning	Students' dialogue
Teachers' scientific preparation	Scientific dialogue
Desire for scientific ideas	
Sense of touch	
Reflections' content	Content of consolidation phases
Summaries' content	
Reflection at the end only	Time for reflection
Reflection halfway Reflection when students are receptive	
Desire for short reflection Reflection too short Reflection duration improved	Duration of reflection

Table 2. Examples from the coding process

Raw data	Initial code	Category
"It is very often that we ask questions and then answer them. So, we have to make sure that the kids ask more questions." (teacher, transcript line 602)	Students' questioning	Students' dialogue
"But I would like some input then, because I do not quite know what to say yet." (teacher, transcript line 371)	Teachers' scientific preparation	Scientific dialogue
"But give me the term I will use then, for some say sensors and some say something else, what is best? Nerves? Sense reception?" (teacher, transcript line 454)	Sense of touch	Scientific dialogue
"It became a bit busy during the summary, because then they were so tired." (teacher, transcript line 503)	Reflection too short	Duration of reflection

Despite the planning phase lasting a relatively long time, the reflection sequences came too late, including T2.1 and T2.2: "Also, now I think that it came too late. Thought they were getting a little tired before they started" (T). During planning, teachers and researchers focused mostly on the time spent on the summary as well as the practicalities of the same and what the students should and should not do. The reflection was more diffused.

The duration of the reflection phases was also a highlighted topic. Teachers were considering the students' workloads and eagerly suggested limiting the reflection time: "If there is time, then" (T); "A fairly short one then, really" (T). During the evaluation and redesign phase, they realised that there was too little reflective conversation ("I had expected a little more response maybe" [T]; "Yes, we had hoped that this would just bubble up a little, but we realise that it didn't happen" [T]), and they planned to spend more time on T2.1 and T2.2: "More time spent on reflection perhaps" (T); "mm mm mm, yes" (Ts). Even after the second session, they still realised that too little time was allocated for the reflections and that they were scheduled too late: "It got a little busy during the summary because then they were so tired" (T); "The length … it was good … they had even more potential. They could have spent more time on it for sure" (T).

Regarding students' dialogue, the teachers and researchers aimed to get students to talk and ask questions: "If they are to have their own sheet, then I think we will lose some of that conversation" (T); "It is important that they tell, then" (T). Regarding the content of the consolidating phases, they aimed to help develop the students' ideas: "They would like to show their work" (T); "And then it must be to expose their ideas, what they believe" (R). During evaluation and redesign, they were not sure if the students saw the academic ideas: "We had a desire to, to why" (T); "I think we have to lead them a little because it does not come by itself" (T). Thus, scientific dialogue became an important topic for discussion.

The content analysis revealed minimal quotes on scientific issues during planning; however, during redesign, this was one of the main foci. The teachers did not feel sufficiently prepared professionally: "If you as a teacher knew it quite clearly, you would probably have managed that bit of reflection, yes" (T); "We felt the need, but we may not have done enough" (T); "If we are going to manage a reflection sequence then we must know what we aim to" (R); "Yes, mm, yes" (Rs). T2 asked for help deciding on the right concept to use ("But give me the term I should use then . . . "; see, Table 2), and they decided to introduce the concept of "feelers" in place of "sensory cells". This new focus on a certain scientific term led to an enhanced scientific understanding among the students in session two (as experienced by the teacher): "Now there was a difference in explaining it with why, which we did not have at all before, thanks to the fact that we changed. We got more focus on reflection. We did not have reflection at that level in the beginning" (T).

During the evaluation phase, the participants were aware that the duration of the reflection sequences was shorter than expected. The practical tasks took nearly all the allotted time despite the prior planning for the reflection phases. The teachers stated that the lesson was too long and that the students were too tired to handle a long reflection at the end. During the redesign, they planned for strategies to reach the reflection phase at an earlier stage to improve students' dialogue and link the reflection to scientific ideas. This academic awareness during the redesign led to greater student participation in the second implementation (see, Table 3, T2, no. student turns), but the participants still concluded that there was less reflection than planned. They justified this by the fact that the students were tired. Time constraints linked to the consolidating phases are present in previous studies as well (e.g., Abrahams & Millar, 2008; Karlsen et al., 2021). Time is also considered a general challenge for implementing inquiry-based approaches (e.g., Akuma & Gaigher, 2021).

4.2. Teachers' support of students' interest

Social congruence: All phases of the teaching process were characterised by the teachers' respectful attitude towards the students. They alternated between addressing the whole class and individual students, and they considered each individual student. They addressed individual students with "you", allowed the students time, acknowledged their feelings and made eye contact

Table 3. Number of turns, initiative-response difference (IRD), solicitation coefficient (S) and median for the reflection phases after activities 1 and 2

	Reflection phases after activity 1		Reflection phases after activity 2	
	T1.1	**T2.1**	**T1.2**	**T2.2**
No. turns (teacher/ students)	10/7	33/28	20/12	19/17
IRD*	1.9	0.9	1.2	1.2
Solicitation coefficient	0.73	0.48	0.5	0.16
Median (teacher/ students)	4/2	3/2	3.5/2	3/2

*IRD was interpolated (IM) in relation to the number of responses greater than (ng), less than (nl) and equal to (ne) the median according to the formula IM = M + ((ng − nl)/2 * ne).

with them. Teachers acknowledged students' input by exhibiting positive interest, and they also praised the students: "Was that what you were thinking? OK. That was interesting" (T2.1); "You have to put your hands in your lap and listen carefully now because Line said something that was really wise" (T2.2). They were also aware of the students' concentration, and they provided breaks during which they sang. The teachers acknowledged that the students eventually became tired: "Now I feel that it has become very difficult to sit still. Are we a little tired?" (T1.2).

Cognitive congruence: The teachers encouraged the students to explore. The language they used was adapted to the student group, and they explained themselves in an understandable manner. They supported verbal language with nonverbal communication through movements and gestures. The teachers modelled what the students were to do and made sure that the students understood the same. When students worked together in pairs, the teachers circulated between the groups to promote exploration, asked open-ended questions and supported them. Both teachers related back to the first activity, but T2 also encouraged the students to create experiences while they talked, which they connected to the dialogue: "Feel your elbow, touch and feel the skin under your elbow. Squeeze there. Then gently squeeze your lip. Why does it hurt more if you squeeze your lip than if you squeeze under your elbow?" (T2.2). T2 adapted the use of the scientific term "tactile receptors" to the student group and used the word "feelers" instead. This word is close to the verb "to feel", which was a familiar word to the students and, therefore, easier to understand.

Subject-matter expertise: At the end of the second reflection phase (T2.2), T2 introduced a scientific concept ("feelers") and explained that the number of "feelers" determines how painful it is when one pinches different parts of the body. In T2.2, T2 linked the feeling of hunger to belonging inside the body and established that the feeling is called "hunger". One student shared a story about someone cutting off their tongue. T2 turned the dialogue to talk about the "feelers" that were introduced in the previous session and expanded from "feelers" detecting pain to sending these signals to the brain: "Because 'feelers' have two functions in our body. And they are very important. When you feel something, such as your thumb. When you squeeze, the 'feelers' send a signal to the brain up in the head and then it sends a message to the brain" (T2.2).

For an exploratory teaching approach to support students with developing their understanding, it is important that students' interest is aroused and maintained, and the teachers play an important role in this regard (Rotgans & Schmidt, 2011; Skalstad & Munkebye, 2022). As Dewey (1933) points out, interest is the driving force for processing experiences. According to Rotgans and Schmidt (2011), social congruence and subject-matter expertise affect cognitive congruence, which together affect the interest in a given situation. In this study, we found that teachers showed social congruence. The classroom climate was characterised by respect and recognition, and the teachers were aware of and adapted to the extent to which the students were awake and attentive, which also proved to be positive for younger students' interest in science (Xu et al., 2012). Being met with recognition can open the path for learning by making the students more receptive to, among other things, academic challenges (Jordet, 2020). Our results are in line with those of Skaftun and Wagner (2019), who state that respect and recognition characterise Norwegian classrooms' learning climate.

The teachers encouraged the students to explore; they used concepts that were understandable to the students and supported them with nonverbal communication by modelling what they were talking about. For instance, when they talked about pinching the skin on the elbow, the teachers did it at the same time. In this way, both teachers showed cognitive congruence according to Rotgans and Schmidt (2011). T2 showed a greater degree of cognitive congruence, as T2 also encouraged the students to create new experiences while reflecting on the activity that they had just carried out. T2 also linked it to everyday experiences and made use of a simplified scientific term. T1 had one instance in which they reformulated the students' answers in an incorrect way. This can be perceived as a lack of intersubjectivity and reduces the students' contribution to the dialogue. The same can be said for T1′s repeated return to the same question and the alternation between asking whether the sensations were similar or different. This may indicate that T1′s cognitive congruence was lower than that of T2.

A lack of focus on the subject matter in the first implementation (T1) led to a strong emphasis on the redesign phase. The participants jointly decided that T2 should use the term "feelers" to adapt the term "sensory cells" for the young students. As a result, T2 linked the dialogue to scientific content and was the only teacher to exhibit subject-matter expertise. T2′s students contributed more to the dialogue than those of T1, which can be interpreted as the students being more engaged and interested in talking about their experiences. This can be explained by the declining interest among the students due to the weaker subject-matter expertise and cognitive congruence of T1; maintaining interest has been emphasised as being important in scaffolding (cf., Wood et al., 1976). On the other hand, the limited contribution to the dialogue from the students could also stem from the students being overloaded, which both T1 and T2 expressed on several occasions. However, we must take into account that there were two different groups of students in the two implementations, which may have had an impact on how they responded. If the purpose of reflection is to link experiences with theory, it is worrying that T1 did not show any kind of subject-matter expertise. In the Norwegian context, this is not surprising, since 40% of the teachers who teach science in primary and lower secondary schools lack formal education in science (Perlic, 2019). Research indicates that teachers with weak confidence in their ability to teach science try to avoid it (Gerde et al., 2018). A recent Irish study reported, however, that despite a lack of science knowledge and pedagogical content knowledge, teachers believed that they had the opportunity to implement science activities (Finucane, 2021).

4.3. Characteristics of the teacher–student dialogue

Both sessions had two exploratory activities with subsequent reflections. The first analysis compares the reflection sessions T1.1 and T2.1 (Table 3).

Table 3. Initiative-response analysis and the reflection phases T1.1, T2.1, T1.2 and T2.2. IRD = initiative-response difference (Linell & Gustavsson, 1987).

In reflection phase 1 (T1.1), T1 accounted for 58% of the turns. T1 asked many questions (S = 0.73), and half of these could be answered with "yes" or "no"; for example, "Could you feel it everywhere?". T1 dominated the interactional space (IRD = 1.9), and the students responded with minimal responses (yes/no).

In reflection phase 1 (T2.1), T2 accounted for a total of 33 utterances, in contrast with T1′s 10 utterances. T2 did not dominate the dialogue to the same degree as T1 (IRD = 0.9) and asked fewer questions (S = 0.48). In the beginning, T2 asked yes/no questions and received minimal responses from the students. Towards the end of the reflection, T2 encouraged students to gain experience while engaging in dialogue: "Touch and feel a little on your hair; does it hurt, if you pinch your hair, or stroke like this?". T2 then created links to students' experiences by asking "why" questions. Students responded with extended answers: "I found that there was blood in my lips and the skin does not hurt"; "It is thickest skin on the arm. It does not hurt on the elbow". This led to the students becoming more involved in the dialogue, which contributed to a better collaboration to continue the dialogue.

In reflection phase 2 (T1.2), T1 accounted for 62% of the turns and had a total of 32 utterances. T1 dominated the interactional space to a lesser extent than in reflection phase 1 (IRD = 1.2). T1 started with yes/no questions and related back to previous questions by alternating between asking whether it was the same or different. After the first adequate student response, there were few responses from the students.

Then T1 asked a "why" question. This part lacks cohesion. The first student response focused on the fact that the cause may lie in the strength of the influence that causes it to hurt. T1 reformulated the answer to be about a place on the body. The next student response had the same focus as the first, whereupon T1 again reformulated the question to be about a place on the body. T1 asked the student for a confirmation that he had understood correctly, which the student rejected. Then T1 reformulated the question so that it was in line with what the students meant and asked a new question: "Why is it like that? What do you think? Why is it like that, Carl, that you can hit yourself harder here than here? Is that a good question?". The students were restless, and, after T1 had asked the question again, one student answered, "Because it's harder where you fall, maybe". Then, T1 summarised, "It's harder where you fall, yes. Like if it was very painful to sit on your knees, how would it have gone with Doris then? If it had been very painful on your knees? Do you think Doris had been allowed, been able to sit like that then?". T1 summarised the answers to become about whether it feels the same all over the body, which did not coincide with the students' utterances.

In reflection phase 2 (T2.2), T2 had 53% of the 36 turns. T2 dominated the interactional space to a greater extent than in reflection phase 1 (IRD = 1.22) but asked fewer questions (S = 0.16). In this part, one student contributed with a clarifying question (S = 0.12). T2 started by asking, "We know what we have done; what have we found out?". After two responses from the students, T2 summarised and went on to ask why. In this section, T2 linked the students' answers to what they had experienced during the lesson while simultaneously providing new examples that the students could relate to. T2 said, "Because we are different, yes. But we talked about hair for example. Another thing, if you cut your nails, it does not hurt so much; but if we cut our finger, it can hurt." T2 did not ask as many questions in reflection phase 2 as in phase 1, but they still dominated the interaction space to a greater extent. In addition to asking questions, encouraging and asking for action reflects a strong initiative. T2 encouraged students to feel their hair, fluff gently, feel the hair sticking to the skin, feel their elbow and feel the thickness of the skin. The students contributed to a greater extent in this phase by directing the dialogue towards a new topic related to hunger, and they pursued their own input.

In summary, T1 and T2 had approximately the same number of turns and dominated the interaction space to the same degree in reflection phases 1 and 2; however, there were differences between the two phases of reflection. T1 considered the students' answers and eventually came to a conclusion they could agree on. This conclusion was whether it hurt just as much in different places on the body. T2 spent less time summarising the results than focusing on "why" questions. The students were encouraged to create new experiences while engaging in the dialogue, and T2 also highlighted experiences from the students' everyday lives. The students contributed to a greater extent in both of T2's phases.

A dialogue for extended understanding is difficult to achieve if the teacher does not know which idea to negotiate (Wood et al., 1976; cf. first implementation), like in T1.1, in which T1 constantly repeated students' utterances. Based on the planning, T2 knew in advance where they would lead the students and managed to get the students to come up with new ideas. The students were able to follow the dialogue and contributed to a greater extent. In the first implementation, the dialogue was characterised by a failing cohesion, which may be due to the fact that the goal of the dialogue was unclear. The results are in line with those of Scott et al. (2011), who emphasise the importance of teachers' appropriate planning and academic and didactic knowledge to facilitate students' understanding.

In the reflection phase after activity 2, T1 constantly related back to the question of whether the students' experiences were the same or different, which contributed to maintaining the goal of the activity, in line with the findings of Wood et al. (1976) scaffolding strategies. This is in line with Furtak and Alonzo (2010) study, which found that elementary teachers emphasised their students' doing and feeling, rather than thinking, by promoting activity over understanding. T1 asked a "why" question but failed to maintain intersubjectivity, which hindered students' contribution to the dialogue. T2 dominated the interaction space to a greater extent in this reflection phase but still asked fewer questions. From asking for the students' conclusions, she quickly moved on to asking why, and she connected the content to the students' everyday lives, encouraging them to create experiences simultaneously. In this way, T2 helped the students establish continuity in their experiences by linking their previous experiences to what they experienced in the moment. This gives the students' experiences pedagogical value (Dewey, 1938a; Kersting et al., 2021). The students responded to the actions of T2 by providing extended answers and examples of their own experiences. By introducing "why" questions, the teacher opens up the inquiry and facilitates students' vital experiences in line with the findings of Dewey (1933).

5. Conclusion

According to Akuma and Gaigher (2021), future efforts of researchers and teacher-support providers should contribute towards a greater use of practical work that focuses on critical learner engagement. In this study, we found that the teachers show strong social congruence, while their cognitive congruence is relatively weaker. However, this could be strengthened by conducting more frequent reflection phases in which students' experiences are immediately followed by a short reflection phase, especially for younger students. This differs from having consolidation as a separate final phase (Pedaste et al., 2015).

More frequent reflection can guide exploration, as the "why" questions may be introduced at an earlier stage of the exploration. This, together with the strengthened subject-matter expertise of the teachers, could contribute to a change in the direction of exploration from a "what" question to a "why" question. Shifting the emphasis from "what" questions to "why" questions will also increase students' cognitive challenges. Together, these could provide opportunities to maintain students' engagement through strengthened interest.

While the teachers in this study displayed social and cognitive congruence, when it came to subject-matter expertise, the teachers and researchers were too diffused in their planning. The content analysis points to the importance of teachers knowing in advance exactly which scientific concepts to negotiate. Based on our analyses, we suggest that the important negotiations connected to the subject matter need to take place immediately—almost at the same time as the practical activity. Reflective conversations cannot wait until the end of the lesson. Our main finding is as follows: to help young students grasp scientific ideas, they need to have their practical activity fresh in their mind and be in the mood to pay attention to the teacher. A closer connection between students' experiences and the teacher–student dialogue, by linking the experiences to prior knowledge or students' context, may be more important for young students than we might have previously assumed.

Conducting shorter reflection phases closer to when the experiences are created might help ensuring that there is sufficient time for students' reflection. Exploratory conversations after practical activities are challenging for teachers to achieve despite the extensive time allocated for planning, as shown in previous studies (e.g., Ødegaard et al., 2014). Initiative-response analyses demonstrate the potential for more student reflections. The students were challenged through questions, which unfortunately could be answered with a "yes" or "no" and did not invite the students to give extended responses. Despite good planning, the teachers perceived a lack of time when it came to reflection. Both the teachers and the students were extremely involved in the practical activities and spent more time than planned on this phase.

6. Implications, limitations and research directions

We suggest that teachers, when working with younger students, break the usual practice where the inquiry cycle's final step is the consolidating phase. Promoting reflection related to the students' experiences while these are still fresh in their minds will make it easier for them to establish connections between the experiences and theory. Organising shorter reflection phases closer to when the experiences are created might also help ensuring that there is sufficient time for students' reflection. Exploratory activities are considered important in science teaching in

Norwegian schools (Ministry of Education, 2020), and, based on the results of this paper, we claim that special consideration must be given to younger students during such activities.

The participating teachers and students were recruited through opportunity sampling due to the fact that a limited number of schools took part in the lesson study project. The selected school chose exploratory approaches as a topic for their lesson studies. When discussing the data, we need to consider that the teachers involved may be well-intentioned, and they do not necessarily represent the wider population. On the other hand, they might have chosen this topic because they saw potential for improvement in this regard. The lesson was executed in two different student groups in the two implementations. Thus, this must be taken into consideration when discussing the results. Having different student groups might have implications for teachers' scaffolding and dialogue. The presence of several teachers and researchers as well as video cameras and audio recorders in the classroom might also have had an impact on students' behaviour. Finally, as the lesson study was conducted in a Norwegian context, countries with different cultural backgrounds may have to apply our findings with caution.

Given our main findings in this study, it could have been interesting to conduct a study with the youngest pupils with a focus on exploratory activities that include a closer connection between the pupils' experiences and the subsequent reflection. Further, our study highlights weak subject-matter knowledge among the teachers. Being able to strengthen the teachers' subject-matter expertise to see what implications (if any) it would have for the reflective conversations between teacher and students regarding the students' experiences would have been of interest as well.

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Data availability statement
The data that support the findings of this study are available from the corresponding author, EM, upon reasonable request. https://www.ntnu.no/ansatte/eli.munkebye

Disclosure statement
The authors have no relevant financial or non-financial interests to disclose.

Ethics approval
The Norwegian Centre for Research Data (NSD) assessed and ensured that the processing of personal data in this project is in accordance with the relevant privacy regulations (case number 49,645).

Consent to participate
The teachers provided their consent to participate in the study. Parental and guardian consent was collected in writing by handing out an information letter and consent forms. Personal data were processed based on these consents. The students were informed before each data collection session and were free to not participate and withdraw at any point without justification.

Consent for publication
The teachers provided their consent to publish results from the project. Parents and guardians provided written consent for us to publish the results of the project. The submission and publication of the manuscript have been approved by all authors.

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