European Journal of Science and Mathematics Education, 2024, **12**(1), 139-155
ISSN: 2301-251X (Online)

OPEN ACCESS

**Research Article**

# Teachers' use of inquiry and language scaffolding questions when preparing an experiment

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**Citation:** Øyehaug, A. B., Kouns, M., & Savelsbergh, E. R. (2024). Teachers' use of inquiry and language scaffolding questions when preparing an experiment. *European Journal of Science and Mathematics Education, 12*(1), 139-155. https://doi.org/10.30935/scimath/14074

**ARTICLE INFO**

Received: 30 Jun 2023

Accepted: 27 Oct 2023

## ABSTRACT

This study analyze data from three national contexts in which teachers worked with the same teaching materials and inquiry classroom activities, investigating teachers' use of strategies to promote interaction and scaffolding when participating in a professional development program. The data material is collected from three case studies from the Netherlands, Norway, and Sweden, respectively. Each case is from a teaching unit about green plants and seed sprouting. In one lesson in this unit, students were involved in planning an experiment with sprouting seeds, and this (similar) lesson was videotaped in three national settings. The main research question is, as follows: How do primary teachers use questions to scaffold conceptual understanding and language use in inquiry science activities? The data analysis shows that teachers ask different kind of questions such as open, closed, influencing and orienting questions. The open, orienting questions induce students to generate their own ideas, while closed orienting and influencing questions often scaffold language and content-specific meaning-making. However, both open, closed, orienting and influencing questions can scaffold student language and conceptual understanding. Often, teacher questions scaffold both language content-specific meaning-making at the same time. The study shows the subtle mechanisms through which teachers can use questions to scaffold student science literacy and thereby including them in classroom interaction.

**Keywords:** inquiry questions, science experiments, language scaffolding, primary school science, literacy

## INTRODUCTION

Ensuring that everyone has an equal opportunity for educational progress in all subjects including science remains a challenge worldwide. In science classrooms, diverse learners should, for instance, be included in different inquiry driven learning activities. Scientific practices that involve students in formulating questions, making and testing predictions, developing hypotheses, collecting data, and drawing inferences have shown to improve engagement and learning when compared to traditional teaching approaches (Colburn, 2006; Geier et al., 2008; Hmelo-Silver et al., 2007). Baurhoo and Asghar (2014) suggest that through inquiry-driven activities teachers can employ several alternative strategies to motivate students with diverse backgrounds to ask questions, conduct observations, test their predictions, construct hypotheses to explain natural phenomena and communicate those ideas to others. However, other studies show that teachers often face challenges when interacting with students in science teaching, especially when it comes to the way they ask questions to engage and to activate student thinking. For example, Roehrig and Luft (2004) observed that the way teachers asked questions was limited by the students' expectations that teachers would give them the correct answers. Mortimer and Scott (2003) add that teaching that emphasizes the language of science includes an understanding of scientific concepts, critical thinking and argumentation, development of theories and other important features of science. For example, students can develop models, create explanations and use data to argue, all of which will inevitably lead to a development of scientific use of language (Lee et al., 2013). Consequently, teachers use of language can be challenging for many students when they learn science, partly because science language has a specialized vocabulary with both very precise and more general subject words.

Supporting students learning of science when it comes to inclusion, scientific practice and language might seem a complex and daunting task. Students need scaffolding to move between teacher-directed forms of inquiry and student-directed forms, and they need to be provided with the quality in scaffolding (Biggers, 2018). Jakobsson and Kouns (2023) explored small-group work in science and concluded that teachers had to facilitate for dialogical situations in order to let all students to develop their language use in science, primarily through probing a more precise way of expressing themselves and putting their scientific ideas and thoughts into words. Moreover, learners in elementary school will usually not be able to step immediately into a completely open-inquiry experience. In an investigation of how teachers were scaffolding science inquiry, Spaan et al. (2022) found that assigning tasks to design experiments or generate predictions is less common and activities fostering discussions are rarely observed. Some studies have investigated the use, planning and implementation of elementary science curriculum materials (e.g. Edelson et al., 2021), while others have focused on experimenting with instructional materials that promote science and subject language development with elementary students (for instance, Lee et al., 2019). However, little research has been conducted with in-service elementary teachers during scientific practices in specific contexts such as planning an experiment. Moreover, there has also been little research on how elementary teachers ask questions in order to scaffold both understanding of scientific practices and science language development. To address this gap in existing research, we focused on how elementary teachers ask questions to scaffold the scientific practice of planning an experiment and subject language development.

In our study, elementary teachers in Norway, Sweden, and the Netherlands participated in PD-courses and had access to teaching material with science inquiry activities. The courses and material provided tools and ideas regarding how to make science classroom practice more inquiry-based and interactive, and included examples of how to scaffold scientific inquiry and the use of scientific language. In short, participating teachers were expected to have a larger repertoire of strategies that could contribute to students' active participation, scientific understanding and language development. In this study, we will investigate in more detail how such teachers engage students and scaffold scientific practice. Such a study will be important for further development of course material for use in teacher education and professional development for teachers. In this study, we want to explore what kind of questions teachers ask to help students design an experiment with sprouting seeds, and how they scaffold the language and conceptual idea of planning this experiment.

We address the following research questions (RQ):

**RQ1.** What characterizes questions primary teachers ask in preparation of an experiment?

**RQ2.** To what extent do questions in this context scaffold science understanding and scientific language development?

## THEORETICAL PERSPECTIVES

### Categorizing Teacher Questions

In studies of teacher questions in dialogues, it has been common to categorize the questions teachers ask students. Commonly, teacher questions are divided into categories, such as open/closed, authentic/non-authentic, or reference questions/viewing questions. Nystrand et al. (1997) categorized questions that could

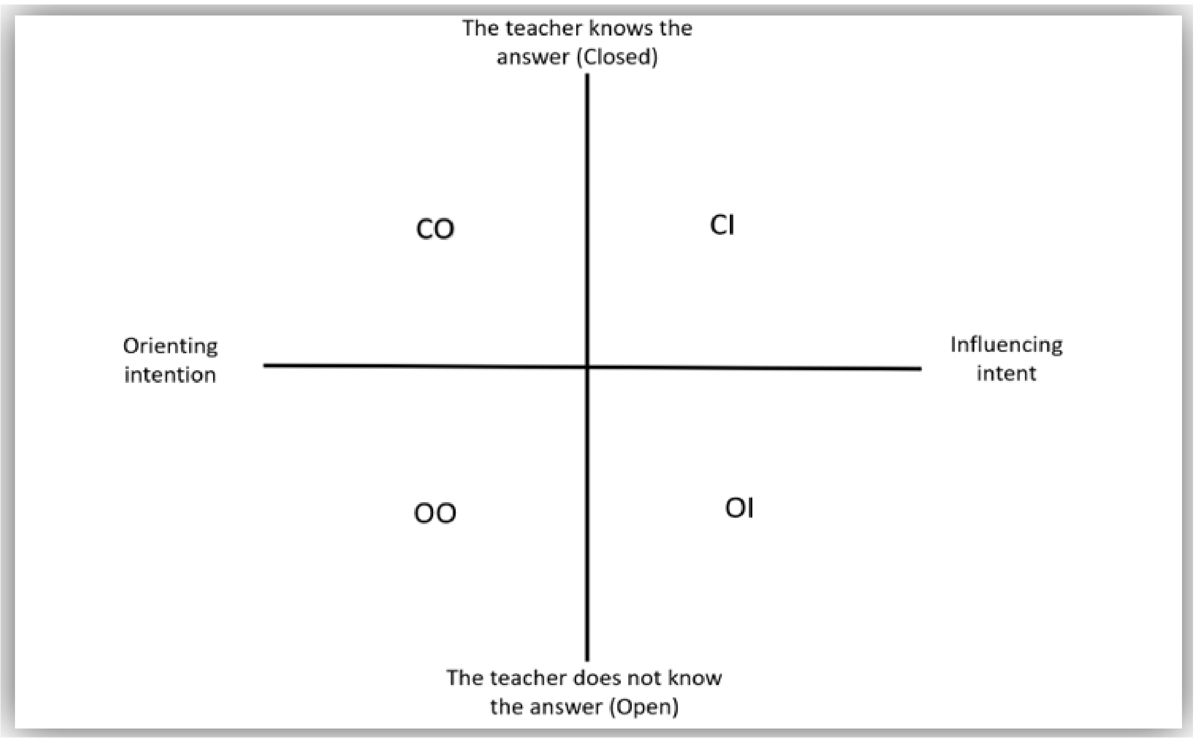

**Figure 1.** Questioning model (Ulleberg & Solem, 2018, reprinted with permission of the authors)

be answered in many different ways as open, while closed questions expected one particular answer. This will also include yes/no questions. A closed question is a question with one “final answer” (Nystrand et al., 1997). Andersson-Bakken (2015) claims what is most important for the classroom dialogue is to follow up both open and closed questions with in-depth questions. Brubacher et al. (2019) found that children tend to find closed questions easier than open questions because they require less reflection to answer, but also that they feel more listened to and better able to give their stories in response to open question. Mapplebeck and Dunlop (2021) revealed that when students were discussing open questions, two characteristics were important to them: they made them think, and they were made to work out answers for themselves. Ulleberg and Solem (2018) have developed a model with different categories of questions for use in mathematics teaching, which is based on a similar model of asking questions in therapy, guidance and management (Hornstrup et al., 2009). The purpose of the original model was to compel the professional to reflect on and clarify the purpose of the questions asked. Ulleberg and Solem’s (2018) model (see **Figure 1**) is adapted to teacher questions and has two main axes. The endpoints on the vertical axis are “the teacher knows the answer” and “the teacher does not know the answer” and can be linked to so-called open and closed questions.

However, there will be fluid transitions between the teacher’s expectations of the answer, sometimes the teacher knows exactly what the answer is, in other situations, some answers are more correct than others but can be formulated in different ways. And in some cases, the answer is unknown to the teacher, who is genuinely curious about what the student has to say. On the horizontal axis, the focus is on the intention or purpose of the question. On one side of the axis, teacher intention of the question is to orientate themself about what students think, what they remember, what kind of knowledge they have, etc. On the other side of the axis, teacher intention of the question is to influence students’ thinking. This includes questions that stimulate students to think further, to explore, to explain, to justify and to discover new connections. The two axes form a cross with four areas, thus four question types (**Figure 1**). Ulleberg and Solem (2018) discuss how different question types affect movements in class conversation and how the model can be used as an analytic tool for developing and analyzing class discussions in mathematics. In a science inquiry context, questions can be a tool for scaffolding student language development and helping them understand the idea of an experiment. Ulleberg and Solem (2018) four question types can be seen as different strategies to support science understanding and language development when students participate in scientific practices.

## Questions Promoting, Scaffolding, & Developing Scientific Thinking

Through a science inquiry approach, students can be stimulated to formulate questions, make hypotheses, observe and then reflect on scientific phenomena. Zacharia et al. (2015) argue that participating in and understanding different phases of scientific inquiry (formulating questions and designing, exploring, and drawing conclusions) poses several challenges to students, especially during the design phase. This makes it particularly difficult for teachers to include students in such practices. As noted by Klahr and Nigam (2004) and Zion et al. (2005), it is important to support students' conceptual knowledge and procedural skills during open inquiry. Without this support, students have difficulties with performing inquiry procedures and proceeding within and between inquiry phases. For instance, in the experimental design phase, students are often expected to identify independent and dependent variables, and then specify which dependent variable will be investigated in relation to which independent variables in each round of experimentation. This will be an important part of formulation hypotheses. Thus, failure to implement an appropriate experimental design will lead to failure in addressing the hypotheses under investigation (Arnold et al., 2014; Pedaste et al., 2015). For teachers to address the procedural domain in the phases of designing and conducting the research and in the conclusion phase, they could use strategies such as questioning, providing embedded scaffolds with expert guidance (Saye & Brush, 2002) and making connections with relevant everyday contexts (Van Graft et al., 2009). Thus, teacher use of different questions seems to be useful in supporting students during experimental design. Florian and Spratt (2013) posit that learning and the experiences of individual students can be enriched in the sense of social constructivism, as they profit from each other's experience in cooperative activities. Such activities can be facilitated by asking open questions and designing joint learning situations in different phases of an experimental design. Science is as much about explanatory models as observations. Thus, it is important to draw out students' own ideas and expectations.

Teachers often start these discussions by asking questions to orient themselves about what students think, what they remember and what kind of knowledge they have, etc. (Ulleberg & Solem, 2018). Furthermore, teachers often take these discussions as a starting point in subsequent discussions, thereby highlighting students' diverse thoughts and allowing multiple perspectives. Secondly, teaching should enable participation. This means giving students the chance to co-determine the content and to consider their individual ideas, interests or abilities as fruitful. Thus, situations need to be created in which children answer questions, cooperate and participate in processes of discipline specific co-construction (Rott & Marohn, 2018). Each individual develops different interests and motivation. Therefore, teaching methods in science should be accessible to and engage all students. Teachers can structure conversations related to experiments and demonstrations in a way that might promote reflection and learning (Lemke, 1990; Wellington & Osborne, 2001). For instance, they can ask questions and respond to students' statements in qualitatively different ways by using both orienting and influencing questions (Ulleberg & Solem, 2018). The classroom dialogue is often seen as a triadic dialogue, due to a three-part question-answer feedback sequence (Lemke, 1990; Mehan, 1979; Sinclair & Coulthard, 1975). Kolstø (2016) suggests activating and idea-generating dialogues as introductory dialogues, where prior knowledge and experiences, and ideas are highlighted.

Hardman (2008) underlines the relation between promoting inquiry and scientific thinking and the teacher higher-order questions. To merely replace students' conceptions with the scientifically accepted ones is seen as ineffective (Ozdemir & Clark, 2007; Posner et al., 1982). Teaching requires feedback strategies that support student thinking and argumentation and facilitate students grasping complex and demanding science practices. Biggers (2018) points out that because the practice of asking questions is fundamental in the nature of science this must be incorporated already in primary school. Teachers' questions in the inquiry classroom not only explore and make student thinking explicit but also serve to scaffold student reflections. According to Croom and Stair (2005), relevant use of questions can contribute to the development of students' ability to think critically and can strengthen their understanding. Moreover, teachers' use of questions and feedback on students' responses can help students make connections between what they already know, and the new ideas presented to them. Scott et al. (2011) refer to such strategies as pedagogical link-making strategies. Biggers (2018) suggests that inquiry should be structured to challenge students not only with the content but also with the amount of autonomy they are provided in designing and conducting the investigation. Furthermore, the questions teachers ask and the way they are formulated can greatly influence students'

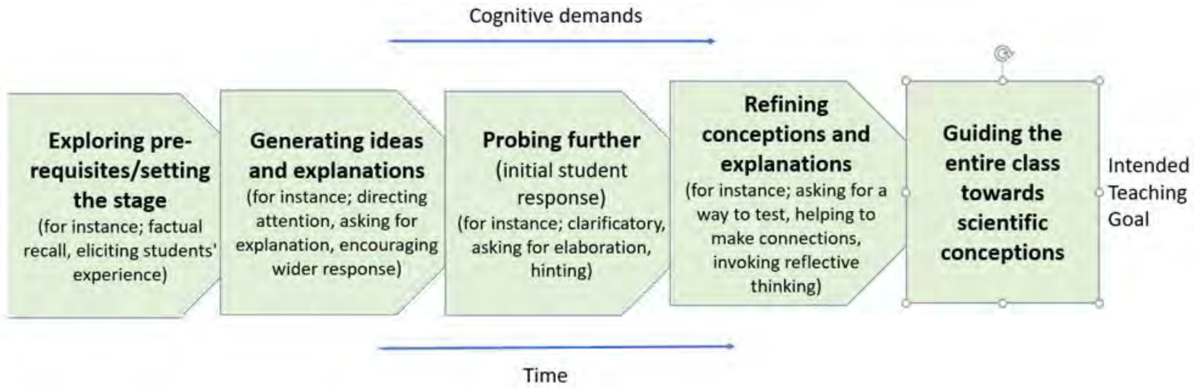

**Figure 2.** Progression of questioning in inquiry teaching (Adapted from Kawalkar & Vijapurkar, 2013)

thinking when trying to understand new phenomena and scientific processes (Chin, 2007). She describes four approaches (namely Socratic questioning, verbal jigsaw, semantic tapestry and framing) and several strategies within these approaches that encourage student reflections, thinking and responses. Kawalkar and Vijapurkar (2013) suggest that the purpose of questioning is to elicit students' ideas and help students to articulate them, to elaborate and reflect on their own as well as their peers' thinking, to challenge them to resolve inconsistent views, to construct relevant relationships, and to provide a setting for active student inquiry. Their analysis of teachers' questions led to five broad categories in which the teacher can facilitate such an inquiry in the classroom through a progression of questions (see **Figure 2**).

## Questions Scaffolding Subject Language Development in Scientific Practices

Lee and Buxton (2010) indicate that science and subject language teaching must go hand in hand. Science teaching can be regarded as a "secondary discourse" (Gee, 1996), the use of language is very different from what students experience in everyday life. For example, Brown and Spang (2008) emphasize that the grammatical properties, the meaning of words and the semantic patterns (Lemke, 1990) typical for science language, create difficulties for students. In addition to specific science concepts, there are everyday words and expression with a specific meaning in science (for example, heat, experiment, power, and energy). The goal is for students to be able to participate, understand, communicate, and ultimately master the use of the scientific language, concepts and theories in this discourse. Several researchers underline the importance of connecting everyday experiences, on the one hand, and the subject content, on the other. For example, Tan et al. (2012) highlight that science teachers should have knowledge of how they can give students the opportunity to connect science content to language usage and the experiences they have outside school. Supporting students' language-wise in science teaching can be relatively complex as the language used often has smooth transitions between everyday language and scientific language (Halliday & Martin, 1993). We can say that the language in science education is in a kind of "hybrid space" and that it can be described as a "hybrid language" (Lemke, 2004; Nygård Larsson & Jakobsson, 2020). For example, the teacher can explicitly point out when and why it is appropriate and functional to use scientific language and word choice or everyday words. When the teacher offers help and support to the development of scientific language, Smit et al. (2013) define it as a language scaffolding strategy.

They suggest that language scaffolding strategies can be planned or take place more spontaneously in interaction with students in the classroom for example, reformulation of utterances or requests for more precise wording. Haug and Ødegaard (2014) argue for facilitating students to speak science themselves, for example by asking them to use scientific concepts in sentences. Xu and Harfitt (2019) developed categories of responses ("conceptual scaffolds") to understand how teachers used language to facilitate an understanding of science. Examples of such responses are mediation (for example by comparing the language of science with everyday language), requesting elaboration, translating, provoking a discussion and withholding information. Thus, teacher questions and feedback can stimulate both students' scientific thinking and development of scientific language. What we need to know more about is what kind of questions teachers actually ask when students participate in scientific practices, and how these questions can include the different students in different phases of scientific inquiry.

## METHOD

### Design

For this purpose, we examined classroom data, collected within the research project “*Inclusive science teaching in multilingual classrooms–A design study*” (funded by NordForsk). A multidisciplinary team of language and science pedagogy specialists from teacher education institutes in the Netherlands, Sweden, and Norway designed three language-oriented science teaching units on sound, technological maintenance and plant growth. These topics were selected to cover a wide range of (primary) curricular content. Principles of design-based research were followed (Bakker, 2018), and the design process allowed for empirical findings to influence new stages of material development and improve teaching practice in an intervention process. Strategies for inclusive science teaching (for instance, promoting interaction and language scaffolding) were embedded in the instructional materials. To accompany the teaching units, a resource guide for inclusive science teaching was developed, including an elaborate explanation of each language-promoting strategy and accompanying examples of how to use them. Twenty-two teachers participated in a similarly outlined four course days (four-six hours). The professional development sessions were developed by researchers from the three countries and included four comparable sessions of between two and a half and four hours, which took place between autumn 2018 and summer 2019 in all three countries. On these course days, the teachers were introduced to the scientific content, and they became acquainted with strategies for promoting students’ oral participation, scientific thinking and language development. They also gained insight into the actual teaching material and exchanged experiences. During the sessions, participating teachers were actively introduced into scientific inquiry in order to experience and more deeply understand the scientific phenomena involved and to promote their engagement with scientific content (e.g., Wellington & Osborne, 2009). Furthermore, teachers were encouraged to adapt instructional activities to their own contexts to make learning meaningful and useful for their own teaching. The participants in this project were teachers from the Netherlands, Norway, and Sweden, and they entered the program voluntarily and were interested in realizing language-oriented science education. In our study, three female teachers from this group were examined more closely: Anna (from Sweden), Charissa (from Norway), and Lisa (from the Netherlands). These teachers all had several years of teaching experience, and they were filmed during the same lesson in the same teaching unit (preparing an investigation of sprouting seed).

### Data Collection: Planning An Experiment With Growing Seeds

The data material was collected from the third and final teaching unit (plant growth). In this unit, students learned about the characteristics and needs of seeds and plants, performed an experiment with sprouting seeds, observed “a garden in a bottle” with the aim of developing an initial understanding of the process of photosynthesis. One of the lessons was designed to scaffold students’ planning and preparing of an experiment with sprouting seeds. Students were expected to share their ideas about what a seed needs in order to sprout, suggest how to test this, and formulate questions and hypotheses for the experiment. The teaching material emphasized teachers’ facilitating and scaffolding of the students’ discussions and sharing of ideas when planning the experiment, and the provision of examples of interactive scaffolding strategies and questions. Concrete examples of interactive language scaffolding strategies and of targeted language production were presented in the material. The teaching material had a special focus on language scaffolding strategies, such as repeating correct student utterances, reformulating utterances, referring to particular words or formulations, and asking students to improve their scientific language. In this study, we only analyzed the first part of the lesson from the material in two contexts: when children share ideas about what a seed needs in order to sprout, and when they plan this experiment. In the teaching material, teachers are recommended to start with open questions about seed sprouting, and to let students talk in small groups about factors that are relevant for seed sprouting and about procedures in the experiment (promoting interaction in science). It is made explicit how teachers can help students to understand features of controlled experiments. The material emphasizes that all factors in the experiment should be the same except for the factor that the students were to investigate. The students’ understandings of the scientific content and the scientific process take precedence over their use of correct scientific language. This means that, at this point, students were not expected to use words such as hypothesis and independent/dependent variables. The data

**Table 1.** Categories of teacher questions (cf. Ulleberg & Solem, 2018)

| Category | OO | CO | CI | OI |
|---|---|---|---|---|
| Description | Teacher does not know answer & purpose is to be oriented in how students think scientifically. | Teachers know answer & there is (roughly) only one answer that is correct. Purpose or intention is to be oriented & uncover correct answer. | Teacher knows answer & purpose is to influence & challenge student's thinking in a certain way. | Teacher does not know answer & purpose is to challenge students to think further without leading them. |

material in this study consists of transcripts of three videotaped teacher-led classroom conversations of approximately 30 minutes. Each of the three teachers commenced their lesson by promoting experiences and thoughts about sprouting seeds, for example by asking questions that could clarify ideas about what seeds need in order to germinate. They also tried in different ways to initiate discussions about how to investigate the factors needed for germination.

## Data Analysis

In this study, we were interested in what kind of questions teachers asked and to what extent they scaffolded scientific understanding and language. The use of questions in the transcripts from the classroom discussions was subjected to in-depth analysis. The coding process builds on video data collected during seven lessons (each lasting 40-70 minutes, four lessons from Norway, one from Sweden and one from the Netherlands), and all these video recordings were transcribed. Ulleberg and Solem's (2018) model provided the starting point for the analytical examination of teacher questions, and four main categories of questions were distinguished (see **Table 1**).

Six researchers participated in the abductive analysis (Timmermans & Tavory, 2012) of the teacher questions, and we carried out independent analyzes to then compare the results and degreed to a consensus of categories. Tentative codes were developed by trying to group questions in these four categories. Questions, where the teacher knew the answer and where the purpose was to be orientated and to uncover the correct answer were categorized as type closed orienting (CO)-questions. These typically involved questions to which students could only answer yes or no, but also asking to remember particular concepts or give name to for instance parts of a seed. The questions that involved more of an influence, where the teacher obviously knew the answer, but the purpose was to challenge the students' thinking and influence it in a certain direction, were categorized as closed influencing (CI) questions. We categorized questions, where it was obvious that the teacher did not know the answer and the purpose was for them to orientate themself in the students' way of thinking as open orienting (OO) questions. Although some of the questions were open, the purpose was to challenge the students without leading them. Such questions were categorized as open influencing (OI) questions. We also counted the occurrences of these four main question strategies (OO, CO, CI, and OI) to gain knowledge of their relative frequency. Based on these four question categories, we performed a further coding using an abductive process (Timmermans & Tavory, 2012) of repeated movements between the data and our theoretical understanding of how the four categories of questions could scaffold understanding of scientific content and use of scientific language. Although scaffolding of both scientific content and language often are intimately interwoven, we chose to separate them for analytical reasons.

The identification of sub-categories of science scaffolding was inspired by the framework of categories that underpinned inquiry lessons used by Kawalkar and Vijapurkar (2013) (**Figure 2**). Similarly, the identification of sub-categories of language scaffolding was inspired by language scaffolding strategies used by Smit et al. (2013). These language scaffolding strategies were also emphasized in the teaching material. The sub-categories of questions that emerged from the coding were then sequenced and grouped/regrouped according to relatedness. The categories of teacher questions scaffolding scientific understanding and language that represents the consensus of coding are shown in **Table 2**, together with typical questions from our data. In the analyze on how teacher questions could scaffold understanding of scientific content and use of scientific language, we used the categories in **Table 2**.

**Table 2.** Categories of teacher questions scaffolding scientific understanding & language

| MQS Scientific scaffolding strategies (Kawalkar & Vijapurkar, 2013) | | Language scaffolding strategies (Smit et al., 2013) |
|---|---|---|
| OO | Eliciting student thoughts (*Can I hear what you have been talking about?*)<br>Encouraging wider response (*So, you think a seed needs light to sprout. What do you others think?*) | Asking students to independently formulate own thoughts (*What do you think a seed need to sprout? Discuss in groups*.) |
| CO | Asking to clarify (by directing attention or by making connections or hinting) (*Are water & nutrition exactly same?*)<br>Factual recalling (from student's observation & experiences) (*How many seeds did you see in movie? Do you remember what this port of seed was called?*)<br>Encouraging students to take a side (*This seed need water (…) Do we agree with that or not?*) | Repeating correct student utterances (*That plant will die if it does not get water. Do you agree?*)<br>Reformulating students' utterances into more academic wording (*So, for the seed to sprout, it needs water & sunlight?*)<br>Referring to or introducing specific words or formulations (*This is called endosperm. Do you agree with that?*) |
| CI | Asking for explanation or elaboration by recalling observations, experiences, or own utterances (*Can you explain why you think a seed need sun to sprout?*)<br>Asking for explanation or elaboration by hinting (*And how can we investigate that? Because it must be something we can explore here in classroom, right?*)<br>Asking for explanation or elaboration by helping to make connections (*Plant will die in winter. Why is there a connection between temperature & winter?*) | Asking to independently formulate explanations or elaborations by:<br>-Recalling observations, experiences, own utterances, by hinting or making connections (*Can you explain what you observed?*)<br>-Repeating correct student utterances & concepts or reformulating into more academic wording (*That plant will die if it does not get water. Can you explain why? So, for seed to sprout, it needs water & sunlight. Can you say more about how this works?*)<br>-Make quality of student contribution explicit (*That was well formulated about seed. But how will this work?*) |
| OI | Asking for a way to test/find out (*How can we investigate this?*)<br>Asking for inference (*What do you think is most important factor in making seeds sprout?*)<br>Encouraging wider response & invoking reflective thinking (*How can this group find out if temperature influence seed germination?*) | Asking students to independently formulate own thoughts (by invoking reflective thinking & by recalling, repeating, reformulating, or making quality explicit) (*How can we investigate this do you think? Discuss in groups.*) |

Note. MQS: Main question strategy

**Table 3.** Teacher's use of different questions in sequence analyzed (number [n] & percentage [%])

| | Number of questions | OO | CO | CI | OI |
|---|---|---|---|---|---|
| Anna (S) | 31 | 6 (18.0) | 18 (55.0) | 7 (21.0) | 2 (6.0) |
| Lisa (NL) | 54 | 13 (24.0) | 16 (30.0) | 19 (35.0) | 6 (11.0) |
| Charissa (NO) | 42 | 6 (14.0) | 21 (50.0) | 10 (24.0) | 5 (12.0) |
| Total | 127 | 25 (20.0) | 55 (43.0) | 36 (28.0) | 13 (10.0) |

## RESULTS

### Orienting & Influencing Questions When Students Prepare An Experiment

In investigation of teacher questions, we counted the occurrences of four main question strategies (OO, CO, CI, and OI) to gain knowledge of their relative frequency. **Table 3** presents an overview of three teachers' use of different types of questions in a similar part of the same lesson when students prepare an experiment.

There were a total number of 127 questions, and all three teachers asked all categories of questions, OO and influencing, and CO and influencing.

### Open Orienting Questions About Seed Sprouting & Procedures in Experiments

25 out of 127 teacher questions were OO, with the teachers asking such questions to orient themselves with regard to students' thinking about factors in seed sprouting and procedures in an experiment. Charissa (NO) and Anna (S) used OO questions to involve students by letting them talk in groups about the factors that are relevant for sprouting (for example, *What did you discuss in the groups or around the tables? What were you talking about*?). They applied the same method to initiate group work in the experiment. These questions scaffolded science by eliciting thoughts, and scaffolded language by asking students to independently

**Table 4.** Science & language's scaffolding strategies in one CO question

| Charissa's CO question | Science scaffolding strategy | Scientific language scaffolding strategy |
|---|---|---|
| Yes, so, Mark's plant gets little water, I say little water, but it gets light. Sunlight but little water. Molly's plant gets a lot of water but no light. So, can we really know whether size of plant has to do with light or with amount of water? | Factual recalling from student's observation.<br>Clarifying by making connections between size of plant & factors of light & water. | Repeating correct pupil utterance.<br>Reformulating student utterances into more academic wording. |

formulate their own thoughts. Both Charissa and Anna asked several students to answer, and repeated student utterances about factors concerning sprouting and procedures in an experiment, thereby scaffolding science by encouraging a wider response from the students. Lisa (NL) also asked students similar OO questions about factors that are relevant for sprouting, but without letting them talk in groups. She asked general OO questions regarding what the different groups wanted to investigate, repeating these later in the dialogue.

## Closed Orienting Questions About Seed Sprouting & Procedures in Experiments

The three teachers asked several CO questions (CO: 55 out of 127 questions). These questions were mostly factual recall or clarifying questions (students could answer yes or no) concerning important features and principles of seed sprouting and experiments. The Norwegian (16 out of 54) and Swedish teacher (18 out of 31) most frequently asked CO questions.

### *Factors for seed sprouting*

The three teachers all asked CO questions about factors for seed sprouting. For example, Anna (S) started the sequence in focus by asking CO questions drawing on what had been observed in the video of the sprouting seed (for example: *You mean the seed, of course. Something happened to the seed. Or not?).* Lisa (NL) also asked several CO questions that were relevant to identify factors for seed sprouting based on earlier experiences in the school garden (for example: *Because carrot seeds, as we have seen, are extremely small. How many did Mr. Luuk have in that tray?).* Both these examples scaffolded science by factual recalling from student observations and experiences, and they scaffolded language by reformulating students' utterances. Furthermore, Charissa (NO) asked a CO question based on earlier discussions about the seed and endosperm (*Endosperm, what was that?),* thereby factual recalling from student experience in the classroom. All three teachers asked CO questions as responses to student utterances to clarify ideas about factors for seed sprouting. In fact, Anna asked as many as eleven such questions. For example, she asked: *So, for the seed to sprout, it needs water and sunlight?* and *That plant will dry out, if it's too warm, you mean?* These questions scaffolded science by using hinting to get the students to clarify, and scaffolded scientific language use by repeating student utterances.

### *Procedures in experiments*

Anna (S), Lisa (NL), and Charissa (NO) all asked several clarificatory CO questions in response to student utterances about experimental procedures, thereby trying to refine the idea of independent and dependent variables in an experiment. For example, Anna asked: *So, you mean that we should sow two seeds that are the same, like Sana said. Should we put one in the window, where it gets sunlight, and one hidden somewhere?* and Lisa asked: *So, one will get water, and the other will not?* Both these questions scaffolded science thinking by using hinting to obtain clarification, and scaffolded scientific language use by reformulating student utterances. Charissa, on the other hand, showed the students a movie about two children performing a controlled experiment to explore the importance of light, heat and water for plant growth. She then asked some CO questions, drawing on what had been observed in the video to refine the idea of independent and dependent variables in an experiment. For instance, she asked a CO question that was on a student utterance about two children's plants, **Table 4** shows how this question scaffolded science thinking and scientific language use.

## Closed Influencing Questions About Seed Sprouting & Procedures in Experiments

Somewhat less frequently than CO questions, the teachers asked CI questions (36 out of 127), and these were asked to influence students to express correct ideas about germination and the seed experiments.

**Table 5.** Science & language scaffolding strategies in one CI question

| Lisa's CI question | Science scaffolding strategy | Scientific language scaffolding strategy |
|---|---|---|
| Space, you said. Space, yes . You said something really good (...) Mr. Luuk (gardener) often talks about dimensions. Why do you think we need space? | Asking for explanation by recalling experiences. | Asking students to independently formulate explanations by:<br>-Recalling experiences.<br>-Repeating correct student utterances.<br>-Making quality of student contribution explicit. |

### Factors for seed sprouting

Anna (S), Lisa (NL) and Charissa (NO) all asked CI questions to influence students to elaborate on their own ideas regarding what a seed needs in order to sprout. Lisa, for example, drew on observations from the movie about a sprouting seed by asking what happened when something came out of the soil: *What happened? What did we see?* This question scaffolded science thinking by asking for elaboration by recalling observations, and, at the same time, it scaffolded language use by asking students to independently formulate this elaboration. Anna asked a CI question about nutrients (*Where do nutrients come from?*), thereby scaffolding both science and language by asking for an explanation by recalling. Charissa asked a similar, CI question: *What do you know about seeds and nutrition? We talked a little bit about it, about the seed here and what the seed consists of, and then we got into nutrition*. This question scaffolded science thinking by asking for elaboration by recalling experience from earlier in the lesson, and, at the same time, it scaffolded scientific language use by asking students to independently formulate this elaboration. Lisa responded to a student who suggested that sunlight is important for sprouting with this CI question: *So, sun in fact, spring. Why am I making a connection between sunlight and spring?* This question scaffolded science by asking for explanation by connecting sunlight to spring, and it scaffolded language by asking students to independently formulate this explanation. Later on, she asked another CI question, based on a student utterance about seeds needing space in order to sprout, **Table 5** shows how this question scaffolded science and language.

### Procedures in experiments

As a response to student suggestions, Lisa (NL) and Charissa (NO) asked some influencing CI questions to encourage students to elaborate on procedures in an experiment. These questions often hinted at important perspectives in order to refine the idea of independent and dependent variables. For example, Charissa asked the following question based on the movie about two children doing a controlled experiment: *What did Mark and Molly do in order to find out what was actually causing one plant to grow bigger and more healthily than the other*? This question scaffolded science thinking by asking for elaboration by recalling observations from the movie, and it also scaffolded scientific language use by asking students to independently formulate this elaboration. Another example was when Lisa asked a question in response to a student's suggestion about procedures in the seed experiment: *You will plant one indoors and one outdoors, both in a sunny spot. So, the only difference will be ... what is the difference actually*? This question scaffolded science thinking by using hinting to ask for an explanation, and also scaffolded language by asking the student to independently formulate this explanation by means of hinting and repeating correct a student utterance. Anna did not ask any CI questions about procedures in an experiment.

## Open Influencing Questions to Invoke Reflective Thinking

The least frequently asked type of question was OI question (OI: 13 out of 127 questions). From the context, it seems that teachers mostly asked these questions in order to influence students to express their own thoughts and to invoke reflective thinking when planning the seed experiment. For example, Anna (S) asked the following question to a group of students who wanted to find out whether sunlight and water were necessary for sprouting: *But how are we going to test that a seed needs these things, that it needs water and sunlight?* This question scaffolded science thinking by asking for a way to find something out, and also scaffolded scientific language use by asking students to independently formulate their own thoughts by invoking reflective thinking. Sometimes these questions were repeated and asked to the whole group, thereby scaffolding science by encouraging a wider response.

**Table 6.** Excerpt of a dialogue between Lisa & two of her students

| | Teacher questions & student responses | Question type | Science scaffolding | Scientific language scaffolding |
|---|---|---|---|---|
| Lisa (NL) | I put seed here (on desk), & then I will look at it tomorrow & day after tomorrow, & next week. Do you think, this is most important thing, do you really think something happens to seed? | CO | Asking to clarify by hinting. | |
| Student A | No. | | | |
| Lisa (NL) | Why not? | CI | Asking for explanations. | Asking to independently formulate explanations. |
| Student A | Because there is no soil. | | | |
| Lisa (NL) | Because there is no soil–So, you say they need soil, what else? What do you think, student B? | CI | Asking for explanations. | Asking to independently formulate explanations by repeating correct student utterance. |
| Student B | Because kind of, little seed, & then there will be roots & roots grow from ground. | | | |
| Lisa (NL) | But cannot those carrots/roots emerge on a table? Why not? | CI | Asking for explanation by hinting. | Asking to independently formulate explanations. |
| Student B | You will need water for that. | | | |

**Table 7.** Excerpt of a dialogue between Charissa (NO) & two of her students

| | Teacher questions & student responses | Question type | Science scaffolding | Scientific language scaffolding |
|---|---|---|---|---|
| Student C | We would like to investigate importance of water for seed sprouting. | | | |
| Charissa (NO) | You would like to find out about importance of water. Mm. How are you going to do that? | OI | Asking for a way to find out. | Asking to independently formulate own thoughts. |
| Student C | I will give one seed too much water. | | | |
| Charissa (NO) | Yes! You could have checked … you think you can give one too much water? And other? | CI | Asking for elaborations. | Asking to independently formulate elaborations by repeating correct student utterance. |
| Student C | Give it less water. | | | |
| Charissa (NO) | OK. What has this group been talking about? | OO | Eliciting student thoughts. | Asking to independently formulate own thoughts. |
| Student D | We can put one seed somewhere cold & one somewhat hot. | | | |
| Charissa (NO) | Yes. And otherwise, everything else same? Yes. | CO | Asking to clarify by hinting. | |

## Dialogues & Questions Facilitating Scientific Thinking & Use of Language

As we have seen, all three teachers asked different questions that scaffolded both science and language when it came to factors needed in order for a seed to sprout. **Table 6** shows an excerpt of such questions that were asked by Lisa (NL) in a dialogue. This dialogue is chosen to show how the three teaches typically asked different questions in dialogues about what seeds need to sprout.

After student B (see **Table 6**) had suggested that the reason why the seed would not sprout on the table was because there was no water present, Lisa stated that nothing was going to happen even if water was added on the table. She did not follow up with questions scaffolding the reason why sunlight, water and temperature are relevant factors to investigate for seed sprouting. In fact, the three teachers asked very few hinting or connecting questions to facilitate the understanding of which specific factors should be investigated in the seed experiment. Therefore, they did not necessarily help students to understand this important part of the experiment. Moreover, the three teachers asked different questions that scaffolded both science thinking and scientific language use when it came to encouraging students to elaborate on procedures in an experiment. **Table 7** shows an excerpt of questions asked by Charissa (NO) in a dialogue.

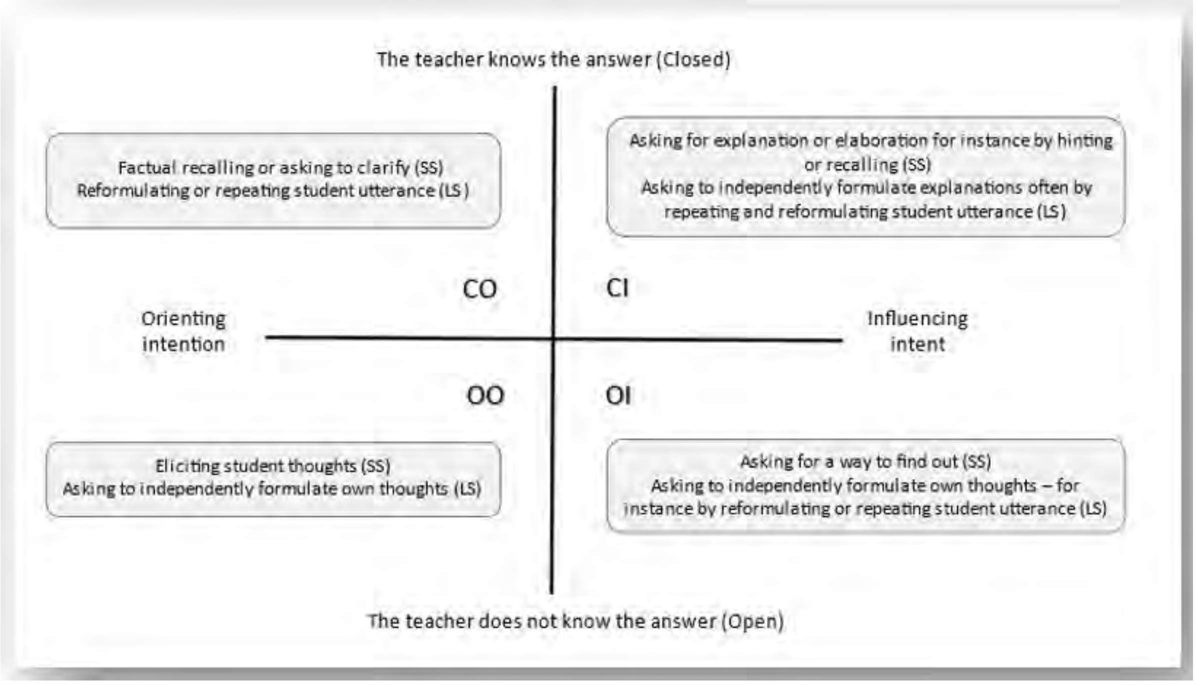

**Figure 3.** Typical questions in this study that combine scaffolding of science content (SS) & science language (SL) placed in questioning model (Adapted from Ulleberg & Solem, 2018)

In this excerpt, we see that Charissa used the different categories of questions to scaffold science thinking and scientific language use when it came to dependent and independent variables in an experiment. All three teachers used similar strategies when asking questions in this context, thereby helping students to understand this aspect of an experiment.

**Figure 3** shows how typical questions in this study combined science and language scaffolding, summing up examples mentioned in the result section.

## DISCUSSION

In this study, we have analyzed teacher questions in three national contexts in which teachers worked with the same teaching materials preparing an experiment with sprouting seeds.

### Orienting & Influencing Teacher Questions When Students Prepare An Experiment

All three teachers asked open questions when preparing an experiment. OO questions served the purpose of orienting themselves about student thinking around seed germination and procedures in an experiment, and OI questions mostly to influence students to express their own thoughts and invoke reflective thinking when planning the seed experiment. The teachers' intention with these questions seemed to be to orient themselves about what students were thinking (Ulleberg & Solem, 2018). Teachers may be genuinely curious about what they have to say, and students got the chance to co-determine the content and to consider their individual ideas, interests or abilities as fruitful. Thus, the teachers created situations in which children cooperated and participated in processes of discipline specific co-construction (Rott & Marohn, 2018). Andersson-Bakken (2015) claims that it is unimportant whether a question is open or closed for the development of the conversation. OO and OI questions in this study engaged students, being the starting point of productive class discussions by eliciting thoughts in the first phase of inquiry activities (Kawalkar & Vijapurkar, 2013). Because these questions ask students to independently formulate their own thoughts, they can scaffold use of scientific language (Smit et al., 2013), and make students think and work out answers for themselves (Mapplebeck & Dunlop, 2021) When asking these open questions, all three teachers often facilitated group work (think-pair-share). For instance, Charissa and Anna asked students OO questions to generate explanations on what seeds need for sprouting both before and after group work. In addition, they asked similar, but more general, OO questions about experiment procedures after group work. In this way, teachers enabled participation by bringing out student ideas and expectations. Brubacher et al. (2019) found that children feel more listened to and better able to give their stories in response to open questions. Prior knowledge and experiences as well as ideas were highlighted, which is an important part of activating and idea-generating dialogues (Kolstø, 2016). The way teachers asked questions indicate that there is an equality between the teacher and student voices. To let different students talk after group work can be an important strategy for designing joint learning situations in scientific inquiry relevant for all learners. In addition, Lisa asked several OO questions about how they had cooperated in their groups. The quality of the cooperation can be enriched as the students profit from each other’s experiences as a form of social constructivism (Florian & Spratt, 2013).

## Use of Questions to Scaffold Understanding Idea of An Experiment

In this study, the three teachers asked several CO, CI, and OI questions to influence students’ science thinking, thus recognizing the cognitive difficulty of learning the idea of science (Ulleberg & Solem, 2018). These questions often were responses to student utterances, that is, teachers trying to recognize barriers in students’ grasping of the idea of an experiment. There were several examples of triadic dialogues, due to a three-part question-answer feedback sequence (Lemke, 1990; Mehan, 1979; Sinclair & Coulthard, 1975). The questions teachers ask and the way they are asked can greatly influence students’ thinking when trying to understand new phenomena and scientific processes (Chin, 2007; Croom & Stair, 2005; Kawalkar & Vijapurkar, 2013). For instance, Anna and Charissa posed clarificatory and factual recall CO questions to influence and to help students understand the relevant factors there were to investigate in the seed experiment. Brubacher et al. (2019) found that children tend to find closed questions easier than open questions because they require less reflection to answer. Moreover, some of the questions made connections with earlier experiences outside the classroom (Van Graft et al., 2009). All three teachers also asked several questions prompting students to elaborate and explain scientific ideas, for example, Lisa, who asked why she connected between sun and spring. In this question she scaffolds science understanding by connecting two ideas (Kawalkar & Vijapurkar, 2013). Moreover, all three teachers asked both CO and CI questions as responses to student responses about experiment procedures. In this way, they supported students’ conceptual knowledge and procedural skills during open inquiry (Zion et al., 2007). Klahr and Nigam (2004) argue that familiarization with experimental design should begin as early as primary school–as is done in this study. All three teachers asked questions to facilitate independent and dependent variables (see examples, **Table 5**, **Table 6**, and **Table 7**). Other CI questions (type CI) were typically hinting at or asking students to elaborate (for instance, Lisa to a student who wanted to experiment with clean and dirty water: *And how can we investigate that? Because it must be something we can explore here in the classroom, right?)*. This can be considered feedback strategies that support students’ own thinking and argumentation, and according to Hardman (2008), this promotes inquiry and scientific thinking. However, without sufficient support from teachers, students will have difficulties performing inquiry procedures and moving between inquiry phases. Even though Lisa asked more influencing CI questions than the other two teachers in dialogues relevant for sprouting, she did not ask questions that helped students to understand what factors are most relevant for sprouting, and therefore feasible to investigate (see **Table 6**). This example shows that she did not fully recognize the barrier students faced when specifying dependent variables that could be investigated in the seed experiment. Failure to implement an appropriate experimental design will lead to problems in addressing the hypotheses (Arnold et al., 2014; Pedaste et al., 2015), and teachers will have problems with supporting students during the investigation. In this case, she probably could have asked more influencing questions to promote students expressing themselves about water, sun and temperature as factors for seed sprouting. On the other hand, the three teachers asked feasible questions that helped student understand dependent and independent variables in an experiment (see example **Table 7**). The least frequent question type was OI questions (type OI), which teachers asked mostly to influence students to express their own thoughts and to invoke reflective thinking when planning the seed experiment. In these situations, the teacher did not know the answer, with the purpose of the question being to challenge students to think further and more independently (Ulleberg & Solem, 2018). Such questions can probably greatly influence students’ thinking when trying to understand the idea of an experiment (Chin, 2007).

### Use of Questions to Scaffold Scientific Language Development

The three teachers also asked questions that scaffolded scientific language use, thus recognizing the barrier of developing a scientifically functional language in science (Brown & Spang, 2008). The language scaffolding strategies made visible in the teachers' repertoire of questions seemed to be different ways to scaffold language development, for instance by facilitating students to speak science themselves (Haug & Ødegaard, 2014). The language scaffolding strategies are in line with what was suggested in the teaching material (Smit et al., 2013) and took place spontaneously in interaction with students in the classroom. However, there were no, or very few, examples of questions that referred to or introduced particular words and formulations, or questions that asked students to improve spoken language. The context was planning an experiment, and questions were asked in hybrid and everyday language. To plan an experiment can be regarded as a "secondary discourse" (Gee, 1996), that is, very different from what students experience in everyday life. As Lee and Buxton (2013) recommend, science and language teaching go hand in hand. Students were asked to elaborate on observations, experiences in their everyday language. On some occasions, the teachers facilitated the functional use of scientific language and specific words (for instance the word *nutrition*) (Halliday & Martin, 1993; Lemke, 2004; Nygård Larsson & Jakobsson, 2020).

### Use of Questions to Scaffold Idea of An Experiment & Scientific Language Development

Three teachers often asked questions that combined scaffolding science content and language, both in influencing and orienting ways (see **Figure 3**). Thus, they targeted both the barrier of developing a scientifically functional language in science and the barrier of understanding the idea of an experiment. There are several examples of combinations of language scaffolding strategies and science content specific strategies used simultaneously in teacher questions (Kawalkar & Vijapurkar, 2013; Smit et al., 2013). For instance, Charissa asks a question about nutrition that is clarificatory and helps to make a connection between concepts (science content specific strategies), at the same time, she reformulates the student utterance into more academic wording in the form of a question (language scaffolding strategy). There are several other examples, where teachers ask questions that are both clarificatory and reformulate student utterances into more academic wording (see **Table 4**, **Table 5**, and **Table 6**). Another typical combination is when teachers ask students to elaborate on and explain scientific ideas (science content specific strategies), while simultaneously asking them to independently formulate an explanation (language scaffolding strategy). This can be compared with one of the categories of responses Xu and Harfitt (2019) developed to understand how teachers use language to give students an understanding of science, namely category "requesting elaboration".

## CONCLUSIONS & IMPLICATIONS

The data analysis shows that teachers ask both open and closed, and influencing and orienting questions, and that these can be considered as important scaffolding strategies when young students prepare an experiment. The open questions can help different students to discover their own ideas and facilitate cooperation and discussion. OO and OI questions allow students to cooperate with the content. When students share ideas, teachers can follow up with new more influencing questions. Furthermore, both CO and influencing and OI question can scaffold student language and conceptual understanding. Thus, appropriate questions can be a way of recognizing the barrier of developing a scientifically functional language in science and the barrier of understanding the idea of an experiment. In this study, teachers scaffold both content-specific meaning-making and language through their choice of question type. For example, when teachers ask follow-up questions based on pupils' ideas, they choose question types that scaffold both content-specific meaning-making and language simultaneously. But sometimes their choices of question do not help student to understand scientific practice. For instance, there seems to be a lack of influencing questions that invoke student reflections relevant for the idea of an experiment. Furthermore, the language scaffolding does not consistently invoke students to independently formulate explanations in more of a science wording. The study shows the importance of asking a variety of question types in order to include pupils in classroom interaction. Also, teachers can be supported to raise questions that are adapted to different phases of scientific inquiry in particular activities. In this study, we suggest four categories of questions (OO, CO, CI, and OI) as a framework for questions scaffolding scientific thinking and language development in science inquiry classroom.

**Author contributions: ABØ & MK:** writing article & ERS: collected & transcribed data from Netherlands & participated in several discussions about how to analyze & present data. All authors approved the final version of the article.

**Funding:** *Inclusive science teaching in multilingual classrooms–A design study* (2018-2021) funded by NRO/NordForsk #86052, directed by Maaike Hajer, University of Applied Sciences, Utrecht, the Netherlands.

**Ethics declaration:** The authors declared that the study was approved by the institutional ethics committee of Norwegian Agency for Shared Services in Education and Research on 24 September 2018 (Approval code: 944915). All data is collected with the informants' consent, thus meeting ethical standards. The video data has been stored appropriately.

**Declaration of interest:** The authors declared no competing interest.

**Data availability:** Data generated or analyzed during this study are available from the authors on request.

## REFERENCES

Andersson-Bakken, E. (2015). Når åpne spørsmål ikke er åpne: Hva karakteriserer lærerspørsmål i en litterær samtale [When open questions are not open: What characterizes teacher questions in a literary conversation]? *Nordic Studies in Education, 35*(3-4), 280-298.

Arnold, J. C., Kremer, K., & Mayer, J. (2014). Understanding students' experiments: What kind of support do they need in inquiry tasks? *International Journal of Science Education, 36,* 2719-2749. https://doi.org/10.1080/09500693.2014.930209

Bakker, A. (2018). *Design research in education. A practical guide for early career researcher*. Routledge. https://doi.org/10.4324/9780203701010

Baurhoo, N., & Asghar, A. (2014). Using universal design for learning to construct inclusive science classrooms for diverse learners. *LEARNing Landscapes, 7*(2), 59-81. https://doi.org/10.36510/learnland.v7i2.651

Biggers, M. (2018). Questioning questions: Elementary teachers' adaptations of investigation questions across the inquiry continuum. *Research in Science Education, 48*, 1-28. https://doi.org/10.1007/s11165-016-9556-4

Brown, B. A., & Spang, E. (2008). Double talk: Synthesizing every day and science language in the classroom. *Science Education, 92*(4)*,* 708-732. https://doi.org/10.1002/sce.20251

Brubacher, S. P., Timms, L., Poweli, M, & Bearman, M. (2019). "She wanted to know the full story": Children's perceptions of open versus closed questions. *Child Maltreatment, 24*(2) 222-231. https://doi.org/10.1177/1077559518821730

Chin, C. (2007). Teacher questioning in science classrooms: Approaches that stimulate productive thinking. *Journal of Research in Science Teaching, 44,* 815-843. https://doi.org/10.1002/tea.20171

Colburn, A. (2006). What teacher educators need to know about inquiry-based instruction. In *Proceedings of the Annual Meeting of the Association for the Education of Teachers in Science*.

Croom, B., & Stair, K. (2005). Getting from Q to A: Effective questioning for effective learning. *The Agricultural Education Magazine, 78*(1), 12-15.

Edelson, D. C., Reiser, B. J., McNeill, K. L., Mohan, A., Novak, M., Mohan, L., Affolter, R., McGill, T. A. W., Bukc Bracey, Z. E., Deutch Noll, J., Kowalski, S. M., Novak, D., Lo, A. S., Landel, C., Krumm, A., Penuel, W. R., Van Horne, K., González-Howard, M., & Suárez, E. (2021). Developing research-based instructional materials to support large-scale transformation of science teaching and learning: The approach of the OpenSciEd middle school program. *Journal of Science Teacher Education, 32*(7), 780-804. https://doi.org/10.1080/1046560X.2021.1877457

Florian, L., & Spratt, J. (2013). Enacting inclusion: A framework for interrogating inclusive practice. *European Journal of Special Needs Education, 28*(2), 119-135. https://doi.org/10.1080/08856257.2013.778111

Gee, J. P. (1996). *Social linguistics and literacies: Ideology in discourses*. Taylor & Francis.

Geier, R., Blumenfeld, P., Marx, R., Krajcik, J., Fishman, B., Soloway, E., & Clay-Chambers, J. (2008). Standardized test outcomes for students engaged in inquiry-based science curriculum in the context of urban reform. *Journal of Research in Science Teaching, 45*(8), 922-993. https://doi.org/10.1002/tea.20248

Halliday, M. A. K., & Martin, J. R. (1993). *Writing science. Literacy and discursive power*. University of Pittsburgh Press.

Hardman, F. (2008). Teachers use of feedback in whole-class and group-based talk. In N. Mercer, & S. Hodgkinson (Eds.), *Exploring talk in school: Inspired by the work of Douglas Barnes* (pp. 131-150). SAGE. https://doi.org/10.4135/9781446279526.n8

Haug, B. S., & Ødegaard, M. (2014). From words to concepts: Focusing on word knowledge when teaching for conceptual understanding within an inquiry-based science setting. *Research in Science Education, 44*(5), 777-800. https://doi.org/10.1007/s11165-014-9402-5

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist, 42,* 99-107. https://doi.org/10.1080/00461520701263368

Hornstrup, C., Tomm, K., & Johansen, T. (2009). *Spørgsmål, der gør en forskel. Nye tanker–Nye muligheder* [*Questions that make a difference. New thoughts–New possibilities*]. http://macmannberg.dk/wpcontent/filer/Spoergsmaal__der_goer_en_forskel.pdf

Jakobsson, A., & Kouns, A. (2023). Subject-language perspectives on multilingual students learning in science. *European Journal of Science and Mathematics Education, 11*(2), 197-214. https://doi.org/10.30935/scimath/12568

Kawalkar, A., & Vijapurkar, J. (2013). Scaffolding science talk: The role of teachers' questions in the inquiry classroom. *International Journal of Science Education, 35*(12), 2004-2027. https://doi.org/10.1080/09500693.2011.604684

Klahr, D., & Nigam, M. (2004). The equivalence of learning paths in early science instruction: Effects of direct instruction and discovery learning. *Psychological Science, 15*(10), 661-667. https://doi.org/10.1111/j.0956-7976.2004.00737.x

Kolstø, S. D. (2016). Læring krever språkliggjort refleksjon [Learning requires reflection on language]. In F. Thorsheim, S. D. Kolstø, & M. U. Andresen (Eds.), *Erfaringsbasert læring: Naturfagdidaktikk* [*Learning based on experiences: Science pedagogy*] (199-234). Fagbokforlaget.

Lee, O., & Buxton, C. (2010). *Diversity and equity in science education: Research, policy, and practice*. Teachers College Press.

Lee, O., Llosa, L., Grapin, S. E., Haas, A., & Goggins, M. (2019). Science and language integration with English learners: A conceptual framework guiding instructional materials development. *Science Education, 103*(2), 317-337. https://doi.org/10.1002/sce.21498

Lee, O., Quinn, H., & Valdes, G. (2013). Science and language for English language learners in relation to next generation science standards and with implications for common core state standards for English language arts and mathematics. *Educational Researcher, 42*(4), 223-233. https://doi.org/10.3102/0013189X13480524

Lemke, J. (1990). *Talking science: Language, learning, and values*. Ablex Publishing Company.

Lemke, J. (2004). The literacies of science. In E. W. Saul (Ed.), *Crossing borders in literacy and science instruction* (pp. 33-47). International Reading Association and NSTA Press. https://doi.org/10.1598/0872075192.2

Mapplebeck, A., & Dunlop, L. (2021). Oral interactions in secondary science classrooms: A grounded approach to identifying oral feedback types and practices. *Research in Science Education, 51*(2), 957-982. https://doi.org/10.1007/s11165-019-9843-y

Mehan, H. (1979). "What time is it, Denise?": Asking known information questions in classroom discourse. *Theory into Practice, 18*(4), 285-294. https://doi.org/10.1080/00405847909542846

Mortimer, E. F., & Scott, P. H. (2003). *Meaning making in secondary science classrooms*. Open University Press.

Nygård Larsson, P., & Jakobsson, A. (2020). Meaning-making in science from the perspective of students' hybrid language use. *International Journal of Science and Mathematics Education, 18*(5), 811-830. https://doi.org/10.1007/s10763-019-09994-z

Nystrand, M., Gamoran, A., Kachur., R., & Prendergast, C. (1997). *Opening dialogue. Understanding the dynamics of language and learning in the English classroom*. Teacher College Press.

Ozdemir, G., & Clark, D. B. (2007). An overview of conceptual change theories. *Science & Technology Education, 3*(4), 351-361. https://doi.org/10.12973/ejmste/75414

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., Constantionos, C. M., Zacharia, Z. C., & Tsourlidaki, E. (2015). Phase of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review, 14*, 47-61. https://doi.org/10.1016/j.edurev.2015.02.003

Posner, G., Strike, K., Hewson, P., & Gertzog, W. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education, 66*(2), 211-227. https://doi.org/10.1002/sce.3730660207

Roehrig, G. H., & Luft, J. A. (2004). Inquiry teaching in high school chemistry classrooms: The role of knowledge and beliefs. *Journal of Chemical Education, 81*, 1510-1516. https://doi.org/10.1021/ed081p1510

Rott, L., & Marohn, A. (2018). Choice2explore–A teaching concept for inclusive science education in primary schools. In O. Finlayson, E. McLoughlin, S. Erduran, & P. Childs, (Eds.), *Proceedings of the 12th ESERA 2017 Conference, research, practice and collaboration in science education* (2194-2202). Dublin City University.

Saye, J., & Brush, T. (2002). Scaffolding critical reasoning about history and social issues in multimedia-supported learning environments. *Educational Technology Research and Development, 50*, 77-96. https://doi.org/10.1007/BF02505026

Scott, P., Mortimer, E., & Ametller, J. (2011). Pedagogical link-making: A fundamental aspect of teaching and learning scientific conceptual knowledge. *Studies in Science Education, 47*(1), 3-36. https://doi.org/10.1080/03057267.2011.549619

Sinclair, J. M., & Coulthard, M. (1975). *Towards an analysis of discourse: The English used by teachers and pupils*. Oxford University Press.

Smit, J., Van Eerde, H. A. A., & Bakker, A. (2013). A conceptualization of whole-class scaffolding. *British Educational Research Journal, 39*(5), 817-834. https://doi.org/10.1002/berj.3007

Spaan, W., Oostdam, R., Schuitema, J., & Pijls, M. (2022). Analyzing teacher behavior in synthesizing hands-on and minds-on during practical work. *Research in Science & Technological Education*. https://doi.org/10.1080/02635143.2022.2098265

Tan, E., Barton Calabrese, A., Turner, E., & Gutiérrez, M. V. (2012). *Empowering science and mathematics education in urban schools*. University of Chicago Press. https://doi.org/10.7208/chicago/9780226037998.001.0001

Timmermans, S., & I. Tavory, I. (2012). Theory construction in qualitative research: From grounded theory to abductive analysis. *Sociological Theory, 30*(3), 167-186. https://doi.org/10.1177/0735275112457914

Ulleberg, I., & Heiberg Solem, I. (2018). Which questions should be asked in classroom talk in mathematics? Presentation and discussion of a questioning model. *Acta Didactica Norge, 12*(1), 3. https://doi.org/10.5617/adno.5607

Van Graft, M., Boersma, K., Goedhart, M., Van Oers, B., & De Vries, M. (2009). *De concept-contextbenadering in het primair onderwijs. Deel 1. Een conceptueel kader voor natuur en techniek* [*The concept-context approach in primary education. Part 1. A conceptual framework for science and technology*]. SLO.

Wellington, J., & Osborne, J. F. (2001). *Language and literacy in science education*. Open University Press.

Xu, D., & Hartiff, G. J. (2019). Teacher language awareness and scaffolded interaction in CLIL science classrooms. *Journal of Immersion and Content-Based Language Education, 7*(2), 212-232. https://doi.org/10.1075/jicb.18023.xu

Zacharia, Z. C., Manoli, C., Xenofontos, N., De Jong, T., Pedaste, M., van Riesen, S. A., Kamp, E. T., Maeots, M., Siiman, L., & Tsourlidaki, E. (2015). Identifying potential types of guidance for supporting student inquiry when using virtual and remote labs in science: A literature review. *Educational Technology Research and Development, 63*(2), 257-302. https://doi.org/10.1007/s11423-015-9370-0

Zion, M., Slezak, M., Shapira, D., Link, E., Bashan, N., Brumer, M., Orian, T., Nussinowitz, R., Court, D., Agrest, B., Mendelovici, R., & Valanides, N. (2004). Dynamic, open inquiry in biology learning. *Science Education, 88*, 728-753. https://doi.org/10.1002/sce.10145

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