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5. TEACHER SUPPORT IN TECHNOLOGY-BASED SCIENCE LEARNING

Balancing Procedural and Conceptual Support in Students' Learning Processes

INTRODUCTION

This chapter focuses on the support provided by a teacher in a setting where primary school students worked on a technology-based science project. This setting involved open-ended tasks to be solved through project work, peer collaboration, and the use of various information resources. In today's schools, this type of instructional setting is quite common, which makes them interesting to study. From an early age, students are exposed to conceptual tasks that pose complex multidisciplinary problems, usually involving integration of relevant information by the use of multiple digital and non-digital resources. These types of learning activities, which encompass a high level of student engagement, are referred to as exploratory or inquiry-based activities. In naturalistic classroom settings, the teacher most often acts as an important resource and provides various forms of guidance during students' learning activities. Nevertheless, several researchers have pointed out that rather few studies focus on the role and significance of dialogue-based teacher support in technology-based learning settings. The underlying claim of the current study is that more knowledge is needed about the teacher's role in these types of settings. By taking a dialogic approach (Linell, 2009; Vygotsky, 1986), the study aims to further explore the role of teacher support in technology-based learning in science education by directing the analytical attention towards various forms of teacher support, and their potential roles in facilitating students' development of conceptual understanding.

Studies focusing on classroom dialogues have shown that various forms of teacher support are essential for students' development of conceptual understanding; in particular, two pivotal forms are *conceptual* and *procedural* support (Furberg, 2016; van Leeuwen, Janssen, Erkens, & Brekelmans, 2013).[1] Conceptual support refers to guidance by helping students make sense of the scientific content (i.e., the concepts or processes) associated with the scientific theme of the project, activity, or assignment. In other words, it involves conceptually oriented talk that directs the

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students' and the teacher's attention towards making sense of conceptual issues. As will be discussed in more detail in the review section, teachers may apply several strategies when providing conceptual support. Procedural support involves guidance by helping students regulate their work processes. For instance, this might involve aid in task planning, structuring their work process, finding relevant information, dividing labour between students, and regulating time. The teacher uses both forms to facilitate students' *development of conceptual understanding*. An underlying premise of this study is that the two support forms are to be seen as analytical concepts, implying that they do not necessarily exist as clear-cut entities. In everyday classroom dialogues, the teacher provides both conceptual and procedural support to the students, and often within the same dialogical sequence. The interesting point is to identify what can be seen as *patterns* in the teacher's way of supporting students, as well as how the teacher balances the forms of support within different activity forms of the technology-based science project.

The empirical basis for the current study is a science project about "health and the human body" involving fifth-grade primary school students (aged 10–11) and their teacher.[2] Central themes were the heart and lung functions and the blood circulation system. The learning activities involved a combination of whole-class activities, individual seatwork, and group work. The students used various digital information resources available through their personal iPads. In order to explore the complexity of facilitating students' development of conceptual understanding in these types of settings, we performed detailed analyses of selected student – teacher interactions taking place within the various learning activity settings. We directed the analytical attention towards student – teacher interactions within various activities because such interactions display the challenges experienced by the students as well as the teacher's responses to those challenges. The following research questions guided the analyses:

- *What types of student challenges emerge in the various settings?*
- *What types of support does the teacher provide within the various learning activities?*

Before we enter the empirical analysis section, we will present and discuss relevant findings from previous studies focusing on teacher support in computer-based learning settings. Subsequently, we will account for the underlying sociocultural perspective that forms the underlying premise for our view on teacher support, as well as the applied analytical procedures (Mercer, 2004; Säljö, 2010; Vygotsky, 1978). Then follows a section where we will outline and discuss methodological issues. The analysis section constitutes the hearth of the chapter, comprising detailed analyses of selected excerpts of student – teacher interactions taking place during the science project. The chapter will conclude with a discussion section addressing the empirical analyses in light of the findings from previous research.

STUDIES OF TEACHER SUPPORT IN COMPUTER-BASED SCIENCE LEARNING SETTINGS

Although many studies have documented positive sides of students' engagement in collaborative and inquiry-oriented learning activities involving the use of digital resources, studies have also found challenges in these learning settings. Some of these challenges concern *conceptual aspects* such as making sense of the concepts, problems, or assignments; making sense of and applying digital- and text-based conceptual resources; and engaging in productive conceptual sense-making dialogues with peers (Hmelo-Silver & Barrows, 2008; Mercer, 2004). Other challenges involve *procedural aspects* such as structuring their work process and tasks, practicing time management, and dealing with practical and social sides of peer collaboration (Engle & Conant, 2002; Furberg & Arnseth, 2009). The findings from studies focusing on students' learning processes in technology-supported learning settings provide compelling arguments for the need to explore teacher support in these types of settings. In the following, we present studies of teacher support organised according to their findings related to the significance of providing conceptual and procedural support.

Findings Related to the Significance of Conceptual Support

Several studies have emphasised the significance of student – teacher interactions in terms of providing conceptually oriented aid in computer-supported learning settings (Dolonen & Ludvigsen, 2012; Jornet & Roth, 2015; Mercer, 2004). Mercer and his colleagues studied classroom dialogues and their functions, both in class-wide and small-group settings (cf. Mercer, 2004; Mercer & Littleton, 2007). By analysing student – teacher interactions, Mercer (2004) identified the following central functions of communicative teacher intervention: elicitation of students' understanding, contextualisation and re-framing of students' verbal accounts, and conceptual re-phrasing of students' utterances through the application of more scientific terms. Classroom dialogue studies have also shown positive effects of conceptual understanding on students' development when the teacher provides indirect intervention, for instance by prompting metacognitive questions or encouraging students to retrieve science-based information instead of providing descriptive explanations or prompting fact-based student responses (Hakkarainen, Lipponen, & Järvelä, 2002; Hmelo-Silver & Barrows, 2008).

Studies of student – teacher dialogues have also offered insight into how digital tools can be used as resources in conceptually oriented classroom discussions (Mercer, Hennessy, & Warwick, 2010; Rasmussen & Hagen, 2015). Gillen, Littleton, Twiner, Staarman, and Mercer (2008) demonstrated how teachers used interactive whiteboards in primary science education as instructional resources for facilitating students' development of conceptual understanding. In one of the study's analysed cases, a teacher used the multimodal possibilities of an interactive whiteboard to introduce the students to the phenomenon of evaporation. By using self-produced video clips and video stills to demonstrate how water evaporates in a hot frying pan, the teacher invited the students into a discussion of the process taking place. The analyses of student – teacher interactions showed that the multimodal presentation created continuity between lessons, established shared experience and understanding, and bridged the gap between everyday and scientific explanations of scientific principles.

Findings Related to the Significance of Procedural Support

Concerning the types of support provided by teachers, one of the studies within the SMUL-project mapped different types of teacher interventions in Norwegian classrooms across different types of subjects (Hodgson, Rønning, & Tomlinson, 2012). The systematic observations revealed that the most frequent teacher interventions concerned supervision and follow-up of students' work processes, i.e. forms of procedural support. A case study by Furberg focusing on teacher support in a computer-based science project (Furberg, 2016) further documented the emphasis on and significance of procedural support. Analyses of students' help requests to the teacher during group work showed that 29% of all help requests concerned procedural aspects of their work. Furthermore, guiding students in how to practically plan and carry out the inquiry work became essential support for the students to understand not only the concepts at issue, but also the notion of doing inquiry.

Support aimed at helping students to regulate their working processes has proven to be particularly important in learning situations characterised by exploratory work and student collaboration (Howe et al., 2007; Mäkitalo-Siegl, Kohnle, & Fischer, 2011; Strømme & Furberg, 2015; Urhahne, Schanze, Bell, Mansfield, & Holmes, 2010). One important aspect of procedural support is to help students become self-regulated, and thus be able to regulate and organise their own learning processes and activities in individual as well as in collaborative learning situations (Järvelä, Järvenoja, Malmberg, & Hadwin, 2013). Studies have frequently revealed that students find it challenging to plan, organise work tasks, administrate time use, and locate relevant information resources. This especially applies to experimental learning settings (Lunetta, Hofstein, & Clough, 2007) as well as inquiry-oriented learning settings, which often stretch over time and involve open-ended, unstructured tasks (Urhahne et al., 2010).

In a setting of computer-supported collaborative inquiry learning within physics, Mäkitalo-Siegl et al. (2011) examined the influence of consolidation-oriented teacher support in whole-class settings. In one classroom condition, the teacher provided instructions for consolidation at the beginning of each new inquiry phase in a plenary session. The teacher also evaluated and discussed the results with the students at the end of each inquiry phase. In the other classroom condition, the teacher did not interrupt small-group collaborations with instructions or provide evaluations in a plenary session. Analyses of the students' dialogues during their work processes showed that the students in the first condition sought less help during group-work activities, but showed higher learning gains than students in the condition with lower teacher intervention (Mäkitalo-Siegl et al., 2011).

The review of the studies focusing on various forms of teacher support in collaborative, technology-based learning settings offers a valuable background for understanding the significance of both conceptual and procedural support as ways of helping students in their development of conceptual understanding. However, studies undertaken by Strømme and Furberg (2015) and Furberg (2016) focusing on student – teacher interactions during a computer-supported inquiry-based learning in the setting of science education show how difficult it can be for teachers to find the right balance between providing procedural and conceptual support. For instance, teachers experience difficulties finding the balance between providing the information requested by students and facilitating students in utilising resources and each other's knowledge and understanding.

In the current study, we analysed excerpts of student – teacher interactions taking place in technology-supported science in relation to the outlined conceptualisations of teacher support. Before discussing our analyses, we will provide a brief account of our underlying sociocultural perspective.

A SOCIOCULTURAL PERSPECTIVE ON TEACHER SUPPORT IN TECHNOLOGY-BASED LEARNING SETTINGS

From a sociocultural point of view, the notion of "helping" students in their learning processes is a central issue. This was especially highlighted in Vygotsky's (1978) concept of the "zone of proximal development," referring to the difference between what a learner can do with and without help from more experienced individuals. Vygotsky's concept reveals that help-seeking is not only desirable, but essential to the development of skills and conceptual understandings. An important part of human conduct and learning processes is the use of material tools (Säljö, 2010), which can be seen as cultural artifacts that store knowledge and social practices developed over generations (Cole, 1996). This interpretation implies that digital learning environments—often containing representations such as graphs, visualisation models, or simulations—display and represent experts' knowledge about objects, processes, or phenomena. Students interact with the knowledge and practices stored within digital learning environments when they utilise these representations in their learning activities (Säljö, 2010). In this sense, digital learning environments with their embedded digital tools are resources for promoting students' development of conceptual understanding.

Seen from a sociocultural perspective, learning is a dynamic, social, and interactive meaning-making process (Linell, 2009; Säljö, 2010). Through their interactions, participants try to interpret and make sense of situations, activities, resources in use, and scientific concepts. Within this context, language is considered the most important tool for making sense of the world and for mediating thinking and reasoning (Vygotsky, 1986), with discourse serving as a "social mode of thinking" (Mercer, 2013). Making sense of scientific concepts is a dialogical matter that takes place among interacting participants in specific settings, including help-seeking settings in which students interact with teachers (Strømme & Furberg, 2015). Seeing learning as an attainment of shared meaning and understanding does not imply that students can develop just any interpretation of scientific concepts. Every scientific field encompasses a range of relevant terms and ideas, in addition to valid ways of talking about these matters. In educational settings, students perceive the teacher as an "expert" within specific knowledge domains and the main mediator of valid ways of discussing scientific concepts. The teacher is also a facilitator of prevailing valid methods of understanding assignments and solving assignments in a satisfactory manner (Jornet & Roth, 2015; Strømme & Furberg, 2015).

As previously mentioned, a sociocultural perspective forms the basis for choosing a dialogical approach when exploring support provided by a teacher in this study's empirical setting. The choice of a dialogical approach has consequences and implications for our research design, data, and analytical procedures, as accounted for in the following section.

METHODS

Participants and Educational Setting

The data were produced during a case study as part of the Ark&App project (Furberg, Dolonen, & Ingulfsen, 2015). The empirical setting was a science project about "health and the human body," which took place over the course of two weeks in March 2015. The participants were one class of 18 primary school students aged 10 to 11 years, and their science teacher. One of the strategic focuses of the school in focus was to enhance teachers' and students' digital competency. As a part of this strategy all students are provided with their personal iPad when they reach grade four. This implies that the students and the teacher in focus of this study were in their second year as frequent iPad users. In addition to the iPads, the classroom was equipped with an interactive whiteboard.

The project focused on the four general topics heart and lung functions, blood circulation, and CPR. Each thematic part in the project opened with a whole-class activity focusing on the learning goals and activation of students' prior knowledge, followed by individual activities where the students prepared their contributions to be used in collaborative group-work activities. Each thematic session ended with a whole-class activity involving consolidation and reflection on the undertaken tasks and concepts at issue. The teacher selected the themes and learning goals for the project, as well as planning the learning activities and use of learning resources. The teacher was not given any specific instructions from the researchers regarding her role as a teacher in the project. During the project, the teacher was fully responsible for implementing the instructional design without inference from the observing researchers.

Data Material and Analytical Procedures

The main data material applied in the present study constituted 12 hours of transcribed video recordings of all student – teacher interactions taking place during the project, as well as transcriptions of interaction taking place within three student focus groups. Ethnographic field notes made during classroom observations provided supplementary contextual data for the analyses of the participants' interactions (Derry et al., 2010). Furthermore, resources and products developed by the teacher and the students such as PowerPoint presentations, week plans, project plans, and worksheets were collected. To ensure confidentiality, the participants' names have been anonymised on all materials.

For detailed analyses, we selected five interaction sequences in which the students' and teacher's attention was directed towards making sense of conceptual or task-related issues, in this case heart and lung function. To illustrate the challenges experienced by students within the various learning activities and the teacher's responses to those challenges, we selected one excerpt from the start-up activity, one excerpt from the individual activity, two excerpts from group-work settings, and one excerpt from the whole-class sum-up session. Each of these activities involved the use of various forms of digital resources. We selected the analysed excerpts based on three criteria. First, the chosen excerpts involved settings where the student – teacher interaction focused on talking about scientific concepts and how to complete the assignments. A second selection criterion was that the conceptual focus of the help requested and provided should reflect the *most frequent* conceptual challenges addressed. The third requirement concerned interactional transparency, such that the settings selected involved participants' talk characterised by a certain degree of verbal explicitness (Linell, 2009; Mercer, 2004). Based on these criteria, the selected settings displayed typical interactional patterns of the teacher's way of supporting students, as well as how the teacher balanced the two forms of support within this empirical setting.

The applied analytical procedure was interaction analysis, involving a sequential analysis of the talk and interaction between interlocutors (Jordan & Henderson, 1995). A sequential analysis implies that each utterance in a selected excerpt is considered in relation to the previous utterance in the ongoing interaction. As a result, the focus is not on the meaning of single utterances, but on how meaning is created within the exchange of utterances (Mercer, 2004). This practical guideline for analysis ensures that the participants' concerns and their actual activities—not only the researchers' intentions and predefined interests—are scrutinised (Linell, 2009). The video recordings were transcribed according to Jeffersonian transcription notations (Jefferson, 1984).[3] The discourse took place in Norwegian, and the researchers translated the material. In addition to the detailed examination of the interaction sequences, ethnographic information about the institutional setting was used as a background resource for understanding what was going on.

ANALYSIS OF TEACHER SUPPORT IN A TECHNOLOGY-BASED SCIENCE PROJECT

Some of the most prominent features in this case are the clear and structured instruction and class management that the teacher demonstrated throughout the project. The students were seated in groups of four to five students, and each student had an iPad. The teacher dedicated two to three 45-minute school lessons to each of the four thematic sessions. All thematic sessions were designed in a similar manner, opening with a whole-class activity where the teacher presented the learning goals, activities, assignments, and relevant resources. Then followed a more dialogically oriented sequence where the teacher typically explored the students' prior knowledge of the topic in the coming session. During whole-class activities, the teacher frequently used the interactive whiteboard as a resource.

After the whole-class setting followed a working session starting with an individual activity, which continued into a collaborative group-work activity. The teacher often organised the individual/group-work activities according to a "jigsaw design" (Aronson, Bridgeman, & Geffner, 1978; Brown et al., 1993). The idea behind the jigsaw design is to organise classroom activity that makes students dependent on each other's input to succeed. In this setting, the jigsaw design required students first to work individually to prepare themselves for group work, for instance by reading a designated text, exploring digital representations such as a simulation or a model of the blood circulation, or listening to a text reading. Then followed a group-work activity where the students, based on their notes, explained to their peers what they had learned. Based on their peers' explanations, the listeners were to add new notes to their own. During the individual and group-based activities, the students used their iPads and other digital resources provided by the teacher. Each thematic session ended with a whole-class sum-up activity focused on conceptual recap and reflection. These sessions typically had a dialogic form involving teacher-led discussions. As in opening whole-class activities, the teacher frequently used the interactive whiteboard as a resource during discussions. In the following, we will present and analyse selected excerpts from each of the four activity settings.

Setting 1: Teacher Support in Whole-Class Opening Sessions

Excerpt 1 is from the whole-class introduction setting at the very opening of the project. Prior to the excerpt, the teacher presented the learning goals of the day's lessons, learning activities, and the designated digital and paper-based learning resources. After providing the information, she initiates a whole-class activity where the students are to construct and submit questions about issues that they would like to explore during the project. Using their iPads, the students submit their questions through the web-based group tool Padlet, which enables single users to write notes, comments, or questions on a computer or an iPad, and share them on a workspace for common reflection. Excerpt 1 opens with the teacher instructing the students on how to log in to the common workspace she created in Padlet:

Excerpt 1

1. Teacher: The address is displayed in red (*referring to the link appearing on a hand out*). Once you've entered you can start submitting your questions on the whiteboard. You are allowed to write more than one question
(*the students start writing up question on their iPads*)
2. Teacher: (*opens the web-page so that it appears on the interactive whiteboard*) It's starting to pop up questions
(*students are writing questions individually*)
3. Teacher: So, I want everybody to press "refresh" on your iPad. Then you will see all the questions. […]. Now, I want you to look for a question, which is not yours, which you find interesting
(3) (*several students rise their hand*)
4. Teacher: Eric. Is there a question that you find interesting?
5. Eric: How can the blood vessels fit in our body when they are as long as two times around the Earth? (*quoting a question on the board*)
6. Teacher: Yes. Good question. Two times around the Earth. Hum, that's pretty long. John?
7. John: How many times does the heart of a new-born child beat per minute?
8. Teacher: Does it beat slower? Does it beat faster? Yes, maybe we'll learn about that

Examining these activities in the thematic opening sessions in terms of conceptual and procedural support, we assert that the teacher provided both types of support. As described above, she consistently opened by introducing the session's learning goals, activities, and resources. The interaction taking place in Excerpt 1 shows how she also provided conceptual support in the opening sessions. The selected activity was aimed at identifying the students' prior understanding of the topic by using the students' questions as a starting point. At this point, the teacher avoided answering the students' conceptually oriented questions. Instead, she confined herself to confirming the relevance of the specific questions, as well as elaborating on some of them, as seen in line 8. By refraining from commenting and elaboration on the students' questions, the teacher provided limited, if any, conceptual support. However, another way of viewing the support provided in this setting is to recognise that her use of Padlet offered conceptual support in this setting: By displaying the students' questions on the interactive whiteboard, she turned the students' individual conceptual contributions into a collective endeavour. Likewise, she enforced the collective aspect by instructing the students to engage with each other's ideas. In other words, she provided conceptual support by investigating the students' prior knowledge (making their prior knowledge visible for all students) and thereby guiding the students' conceptual attention. Importantly, she also tried to, and seemingly succeeded in, encouraging the students' academic curiosity.

Setting 2: Teacher Support in Individual Activities

During individual work, the students engaged with assignments prepared by the teacher. In these settings, the students frequently used their iPads, sometimes in combination with a notebook or worksheets. Key learning resources were digital articles and texts about the heart and lung functions and blood circulation developed by textbook publishers or commercial educational-oriented organisations. Most of the resources also comprised visual representations such as simulations, animations, models, and images. To illustrate some typical aspects of teacher support during individual activities, we have selected an excerpt from a session where the students were to monitor whether they had reached the learning goals the teacher presented during the opening of the project. The session took place in the third of the four thematic sessions in the project. In the opening of the individual activity, the teacher gave the students a handout listing detailed conceptual learning goals for each of the thematic areas that the students had explored. The teacher instructed the students to use their textbook or the designated digital resources.

In Excerpt 2, we enter a setting where Carrie summons the teacher for assistance. She is grappling with the question, "Do you know why you have a transportation system in your body?"

Excerpt 2

1. Teacher: Yes? (*approaches Carrie*)
2. Carrie: The text didn't say <u>anything</u> (*points at her textbook*)
3. Teacher: About?
4. Carrie: <u>That</u> (*points at a question "Do you know why you have a transportation system in your body?"*) It didn't say anything
5. Teacher: No, but what do you think? Why do we have blood vessels?
6. Carrie: To <u>live</u>

7. Teacher: Yes, but what do they do? What does it say? (*nods in the direction of the textbook*)
8. Carrie: They carry things around in the body
9. Teacher: Uhum. What are they carrying?
10. Carrie: Carbo::n=
11. Teacher: Look in the text (*points at the text in the textbook*). Then you'll understand (*moves on*)

In this project, as also in this particular setting, the teacher had put a lot of effort into finding relevant information, both presented in textbooks and digital resources, to be used as conceptual support for the students. An important aspect displayed in Excerpt 2 is that the resources do not always provide enough conceptual support for the students, resulting in their asking the teacher for assistance, as Carrie does in Excerpt 2. It seems like her trouble with understanding the question about the transportation system is that she does not see the link between the terms "transportation system" and "blood circulation" (lines 2 and 4). Turning the focus towards the support provided by the teacher in this setting, the analysis shows that the teacher provided both conceptual and procedural support. Concerning conceptual support, the teacher provides this type of support by eliciting the student's understanding through probing cued scientific questions, as well as helping Carrie to see the link between the two terms (lines 5, 7, and 9). However, as we see, she refrains from providing explanations or elaborations on the questions and concepts addressed by the student, and neither does she follow the student into the text-based and visual resources. Instead, she changes her strategy to providing procedural support in instructing Carrie to revisit the textbook (line 11).

The change in support strategy might indicate that the teacher at this point assumed that Carrie was able to find the information she needed in order to answer the question. Another way of putting this is that the teacher in this setting re-established the information resources as the primary conceptual support, as well as substantiating the notion of helping students become independent and self-regulated learners. Nevertheless, it is also possible to see that the choice to provide procedural support may be a missed opportunity for engaging in conceptually oriented dialogues with a student by, for instance, using the textual and visual resources as a starting point. This also constitutes a missed opportunity for making sure that the student has developed a sufficient understanding of the concepts at issue. As the two following excerpts will show, the concept of the blood circulation system turned out to be a difficult matter for the students.

Setting 3: Teacher Support in Group-Work Activity

In order to display typical aspects of teacher support within settings where students worked collaboratively in group-work settings, we have selected two excerpts from a jigsaw activity focusing on blood circulation. As described earlier, a jigsaw activity opens with an individual activity where the students are to prepare for their subsequent group work by reading designated digital texts accessed on their iPads, in this setting texts about blood circulation. The teacher provided all students within a group with different digital texts about the same issue. The jigsaw activity typically ended with a collaborative group-work setting where the students were to share and discuss the notes they made while reading the designated texts.

In the following, we start by presenting two excerpts from a collaborative group activity. Excerpt 3a) is from a setting where the student groups work on their own without the presence of the teacher. The students John, Ola, Linda, and Carrie take turns explaining what they have read. We enter when John, the final student to present, explains about the difference between the small and the large blood circulation system:

Excerpt 3a)

1. John: (*reads from his notes written down on his iPad*) When the heart pumps blood to the lungs and back it is called "the small circulation loop". When the heart pumps blood <u>from</u> the heart <u>to</u> the whole body it is called "the large circulation loop"
2. Ola: <u>Wait</u> (*making notes on his iPad*) Circulation loop (*writes with one hand*) Large?
3. Linda: Circulation loop? (*making notes on her iPad*)
4. Ola: C i r c u l a t i o n l o o p (*spelling aloud*)
5. Linda: I wrote (.) I just wrote the large and small circulation loop
6. John: (*pauses while he waits for the others finishing their writing*)
7. Carrie: l o o p (*writing on her notebook*)
8. John: The largest vein is called aorta
9. Ola: A o?
10. John: It's an important part for, uhm
11. Linda: Aoto? (*writes on her iPad*)
12. Ola: Aorta? (*looks at John*)
13. John: <u>Yes</u>

The interaction taking place in Excerpt 3a) displays that the students experience conceptual challenges on various levels: First, they struggle to spell and pronounce concepts such as *circulation* and *aorta*. Perhaps more importantly, they struggle to understand the meaning of concepts related to the functioning of the heart. All these concepts are complex, and most students encounter these concepts for the first time at this level in the curriculum. Consequently, it is not surprising that the group struggles to understand and apply the concepts in this setting. However, how the students handle challenging concepts is noteworthy. As we observe from the excerpt, the students respond primarily by orienting themselves towards how the concepts are spelled and pronounced. They also use each other's explanations to rectify their own mistakes (such as Linda in line 5). Nevertheless, the excerpt shows that the students make little use of each other to provide or request clarifications, explanations, or visual illustrations that could support them in gaining a deeper conceptual understanding. In other words, the students support each other conceptually, but mainly in terms of spelling and pronouncing complex concepts, and to a lesser extent by elaborating and explaining scientific concepts and processes.

The episode represented in Excerpt 3b) takes place only a few minutes later. John is still sharing his information with the group, and he is here trying to describe the difference between arteries and veins. While explaining, he shows an illustration of the heart function found in an article from a website provided by the teacher. On the illustration, the arteries are highlighted in red and the veins in blue. We enter when the teacher approaches the group to check on how they are doing. She stands quietly beside John and listens to his presentation:

Excerpt 3b)

1.	John:	(*shows the illustration of the blood circulation on his iPad*). I think that the bronchi separate carbon dioxide and oxygen, and the red blood vessels, in a way, those with red blood cells that provide oxygen are called arteies (*the correct term would be* "*arteries*"). And I don't remember what the blue ones are called. It didn't say
2.	Teacher:	(*standing beside John and listens*) Uhum. We say arteries (*looks at John*). But it's not strange that you pronounce it like that because that's the way it's written
3.	Carrie:	Arte:ries?
4.	Teacher:	Arteries, yes
5.	Linda:	John has different facts
6.	John:	Yes, I had a lot of strange text. I didn't understand anything of what you had (*refers to his peers*), so I had to take a lot of notes
7.	Teacher:	Yes
8.	Ola:	What did you have, then? (*looks at John*)

9. Teacher: (*addressing Ola*) There are different texts, right? (*addressing John*) You had the TV2 text, right?

10. John: Uhum

11. Teacher: That one is difficult. That's probably the most difficult text of them all. I agree (*moves on*)

The opening of the excerpt shows John's explanation of the small and the large circulation (line 1). While explaining, he uses several complex scientific terms such as *bronchi*, *carbon dioxide*, and *oxygen*. He has difficulty pronouncing the term *arteries*. The teacher, who was standing quietly in the background, intervenes and pronounces the term correctly (line 2). Linda points out that John's text is different, and that he provided different facts than the rest of them. John agrees, but adds that he needed to make a lot of notes when the others presented their facts as he found it hard to understand their input. He describes his own text as being very "strange" (line 6). The teacher responds by explaining that the students were designated to read different texts, and that John had a particularly difficult text. Then she leaves, and approaches another group.

The interaction taking place in Excerpt 3b) highlights that the students experienced some conceptual challenges with the designated resources, as well as when listening to each other's explanations of the texts they had been reading. Their challenges concerned the pronunciation of scientific terms as well as grappling with their meaning. John used both his notes and a visual illustration of the article as resources while explaining what he had read; in doing so, he provided both visual and textual support for his peers. Despite his efforts, the students still struggled to understand some of the key concepts presented in the text. When the teacher approached them, the students expressed their confusion. Upon hearing the students' struggle to pronounce one of the terms correctly, the teacher intervened by providing a correct pronunciation (lines 2 and 4). Concerning the students' expressed difficulty in understanding each other's texts, as well as their comment on the differences between John's text and the other texts, the teacher responded by picking up on their comments on the differences between the texts. She did not, however, pursue the students' expressed challenge of understanding concepts and issues provided in the students' (in this case, John's) explanation. In a sense, it is possible to say that the students' expressed conceptually related challenge could be seen as an opportunity for the teacher to provide conceptual support, for instance by going deeper into how the concepts and processes are interrelated. Furthermore, the students' focus on a visual representation of cardiovascular system also offered the possibility of using the visual representation as a resource in order to explain and elaborate elements that the students struggled to understand.

Examining Excerpts 3a and 3b together reveals that the students experienced some conceptual challenges. As she did in the individual activity (Excerpt 2), the teacher provided what can be seen as a minimum of conceptual support so that the students could carry on with their work. However, in doing so, the teacher handed over the responsibility for the conceptual sense-making work and their engagement with the learning resources to the students. If we were to understand the teacher's way of supporting the students only from the analyses of student – teacher interactions taking place during individual and group activities, it would seem like the teacher oriented towards providing primarily procedural support, and less conceptually oriented support. A closer look at the dialogues taking place in whole-class sum-up activities, however, shows that this was not the case.

Setting 4: Teacher Support in Whole-Class Sum-up Activity

Excerpt 4 is from the sum-up session taking place towards the end of the previously analysed group-work activity. The teacher gets the students' attention, and opens the shared workspace in Padlet on the interactive whiteboard displaying the questions formulated by the students at the very beginning of the project. She asks the students to reflect on the questions:

Excerpt 4)

1. Teacher: Raise your hand. Are there any questions you still wonder about? (2.0) I hope so because science is really about finding new questions. (2) That's science, and I don't think we've found the answers to all our questions. Annie?
2. Annie: Why doesn't the heart stop when we hold our breath?
3. Teacher: Uhm. Yes. We haven't found an answer to that one. Is there anyone that has an answer to that? John?
4. John: I'm not really a 100% sure but since – As long as we hold our breath the heart will continue to beat until we pass out. So, if the heart doesn't pump, the muscles won't get the nutrition they need. And then you'll pass out
5. Teacher: Uhum. We have learned about breathing. We've learned that breathing and heartrate are not completely related but they do cooperate. They are not the same. So breathing is not the same as the heartrate. As John correctly said; they are related in the sense that if we don't get air into the lungs then the heart will stop beating. Because it's dependent on the cooperation with the lungs. They are not the same but they collaborate. Will?
6. Will: How many blood vessels are there in the body?
7. Teacher: Yes. We didn't exactly find an answer to that, but we do know how long they are. Linda?
8. Linda: A hundred thousand kilometres

9. Teacher: Yes. Or said in a way that makes it easier to understand? Roger?

10. Roger: Two times around the earth

11. Teacher: Yes. Think about that. Someone said earlier that they don't look that long in the textbook. I understand, but then there are all those tiny blood vessels that go into the tips of my fingers that make me freeze when it's cold. They are not displayed in illustrations, but we have to count them in as well

There are aspects of the interaction taking place in Excerpt 4 that we would like to emphasise. The first aspect concerns the teacher's way of providing support in sum-up sessions. In sum-up sessions, as exemplified by Excerpt 4, the whole-class dialogues were mostly teacher-led dialogues where the teacher often invited the students to share their ideas, questions, or comments. She engaged in the dialogue by validating and elaborating on the students' responses (lines 5, 7, 9, and 11). Furthermore, she prepared the ground for letting the students provide conceptual elaborations and explanations to each other's questions and ideas (lines 3, 7, and 9). Subsequently, she picked up on the students' responses by confirming (lines 5, 9, and 11), re-voicing (line 5), applying the correct scientific terms (line 5), and linking related bodily terms and processes (lines 5 and 11). Thus, it is possible to see that the teacher provided a huge amount of conceptual *and* procedural support when facilitating the classroom dialogues in the sum-up sessions.

The second aspect we would like to emphasise concerns the support functions of the interactive whiteboard and Padlet. The interactive whiteboard was a shared object that both students and their teacher oriented towards as we also observed in the analysis of Excerpt 1. In that setting, the shared workspace in Padlet became a resource for the teacher when eliciting the students' prior knowledge by asking them to post questions they were wondering about. In the sum-up session, however, the interactive whiteboard and the questions posted on their shared workspace became an important procedural support by constituting a shared starting point for the classroom dialogue. In addition, they offered support in organising the students' conceptual attention and input. All in all, the analysis of the student – teacher interactions taking place in the whole-class sum-up setting shows the significant role these learning activities had in this project. The teacher used these settings to provide conceptual support and to respond to and elaborate on some of the concepts addressed by the students during the individual and group-based activities. It was in these situations that the relationships between the scientific concepts were explicitly addressed and made visible to the students.

DISCUSSION

In the following, we will open by highlighting some of the key empirical findings from the analysis of the student – teacher interactions within the various learning activities, seen in relation to the two overall research questions focused on the conceptual challenges experienced by the students and the type of support provided by the teacher. Subsequently, we will discuss the empirical findings in light of previously undertaken research. This comparison reveals two issues we will elaborate on, namely the support provided in dialogic whole-class settings and the support provided in individual and group activity settings.

The first issue is *the support provided in dialogic whole-class settings*. Several studies have shown that whole-class dialogues facilitated by a teacher are important resources in students' learning processes (Engle & Conant, 2002; Mercer, 2004). This study's empirical findings were in line with previous research. In particular, the analyses of the interaction taking place within the two whole-class settings showed the importance of student – teacher dialogues in terms of facilitating students' development of conceptual understanding. The teacher invited the students to pinpoint questions that they still wondered about, as well as inviting them to elaborate and provide explanations to each other's questions. Then, she engaged in the dialogue by providing re-formulations, applying the correct scientific terms, and re-framing the students' contributions into a larger scientific context. In the whole-class sessions, the teacher also used the dialogues to ask more open-ended questions as well as more meta-cognitive questions aimed at reflecting on the students' conceptual understanding. These types of meta-cognitive questions have proved to be of high importance for students' development of conceptual understanding (Hmelo-Silver & Barrows, 2008).

A second aspect of the whole-class dialogues concerns the teacher's effort of creating *shared* conceptual sense-making processes. She did this by inviting the students to build on their individual contributions and by letting the students comment on each other's questions. Creating such shared spaces for collective reasoning has proved to be of vital importance for students' development of conceptual understanding (Hmelo-Silver & Barrows, 2008; Mercer & Littleton, 2007).

A third aspect of the dialogues taking place in whole-class settings can be seen in relation to Linn and Eylon's (2011) assertion that an important part of science learning is making scientific ideas and understanding visible to others through dialogues. Along with the productive side of explicating one's understanding or misunderstanding, such dialogues also constitute an opportunity for a teacher to get insight into the students' prior knowledge, what they find hard to understand, or ideas that are in conflict with ideas held by experts in the field. The analyses of the sum-up whole-class settings showed that the teacher exploited these dialogical opportunities in the whole-class settings.

The final facet of the whole-class dialogues concerns the role of the technology in use, namely the shared workspace displaying the students' individual questions. Findings from interactive whiteboard studies have shown how digital representations can serve as productive resources in classroom settings (Gillen et al., 2008; Rasmussen & Hagen, 2015). This was also demonstrated in the current study, when the teacher used the students' questions displayed on the interactive whiteboard to turn the students' individual conceptual contributions into a collective endeavour and engage the students in collective thinking.

In addition to these findings concerning support in whole-class settings, we must also examine *the support provided in the individual and group activity settings*. Our analyses of the interactions taking place within these two settings revealed that the students' conceptual challenges came to the surface. Previous studies have documented the advantages of peer collaboration in enhancing student learning. For instance, several studies have found that peer collaboration helps students develop scientific argumentation skills (Linn & Eylon, 2011; Mercer & Littleton, 2007), conceptual understanding (Furberg & Ludvigsen, 2008; Howe et al., 2007; Linn & Eylon, 2011), inquiry learning skills (van Joolingen, de Jong, & Dimitrakopoulout, 2007), and productive disciplinary engagement (Engle & Conant, 2002). However, studies have also illuminated the challenging aspects of peer collaboration—for instance, that students rarely engage in discussions characterised by "constructive listening" (van de Sande & Greeno, 2012) or "exploratory talk" (Mercer, 2004), and that collaboration as an activity is difficult for students (Furberg & Arnseth, 2009; Strømme & Furberg, 2015). Our analyses of the interaction taking place within the group-work settings likewise uncovered both positive and more challenging sides of these types of settings. On the positive side, the analyses showed that the students participated with a high level of engagement and motivation in the settings where they were to share their experiences and thoughts with their peers. However, it was also evident that they experienced some conceptual challenges in these settings, as well as struggling to engage in "exploratory talk" (Mercer & Littleton, 2007), or talk where the individuals engage critically but constructively in each other's ideas, and where claims and counter-claims are followed by justifications and explanations.

The challenges that the students experienced in the group-work activity can also be seen in light of the instructional jigsaw design. Several studies have scrutinised productive sides of an instructional jigsaw design facilitating students' construction and sharing of scientific arguments (Aronson et al., 1978; Brown et al., 1993; Karacop & Doymus, 2013). However, some studies have reported the more challenging aspects of jigsaw designs (Souvignier & Kronenberger, 2007; Strømme & Furberg, 2015). The current study yielded conflicting findings. On the productive side, the jigsaw design urged the students to present and listen to each other's presentations, as well as making them contribute with different information that expanded their individual contribution. However, as discussed above, the analysis showed that the students grappled with making sense of some of the scientific terms and concepts; furthermore, they did not engage in exploratory-oriented discussions in this setting. The study conducted by Strømme and Furberg (2015) substantiated the same challenge and pointed out that students may rarely challenge their peers to clarify or explain ideas because the concepts are so complex that it becomes difficult for the students to ask good questions or to elaborate. In addition, the study showed the difficulty students might encounter with taking on the role as a scientific "expert" amongst peers, a role most commonly reserved for the teacher (Strømme & Furberg, 2015).

Overall, the more challenging aspects of the individual and group-based activities highlight the importance of both procedural and conceptual support provided by a teacher in these types of settings. In particular, procedural support may include the facilitation of student dialogues enabling students to participate critically and constructively in peer discussions, to elicit and explore each other's ideas, and to settle disagreements. These skills need to be cultivated over time, and research has shown the value of training students to participate in scientific discourse combined with introducing discussion ground rules (Mercer, 2004). Concerning conceptual support, the analyses showed the students' need for such support in both individual and group-based activities where they engage with various forms learning resources. The teacher can provide conceptual support by eliciting students' ideas and areas of confusion, as well as by elaborating, explaining, linking ideas and contextualising. Studies have shown that these types of support are of pivotal importance, also in settings where students engage with technology-supported activities and peer collaboration (Furberg, 2016; Strømme & Furberg, 2015).

It is also worth mentioning the potential of using digital representations as a focus of student – teacher interactions in these types of settings. In the study settings, the students engaged with a whole set of visual representations such as simulations, animations, and illustrations. Many studies have emphasised the potential of using digital representations as resources in conceptually oriented student – teacher dialogues (Furberg, 2016; Gillen et al., 2008). However, our analyses revealed that the digital resources in themselves did not provide enough conceptual support for the students. Consequently, this study illuminates the importance of teacher support in facilitating the students' engagement with the concepts, terms, and processes introduced by such resources.

CONCLUDING REMARKS

As the chapter comes to a close, we want to return to the relationship between conceptual and procedural support. The current study demonstrates the pivotal role of both procedural and conceptual support for students' development of both conceptual comprehension and their understanding of the procedures of doing exploratory and inquiry-related work in science. The findings also illuminate some of the challenges that the teacher might encounter in facilitating students' learning processes in these types of settings. The teacher constantly needs to balance and determine when and how to provide procedural and conceptual support. When considering the activities as a unit, we assert that the teacher balanced her procedural and conceptual support by emphasising different types of support in each activity. While the analyses of the individual and group activities showed that the students struggled and might have benefitted from more conceptual support from the teacher, this balancing act is a difficult one to master.

A teacher's balancing of procedural and conceptual support is always a matter of providing students too much or too little support. On the one hand, it is possible to point at the untapped potential of the student – teacher dialogues taking place in the individual and group-work settings; in particular, these dialogic settings could have offered opportunities for the teacher to engage with the students' ideas and misunderstandings, and to develop shared conceptual understanding. On the other hand, one very important aspect of instruction is to support students in becoming self-regulated and capable of organising their own learning processes and activities in individual as well as in collaborative learning situations. In the end, teachers must continuously adjust their balance between these positions to engage their students and support them in meeting their full potential.

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NOTES

1 van Leeuwen et al.'s (2013) use of the term "cognitive activities" corresponds with the term *conceptual support*, and their term "cognitive regulation" corresponds with *procedural support*.

2 The science project constituted one of 12 case studies performed in the Project Ark&App (2013–2016). See Furberg, Dolonen, and Ingulfsen (2015) for more details about the case study (http://www.uv.uio.no/iped/forskning/prosjekter/ark-app/).

3 Transcript conventions:

=	Break and subsequent continuation of a single utterance
(# of seconds)	The time, in seconds, of a pause in speech
(.)	A brief pause, usually less than 0.2 seconds
.	Falling pitch or intonation
?	Rising pitch or intonation
!-	An abrupt halt or interruption in utterance
Underline	Emphasized or stressed speech
((*italic text*))	Annotation of non-verbal activity

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