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Invoking student resources in whole-class conversations in science education: A sociocultural perspective

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ABSTRACT

Background: While much literature has argued for the value of carefully designed instructional units building on student resources, less work details how students' own invocation of experiences and ideas from their everyday lives plays out in naturalistic classroom dialogues. Employing a sociocultural and interactional approach, this article illuminates how student resources become mediational means in ways that support learning.

Methods: The empirical basis constitutes whole-class conversations involving lower secondary school students and their teacher during a science project about genetics. The applied analytical procedure involves microanalyses of sequences of student–teacher interaction in settings where students invoke resources from their everyday lives.

Findings: The findings demonstrate that student resources became mediational means that (a) enabled students to express and test out their conceptual understanding and scientific reasoning, (b) promoted student participation and curiosity, and (c) positioned students as authoritative and accountable participants in whole-class conversations. Furthermore, how student resources became mediational means was also dependent on the distribution of authoritative roles between students and the teacher.

Contributions: This article provides evidence for the value of invoking student resources in educational dialogues and displays both how they can support learning and the challenges teachers may face in doing so.

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Introduction

For decades, educational researchers have struggled with how to design teaching and learning activities that balance the introduction of canonical content with making science learning personally relevant to students (Kapon et al., 2018; Russ & Berland, 2019). Learning sciences researchers have generally agreed that school matters should engage with the world outside the classroom (Bricker & Bell, 2014; Sawyer, 2014), and many have investigated how to design learning environments where students' everyday experiences can support learning and participation.

Two rather distinct science education research traditions emphasize different aspects of bridging students' experiences from their everyday lives and school science. One tradition involves research associated with conceptual change studies grounded in cognitive and constructivist learning perspectives. A central focus has been on so-called "misconceptions" held to be rooted in students' everyday experiences, and some have argued that these misconceptions are obstacles in students' development of conceptual understandings (Chi, 2005; Vosniadou, 2008). Other researchers within the same research tradition have argued that students' intuitive ideas might be beneficial for school science learning (Campbell et al., 2016). Instead of focusing on students' misconceptions or science difficulties, these authors have placed the main analytical and instructional focus on "student resources"—their preconceptions and ideas about science—that might be intuitive and "raw" but remain the basis upon which scientific knowledge can be built (Hammer, 2000; Luna, 2018).

Another research tradition that over decades has addressed the relationship between students' experiences from their everyday lives and school science has placed a special emphasis on the social and cultural dimensions of learning and teaching. These scholars have argued that invoking resources from students' everyday lives can establish profound, inclusive, and authentic learning environments in science classrooms. For instance, invoking student resources might make complex scientific concepts more tangible for students (Rosebery et al., 2010; Varelas et al., 2008), encourage active participation in academic conversation and discourse (Barton & Tan, 2009; Warren et al., 2001), and destabilize traditional knowledge hierarchies and power relations between teachers and students (Bang et al., 2012; Gutiérrez, 2008). Scholars within both research traditions have demonstrated how researchers and teachers using carefully planned instructional designs targeting student resources and everyday experiences can support students' science learning (see for instance, Elby & Hammer, 2010; Rosebery et al., 2010; Varelas et al., 2008).

While much literature has argued for the value of building on student resources, less work has detailed how students' own invocation of experiences, ideas, and assumptions from their everyday lives plays out in naturalistic educational classroom dialogues in ways that support learning. For instance, how does a teacher handle a situation where a student introduces Spider-Man as a resource for inquiring on the topic of gene transfer? How can a famous soccer player's hair become a resource in a discussion about nature versus nurture? This article provides evidence of the value of invoking student resources in naturalistic educational classroom dialogues and depicts both how they can support learning and the challenges teachers may face in doing so.

By taking a sociocultural and interactional approach to learning and instruction (Hall & Stevens, 2016; Jordan & Henderson, 1995; Vygotsky, 1978; Wertsch, 1998), this article provides insights into how student resources, brought in spontaneously by students, are made sense of and applied in the ongoing interactional work carried out by students and teachers. To provide such insights, we analyze whole-class conversations during a science project about genetics involving lower secondary school students and their teacher. We adopt the term *student resources* to refer to the experiences, ideas, and assumptions about science matter that students bring to school. Likewise, we build on the assumption that such resources can constitute the basis upon which scientific knowledge can be built. We argue that, to understand how student resources can support learning, we need to pay analytical attention to (a) the participants' *conceptual orientation* in conversations invoking and engaging student resources and (b) the *social and structural dimensions* of these conversations, implying a focus on how students are positioned as learners (Engle, 2006; Strømme & Furberg, 2015; van de Sande & Greeno, 2012). Paying attention to both dimensions allows us to examine how students' experiences, ideas, and assumptions can become resources that both support their conceptual development, and enable them to engage in, contribute to, and immerse themselves in dialogues about school science. Furthermore, it enables us to examine how the meaning and function of student resources are intertwined with the distribution of authoritative roles between the students and the teacher. Most important, scrutinizing how student resources can support learning in whole-class conversations provides us the opportunity to generate knowledge about how teachers can facilitate these types of educational dialogues in productive ways. In the following sections, we will discuss findings from previous studies of whole-class conversations and student resources in science education settings.

Student resources and science learning in whole-class conversations

Teachers' facilitation of whole-class conversations

Science education studies have shown that teachers impact the nature of science talk and reasoning through how they frame talk, present a topic and follow up on students' answers, as well through the types of questions they prompt (Berland et al., 2020; Green & Dixon, 1993; O'Connor & Michaels, 1993). Thus, while dialogue-oriented whole-class settings may provide rich learning situations, as multiple students may voice multiple resources for the classroom community to reason with (Clarà, 2019; Kovalainen & Kumpulainen, 2007; Rasmussen et al., 2020), the teacher's role has proven to be important in realizing such potentials. For example, by using specific follow-up questions, the teacher can enable students to produce more sophisticated and extended accounts of their ideas (Scott et al., 2006; Wells & Arauz, 2006). Teachers can further provide conceptual support in the form of elicitation, contextualization, and revoicing (Forman & Ansell, 2002; Howe et al., 2019), and support active participation and engagement by inviting students to share their reasoning, build on each other's ideas, and acknowledge their contributions (Kumpulainen & Rajala, 2017; Rødnes et al., 2021; Tabak & Baumgartner, 2004).

However, studies have also shown that whole-class conversations can be challenging for both students and teachers. Many students can experience whole-class conversations as cognitively, socially, or emotionally challenging. The classroom climate might be experienced as exclusive, participant structures might not provide opportunities for all students to contribute, and many students may be reluctant to participate verbally (Sedlacek & Sedova, 2017; Sedova & Navratilova, 2020). Many teachers lack the competence and skills to transform their teaching to be more dialogic-oriented, even if they know that doing so is important to establish supportive learning environments (Myhill, 2006; Pimentel & McNeill, 2013). Facilitating whole-class conversations can be challenging because it requires teachers to handle the different and sometimes conflicting perspectives and orientations voiced by students in ways that make them meaningful for the whole classroom community (Lemke, 1990; Myhill & Brackley, 2004; Pimentel & McNeill, 2013).

Another conundrum that teachers face in facilitating whole-class conversations, involves the balancing act of introducing students to the disciplinary canonical versions of science and making science learning personally relevant and engaging to students (Kapon et al., 2018). On the one hand, learning science inevitably involves appropriating the tools used by science experts, as well as the authoritative ways of reasoning in science (Aguiar et al., 2010; Lemke, 1990; Scott et al., 2006). In educational settings, the teacher has the designated role as an "expert" within specific knowledge domains and a facilitator of prevailing methods of understanding and solving assignments in a satisfactory manner (Strømme & Furberg, 2015). On the other hand, to make science personally relevant and engaging to students, the teacher must recognize and take students' ideas, interests, and perspectives into account. Scott et al. (2006) argued that there will always be a tension between these two aspects of science teaching. The problem arises when educators focus on students' learning the science canon as the ultimate goal, potentially causing students to disengage from the science discourse. According to Berland and McNeill (2012), students should be given time and space to introduce their own orientations, without being immediately required to adjust them to academic language. Put differently, a version of the science canon should be “a tool that both supports and constrains students’ pursuit of coherent understandings of natural phenomena—of their figuring out—but not the outcome” (Russ & Berland, 2019, p. 286).

Student resources in whole-class conversations

Previous studies have provided valuable insight into how teachers can create educational settings where the experiences from students’ everyday lives are used as resources for engaging students meaningfully in conversations about science (Barton & Tan, 2009; Brown, 2011; Hammer, 2000; Luna, 2018; Warren et al., 2001). Researchers associated with a cognitive perspective, have demonstrated that teachers using carefully planned instructional designs targeting student resources can support students’ conceptual learning. A central idea is that students have available “cognitive resources” in the form of fine-grained elements that can form a basis for their development of conceptual understanding (diSessa, 2006; Hammer, 2000). For instance, students’ sense of springiness can be activated as a resource for understanding the relation between gravity and the passive force exerted by a table on a book. Most students can relate to springiness in some contexts, such as comparing the sensation of jumping on a trampoline with jumping on asphalt (Clement, 1993; Elby & Hammer, 2010). This body of research has shown that these types of preconceptions and everyday understandings can be activated in conversations to enhance students’ conceptual understanding in science classrooms (Hammer & Elby, 2003; Hammer et al., 2012; Luna, 2018).

Studies emphasizing the social and cultural dimensions of learning and teaching have shown that students’ experiences and knowledge from everyday life can support participation in science conversations. For instance, Brown (2011) noted the importance of creating learning environments in which students display “willingness to engage in academic discourse” (p. 679). Encouraging students to mobilize resources from everyday life—and explicitly naming such experiences as potential tools to reason with—can support students’ feeling of ownership of both knowledge and their classroom participation. Studies, most of them intervention studies, have also shown that students are more likely to voluntarily participate in ongoing whole-class conversations when teachers invoke experiences from their everyday lives (Barton & Tan, 2009; Warren et al., 2001). For instance, Warren et al. (2001) found that when the teacher welcomed students’ first language and everyday experiences into class discussions about metamorphosis, more students contributed to the discussions and presented multiple conceptual perspectives. In a study involving elementary school students learning about heat transfer, Rosebery et al. (2010) showed how mobilizing students' everyday experiences and language combined with the teacher's use of specific talk moves (such as requiring students to respond to questions, listen to each other and elaborate their accounts) advanced the conceptual reasoning in the class. In a similar vein, Varelas et al. (2008) found that the teacher's use of discursive moves, such as summarizing student contributions and prompting them to produce arguments for their choices in settings where they engaged with familiar everyday objects as a part of their science lessons, enabled the students (Grades 1–3) to participate in shared conceptual sensemaking.

However, research has also shown the considerable interactional effort that teachers need to provide to create meaningful connections between student resources and academic matters. In a case study involving lower secondary students and their teacher, Silseth (2018) found that the teacher enabled the students to expand and elaborate on their accounts and experiences of both academic and everyday nature by focusing on experiences from their everyday life (e.g., traveling by bus in the local community, exchanging money, experiencing romantic feelings). Yet, the analysis also showed the importance of the teacher's efforts to orchestrate educational dialogs in a manner that encouraged the students to bring in everyday experiences and to identify and enact strategies that enabled them to productively use these experiences for engaging with the academic topic.

Although much research has examined how to design teaching units in which student resources are explicitly activated in science learning, fewer studies have detailed the complexities in how teachers handle experiences, ideas and assumptions about science matter that are invoked by students themselves in naturalistic whole-class conversations. To scrutinize how such resources can support teachers in facilitating whole-class conversations and to examine the challenges teachers may face in doing so, we must address how teachers and students conceptually frame their talk about science and how students are positioned when their experiences, ideas and assumptions are invoked. In the following sections, we will provide an account of our conceptualization of student resources according to a sociocultural perspective and the methods that guide our analytical work.

A sociocultural perspective on learning and student resources

While acknowledging the valuable contributions from previous studies on student resources, we argue that taking a sociocultural approach allows us to extend previous research by focusing on how such resources are intertwined with social and structural dimensions of educational dialogues (Engle, 2006; Strømme & Furberg, 2015). Seen from a sociocultural perspective, learning is situated and enacted in dialogic *meaning-making processes* where interlocutors participate in specific activities (Greeno, 2006b; Säljö, 2010; Wertsch, 1991). Through interactions, participants constantly make sense of and interpret situations, actions, and concepts while making their own interpretation visible and observable to others. In these interactions, every utterance, act or move is context-dependent and given meaning in situ by the interlocutors (Jornet et al., 2016; Warren et al., 2005). Furthermore, the sociocultural perspective on learning emphasizes the role of cultural tools that can be in the form of semiotic or material tools (Danish, 2014; Vygotsky, 1978). Material tools might be calculators, computers, pencils, and kitchen utensils, whereas oral or written analogies, theoretical constructs, and stories represent semiotic tools. Of particular interest in this study are semiotic tools in the form of resources from students' everyday lives, such as knowledge about celebrities, characteristics of family members, or knowledge gained from watching documentaries that students sometimes spontaneously invoke in classroom conversations.

Cultural tools are *mediational means* that enable us to deal with tasks and engage competently in activities that we would not be able to do without these resources (Mercer et al., 2019; Wertsch, 1998). However, we argue that cultural tools cannot be perceived as ready-made means, as they must be made relevant and meaningful by the interlocutors when dealing with specific tasks. They have only "meaning potentials," as they do not contain some kind of underlying or fixed meaning (Furberg, 2016; Linell, 2009; Silseth & Arnseth, 2011). For instance, a metaphor—seen as a semiotic tool—in a classroom discussion about ethical aspects of gene technology comes with a certain meaning potential, but the realized meaning of this metaphor is made by the students and teachers in relation to the context and situation in which it is produced. Consequently, the notion of student resources as mediational means involves the assumption that such resources are not ready-made; rather, they have meaning potentials, and their meaning and function are created through student–teacher interactions. The meaning of student resources—their associated conceptual content, how they are made sense of by the interlocutors, and their function in social interaction—is co-constructed in relation to the context in which they are invoked. In other words, realizing the meaning potentials of student resources as mediational means is an *interactional achievement* among students and teachers (Silseth, 2018; Silseth & Erstad, 2018).

That learning is co-constructed and context-sensitive does not necessarily imply that any interpretation of a scientific concept and all student resources are seen as relevant by the teacher and peers. Every scientific disciplinary domain has a range of concepts and ways of talking about them that are regarded as "authorized versions" of scientific issues (Lemke, 1990; Scott et al., 2006). The question is *how* the relationship between these authorized versions and student resources is negotiated and established. How student resources become mediational means is inseparably attached to the participants' conceptual orientation and the distribution of authoritative roles (i.e. the social organization of the participants in whole-class conversations). In sum, this implies that *which* resources are treated as relevant, by *whom* and *how* these resources become mediational means is a situated and empirical question.

To explore how student resources become mediational means in educational classroom dialogues in ways that support learning, we argue for the importance of combining an analytical focus on the conceptual and the social aspects of how such resources are invoked and enacted. We make use of van de Sande and Greeno's analytical concepts of "conceptual" and "positional framing" (van de Sande & Greeno, 2012). Conceptual framing refers to the way in which participants organize information by bringing it to the foreground or background of their attention when they try to achieve mutual understanding of a concept or problem. When participants' develop a mutual understanding an *alignment* of conceptual framings is established. A focus on the participants' conceptual framings in whole-class conversations where student resources are invoked enables us to understand to what extent and how student resources become mediational means that can support shared conceptual sensemaking. Positional framing refers to

> the way in which participants understand themselves and one another to be related to one another in the interaction, especially regarding the kinds of contributions each of them is entitled, expected, and perhaps obligated to make in the group's activity. (van de Sande & Greeno, 2012, p. 2)

Participants can be positioned as either "source" or "listener," implying different status in the conversation. To understand how student resources become mediational means, we must consider how students are positioned as learners when such resources are invoked in science conversations. Hence, a sociocultural perspective on student resources and learning, combined with an analytical attention toward the notion of conceptual and positional framing, allows us to understand how experiences, ideas and assumptions invoked by students in whole-class conversations can become mediational means that support conceptual understanding and enabling students to engage, contribute, and immerse themselves in dialogues about school science.

The present study

Existing research has underscored the potential of activating student resources from their everyday lives in science learning at school. Yet, we need to know more about the entanglement of conceptual and social processes involved in this type of instructional work. We must carefully examine the complexity, affordances, and challenges teachers might face when invoking student resources in whole-class conversations. By taking a sociocultural and interactional approach, this study aims to further explore this issue by analyzing student–teacher interactions taking place in naturalistic whole-class school science settings. The empirical context comprises whole-class conversations taking place within a science project about genetics involving lower secondary school students and their teacher. The notions of conceptual and positional framing (van de Sande & Greeno, 2012) will guide our analytical efforts in scrutinizing how experiences, ideas, and assumptions about science can become mediational means that support students in these types of educational dialogs. The empirical analysis seeks to provide evidence of how students can support learning and the challenges teachers may face in doing so. The following research questions guided the analyses:

- RQ1: In what ways do student resources become mediational means in whole-class conversations?
- RQ2: Which opportunities and challenges does the teacher face in whole-class conversations where students invoke resources from their everyday lives?

Research design

Participants and educational setting

The data were collected during a science project on genetics, which took place in 11 school lessons over 4 weeks. They were initially collected as part of a larger research project on the use of analogue and digital instructional materials in different subjects, including science. The participants were one class of 38 lower secondary school students, aged 15–16 years, with an even distribution of boys and girls. The school is one of 21 university partner schools selected because they had signaled that they were interested in collaboration with university researchers. The public school was situated on the outskirts of Oslo, Norway, and most students came from the local neighborhood. Socio-economically, most households in the school district were middle-class, and most students had a Norwegian ethnic background.

When initiating contact, we asked the principal to suggest a teacher who could be interested in research collaboration. The designated teacher was in his late thirties and had served as a science teacher for the last 11 years. In order to prepare the data collection, the research team (led by the first author) met with the teacher and assembled information about the instructional design, learning activities, instructional materials, and time schedules. The teacher was not provided any specific instructions regarding his role as a teacher in the project, how to facilitate whole-class conversations or to focus on student resources in his instructional work. During the science project, the teacher was fully responsible for implementing the instructional design without interference or guidance from the observing researchers.

The project comprised several activities addressing various sub-topics related to genetics, such as genetic material, cell division, and environment and heredity. Most lessons were designed in a similar manner: opening with an introductory whole-class session, followed by a group-work session and ending with a whole-class session. The teacher often began by providing a brief overview of the upcoming activities and scientific concepts. The teacher then gave a mini-lecture (5–10 minutes) elaborating on the scientific concepts, often by using instructional materials such as animations, models, and diagrams from websites and TV documentaries. After or during the lectures, the teacher invited students to participate by encouraging them to comment or ask questions or by organizing practical follow-up activities that could engage the students in whole-class conversations. The following group activities were typically open in the sense that the students were introduced to exploratory tasks using sources such as textbooks and web-based instructional materials. Each teaching unit ended with a whole-class session consolidating the students' experiences from the group activities. In general, the learning environment came across as informal, inclusive and open, often with a humorous tone between the students and the teacher.

During the observation of the classroom activities and the transcription of the classroom interactions, we realized that the data set was extraordinarily rich with regard to whole-class instruction. Our observation notes documented that as much as 52% of the 11-hour project took place in whole-class settings. Additionally, the teacher often invited students to share their ideas and reflections, and the students' engagement and participation were characterized by high verbal activity with many participants. Based on these initial observations, we decided to examine the whole-class conversations more systematically with regard to the resources that the students invoked in these settings.

Methods and data

The data were collected from 60-minute school lessons over a period of 4 continuous weeks. The teacher allocated a total of 11 lessons (four double and three single lessons) to the science project. The researchers carried out seven observations, implying that the researchers were present during the whole project. In this study, the primary data constitute transcribed video recordings of all student–teacher interactions in all whole-class sessions during the project (330 min.). Video data enabled us to examine how members of the classroom community oriented to each other in actual sequences of talk. Classroom observation notes provided supplementary contextual data for the analyses of the participants' interactions (Derry et al., 2010; Erickson, 2006).

To begin systematizing the data, we coded all whole-class conversation sessions according to the structural features of the conversations. The applied coding scheme is based on an adaptation of selected categories from a more substantive coding scheme developed by Wells and Arauz (2006) and Nassaji & Wells, 2000). Figure 1 provides a summary overview of the hierarchy of levels at which the coding was conducted.

As illustrated in Figure 1, the most inclusive unit was the *whole-class session*. On the next level, we coded *episodes*, which are smaller interaction units within a whole-class session. An episode constitutes a stretch of discussion related to a specific task or a classroom activity. Each episode includes smaller defined speech units, coded as *sequences*, which constitute the main analytical level of the analyses in the current study. Sequences are speech units composed of an "obligatory nuclear exchange" that includes one or more initiations, responses, and follow-ups between two or more participants (Nassaji & Wells, 2000, p. 383). Shorter whole-class episodes typically included 5–10 sequences, while longer episodes typically included 25–35 sequences. It is important to emphasize that the boundaries between sequences are not always clear-cut and that the identification of sequences occasionally involves qualitative analytical efforts. In the current study, the boundaries between sequences were defined by a thematic shift in the participants' conversations. Subsequently, we coded all identified sequences based on two main types of structural characteristics: *triadic sequences* and *true discussion sequences*. Triadic sequences involve the teacher and *one* student, while true discussion sequences involve "at least three participants, with or without the inclusion of the teacher" (Wells & Arauz, 2006, p. 391). True discussion is a descriptive category that does not involve a prescriptive judgment of the quality of the discussion. In total, we identified 271 conversation sequences, of which 51 were true discussion sequences. Hence,

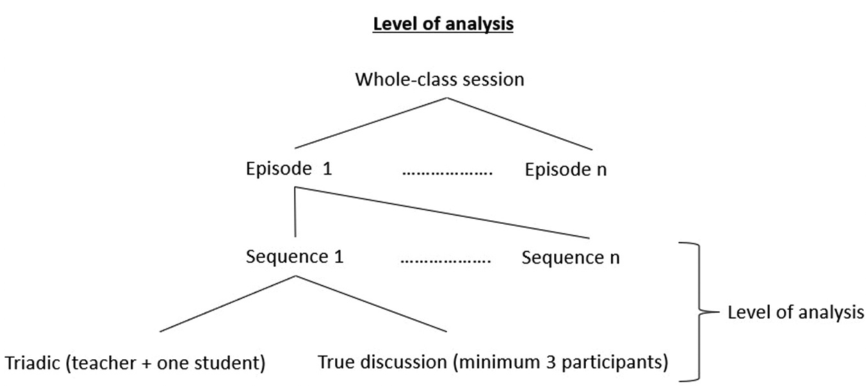

Figure 1. Overview of coded interaction units and level of analysis.

conversation sequences involving more than one student and the teacher were rarer than triadic units. However, the conversation units involving the teacher and multiple students were most often longer in both the time spent on the topic and the number of speech exchanges provided by the students (see Furberg & Silseth, 2018).

For a systematic overview of the resources invoked by students, all instances where students brought in empirical examples, analogies, stories, or references to something they had seen or heard in their everyday lives, were identified. The instances did not include references to scientific issues or content previously presented to students in the school science setting. In total, we identified 77 student resources invoked by the students themselves. As many as 67 of the 77 student resources were invoked in sequences identified as true discussions, suggesting a co-variation between conversations involving student resources and increased student participation.

We used NVivo 11 for coding the data, which was carried out in two stages. First, Author 1 coded the data according to the structural features of the whole-class conversations (see Figure 1). Second, Author 2 examined the coding and singled out sequences that needed to be discussed. Regarding the identification of student resources, Author 2 identified the resources, and Author 1 examined the identifications and singled out sequences that needed to be discussed. In the few incidents of coding disagreement, Author 1, who was physically present in the educational setting and organized the data collection, made the final decision to ensure consistency in the coding. Such disagreements occurred in less than 3% of the total number of coding judgments made. Based on the assumption that the coding of interactional data cannot be a completely objective process, as talk and interaction will always be open to interpretation, we solved coding disagreements in this manner instead of carrying out and reporting on an interrater reliability test (Wells & Arauz, 2006).

For microanalysis purposes, we selected three whole-class sequences identified as true discussion where students invoked resources from their everyday lives. We focused on sequences involving the teacher and multiple students for two reasons. First, situations in which students bring in experiences, examples, and stories from their everyday lives most often occurred in sequences identified as true discussions. Second, sequences involving the teacher and several students can provide insight into how multiple perspectives and resources are presented and become available for the classroom community to engage with. Three criteria guided the selection of the three whole-class sequences. First, in line with our theoretical perspective and research questions, we selected sequences that could serve as *empirical manifestations* of the phenomena under scrutiny. The selected sequences provide a window for examining how the teacher oriented to and appropriated resources that students brought into the whole-class conversations and, thus, how the resources emerge as mediational means. The sequences also provide a window for exploring the challenges and tensions that can emerge in these types of settings. Second, we selected the sequences based on their *interactional transparency*, characterized by a certain degree of explicitness in interlocutors' verbal and physical contributions that makes them available for microanalysis (Linell, 2009). The third criterion relates to the internal validity of the study and concerns the *representativeness* and *typicality* of the selected sequences seen in relation to the whole data corpus: The student–teacher interactions represent typical interactional patterns with regard to how the teacher oriented to, picked up, responded to and made use of the resources invoked by students.

Analytical procedures: Microanalysis of student–teacher interactions

To provide a detailed account of how the participants made meaning of student resources in whole-class conversations, we carried out a microanalysis of naturally occurring classroom discourse. Hence, we applied a moment-by-moment analysis of how teachers and students oriented to each other's contributions in whole-class conversations. In the microanalysis, we focused on how interlocutors co-constructed the activity and collaboratively made meaning of actions and resources recruited in this enterprise (Enyedy & Stevens, 2014; Jordan & Henderson, 1995; Lindwall & Lymer, 2008). This approach enabled us to analytically scrutinize how student resources became mediational means in ordinary instructional settings and to explore opportunities and challenges that emerged in the instructional work. The applied analytical procedure involved sequential analysis of talk and interaction between interlocutors (Hall & Stevens, 2016; Jordan & Henderson, 1995; Linell, 2009). In a sequential analysis, each utterance is considered in relation to the previous and future utterances in the ongoing interaction. Attending to details in the student–teacher interactions and the sequentiality of their utterances in specific interactional moments, we can provide an analysis of "what is going on for the participants in the interaction" (Hall & Stevens, 2016, p. 79).

The interaction analysis of each sequence followed a two-step process, called first- and second-order analysis (Linell, 2009; Silseth, 2018). The first-order analysis involved unpacking and elaborating the participants' contributions and orientations displayed by their interaction. In the second-order analysis, the participants' interactions were seen in light of the analytical concepts of "conceptual" and "positional framing" (van de Sande & Greeno, 2012). By directing analytical attention to both the conceptual dimensions of the sequences and how students and teachers were positioned in the interactional work, we provide insight into how student resources became mediational means for supporting students' development of conceptual understanding and allowing students to engage, contribute, and immerse themselves in dialogues about school science.

We transcribed the analyzed sequences according to Jeffersonian transcription notations (Jefferson, 2004). See Table A1 in Appendix A for the transcription conventions used in this article. The discourse took place in Norwegian, and we translated the excerpts into English. The sequences and analyses have been presented in data analysis seminars, and critical comments and joint analysis efforts from research colleagues have strengthened the validity of the analytical work.

Results

In the following, we present microanalyses of three whole-class sequences where the conversations about genetics revolved around examples, anecdotes or stories from the students' everyday lives. The three sequences provide insights into how student resources, invoked by students themselves, are made sense of and applied in the ongoing interactional work carried out by students and the teacher. The first sequence is from a setting in which participants talk about mutations, where a student brings in a story about a man with a somewhat peculiar trait. Sequence 2 involves a whole-class conversation about heredity material where a student invokes a reference to Spider-Man's superpower. Sequence 3 involves a whole-class conversation about the issue of nature versus nurture, featuring a famous soccer player's hair implants. Together, these three sequences show the various ways in which student resources become mediational means in whole-class conversations in ways that can support student learning and participation and some of the challenges the teacher faces in this type of instruction work.

Sequence 1: Student resources as mediational means providing insight into students' conceptual (mis)understandings

Sequence 1 takes place in a whole-class setting involving a concept-map activity intended to systematize issues, terms and concepts associated with genetics. Based on student input, the teacher wrote and grouped key words on the whiteboard. The teacher and students mentioned the central theme of the theory of evolution several times. The students clearly found the topic intriguing but struggled to differentiate evolution from mutations. Central in Excerpt 1 is a story invoked by the student Tom, involving a man with the capacity to withstand more electrical current than normal. This student example embeds a conceptualization of a scientific principle that is inconsistent with the scientific conceptions held by experts. The analysis of the interaction shows how the teacher handled this tension. We enter the session ten minutes into the activity, when the teacher adds the term *mutation* to the concept map.

The sequence starts with Eric questioning the difference between mutation and evolution (development). He suggests that mutations take place within single organisms and that development concerns "the race." By formulating his suggestion as a question, he signals that he is trying out his understanding and invites the teacher to validate it (lines 1–4). In his response, the teacher first provides a short description of the difference between development and mutations using scientific terms. Then he elaborates by referencing a tame fox that lately has been observed nearby as an example to illustrate how evolution happens on a population level and mutations in the single organism (lines 5–15). His example seems to trigger much engagement among the students, as several students raise their hands. Then he invites Tom, who has been sitting with his hand raised for a while, to contribute. Tom describes a specific man he has heard about that has a peculiar trait. As a result of a mutation, this man's body has a higher tolerance for electrical current (lines 18–20). In his response, the teacher acknowledges Tom's contribution but wants Tom to

Excerpt 1

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Eric:     What's the big difference between a mutation and
          development? (.) is a mutation for instance, a single
          person while development concerns or (0.2) the race. like
          (0.2) what's the difference?
Teacher:  Development is more like on (0.2) what can I say (.) on a
          population level (0.2) mutation takes place within the
          single organism (.) but uhm:: that is (0.3) development as
          such is that the mutation (.) that trait (.) spreads so that
          (.) for instance if all the foxes down at the mire (.) uhm::
          develop a trait over time (.) because those foxes more
          often survive (.) then the other ones without the trait die
          out (.) then perhaps all the foxes suddenly have that trait
          (.) but it's not suddenly at all (.) because it takes a long
          time u::hm and that's what you can call evolution tha::t
          takes place ((several students have raised their hands))
Teacher:  (2.0) We'll never finish this (.) there are so many
          questions ((laughs, and calls on Tom))
Tom:      Yes (.) well anyway (.) it- I've heard of a man that had a
          mutation that made him- in a way he could withstand more
          shock to his body- or current=
Teacher:  =withstand more?
Tom:      More current u:hm to the body in a way without being hurt
          (.) so (.) will his children like come somewhere in between
          an ordinary person and him when it comes to how much- how
          good they withstand currents?
Teacher:  Why do you think in between?
```

Tom: Because it's- if the mother has all normal- li::ke
currency resistance and he ha:s much higher?
Teacher: Uhum (.) well (0.2) if you think like that (.) that u::hm
means that if you cross or copulate someone that ha:ve- u::
hm parents (.) that have brown and blue eyes right? then the
offspring will get something in between (.) but that's not
the way it is (0.2) because there are eye colours that make
it a bit more complicated (0.2) but u::hm it's not like if
you cross a plant (.) let's say a red rose and a white rose
(.) the offspring will become pink (0.2) in between sort of
u::hm (.) that's not how it works necessarily (0.3) this
has to do with dominant and recessive genes ((points at the
concept map on the whiteboard))

---

clarify what he means by "withstands more" shock to his body. Tom offers a short clarification and poses an inferential question about whether the children of this man and an "ordinary person"—a person without such a trait—will withstand current "somewhere in between" the two parents (lines 22–25).

Examining the conceptual orientation in Tom's utterance illuminates some interesting aspects. Here, Tom implicitly invokes the principle of *vertical gene transfer*, which is about the transfer of genes between parents and their offspring. In addition, he invokes procedures belonging to the mathematics domain. In his account, Tom implicitly suggests that the transfer of the electrical resistivity trait can be understood by comparing it to the mathematical procedure involved in average value calculation. He suggests that half of the characteristics of each person in a couple will be merged in an eventual offspring; it will be "somewhere in between" (line 23). In line 26, the teacher asks Tom to clarify why he believes it will be "in between," to which Tom tries to reformulate what he means. The teacher challenges Tom's underlying mathematical idea by introducing two other examples. First, he compares Tom's inference to the inheritance of eye colour, arguing that a child whose parents have blue and brown eyes does not "get something in between" (line 32). Then, he adds weight to this argument by noting that crossing a white and a red rose will not result in a pink flower (lines 35–36). The teacher ends his response by concluding that the inheritance of traits has to do with dominant and recessive genes. By pointing at the concept map on the whiteboard, he indirectly refers to their discussion about dominant and recessive genes earlier in the session (lines 37–39).

Seeing the Sequence 1 interactions in light of conceptual and positional framing (van de Sande & Greeno, 2012) provides insight into how the invoked student resources became a mediational means. As seen in the analysis, the student and the teacher made use of different *conceptual* *framings*. By invoking the story about the current-resilient man, Tom implicitly addressed and tried to make sense of the principle of vertical gene transfer. He used this rather peculiar human trait as an example to request validation of a suggested conceptual framing; specifically, he suggested that the scientific principle of vertical gene transfer can be understood by using average value calculation. The teacher prompted Tom to elaborate and clarify, indicating that he wanted to understand Tom's conceptual framing. Then the teacher challenged Tom's conceptual framing inference by using two other examples, eye colour and flower colours. Furthermore, the conceptual framings of the student and the teacher were not explicitly aligned, as the teacher did not re-visit Tom's story about the current-resistant man or his reasoning within this frame. In terms of the participants' *positional framing*, by presenting his scientific inferences as a suggestion rather than a claim or explanation, Tom positioned the teacher as a source and assumed the role of a listener. By challenging Tom's conceptual framing and orienting the students' attention toward an alternative conceptual framing, the teacher took the source position.

Summing up, the analysis shows that the student resource became a mediational means in the sense of enabling Tom to formulate and test out an inference about mutations while displaying and articulating his conceptual framing to the teacher and his peers. Of equal importance, the story enabled Tom to display what he struggled to understand. From an instructional perspective, the resource invoked by the student became a mediational means that enabled the teacher to gain insight into the students' comprehensions, understandings, and struggles. At the same time, the analysis also illustrates the complexities and possible challenges that teachers can experience when students bring in resources from their everyday lives that are perceived as erroneous or irrelevant. The teacher handled the misalignment of their conceptual framing by invoking other resources (eye colour and flowers) that are more traditional and authorized in the field of science to explain the underlying principle. The fact that the teacher did not re-visit Tom's story about the current-resistant man later in their conversation can indicate that the teacher indirectly dismissed the student resource as irrelevant or invalid. By doing this, the teacher assumed the role of source, while positioning the student in the role of listener.

Sequence 2: Student resources as mediational means that promote engagement, scientific curiosity and testing of ideas

Sequence 2 takes place in an introductory whole-class setting about gene technology, with a focus on the construction of heredity material in animal cells. We enter the whole-class session when the teacher is providing a mini-lecture about human heredity material. Nearing the end of the lecture, the teacher states that only small differences exist between the human genome, plants, and some types of bacteria. He explains that, in principle, the similarity between humans' and other organisms' DNA makes it possible to transfer qualities between species by inserting gene sequences from one organism into another. This "gene delivery" involves the introduction of foreign genetic material, such as DNA or RNA, into host cells. In the analyzed sequence, the teacher explains the notion of gene delivery by providing empirical examples, and one student, Jenny, joins the conversation by invoking a reference to Spider-Man, the famous character from the Marvel universe. The analysis displays how the invoked references emerge and become mediational means in the whole-class conversation, while the students' and the teacher's differing conceptual framings constitute a tension in the interactional work. In the opening of Excerpt 2a, the teacher prepares to elaborate on the notion of gene delivery by using spiders' capacity to produce gossamer as an empirical example.

The teacher starts by elaborating on the principle of gene delivery and its potential advantages by describing spiders' capacity to produce the "super material" gossamer (lines 1–9). Mari enthusiastically asks a follow-up question about whether it is possible "to do that" (line 11). The teacher confirms that this is how gene technology works. Mari immediately asks why this has not yet been done. The teacher explains the potential risks associated with gene technology and gives an example of gene modification involving gene sequences from arctic flounders being inserted into tomatoes (lines 14–16). The students' enthusiasm and interest in pursuing the flounder and tomato example are evidenced by several students promptly raising their hands, talking enthusiastically between themselves and posing questions (e.g., line 17). In his response, the teacher explains how the arctic flounder's ability to withstand cold water is a quality that can be transferred to tomatoes to enhance their cold tolerance (lines 20–26). By explaining that this type of tomato really exists, he provides evidence that gene modification is more than a theoretical construct and occurs in reality with food ingredients sold to consumers. The classroom

Excerpt 2a

```
Teacher:  So we can (0.2) if you take a spider which has the ability to
          produce gossamer right that we try to copy because it's the
          strongest and lightest fabric in the world right (0.2) and
          if we manage to copy that we'll get a new super material
          right (0.3) and the gene or gene combination that enables
          the spider to produce it (0.2) if we identify that part of
          the DNA that we're talking about we can move it to another
          organism (0.3) then the other organism can produce the
          gossamer (0.4) so the recipe is universal.
Jenny:    ((raises her hand))
```

```
11 Mari:     Can we do that?
12 Teacher:  Yes (0.3) that's how gene technology works right.
13 Mari:     But why haven't we done it then?
14 Teacher:  Well we do it (0.2) but there's elements of risks involved
15           right (0.4) so one has to be careful with it (0.6) for example
16           one has moved uhm genes from an arctic flounder into a tomato.
17           ((several students have raised their hands))
18 Anne:     [>How?<
19 Lucas:    [>What's the advantage of that?<
20 Teacher:  Yes because (0.3) that flounder has the quality that it
21           takes-it lives in the Arctic Ocean right the polar area
22           (0.5) and it takes living in cold water and we really want
23           tomatoes that take uhm::: the cold for instance right
24           (0.3) without being destroyed (1.0) that tomato has a name
25           (0.2) it's not for sale in Norway but in the USA you can
26           probably get it (0.2) in cans perhaps.
27           ((several students talk with each other about the flounder
28           and the tomatoes))
29 Liz:      But do you know if it works?
30           ((a student hushes the students that are talking between
32           themselves))
31 Teacher:  Well (0.5) this works right (0.2) but it does not always
32           work the way one believes (0.2) like one ends up with (1.0)
33           one does not always manage to control these things super
34           well.
35           ((several students raise their hands))
```

atmosphere is still elated when Liz pursues the issue, asking if gene delivery has "worked" (line 29). While confirming, the teacher also refers to the potential risks involved and the difficulty of controlling the results of gene modification.

Not willing to let the topic go just yet, several students have their hands raised. In Excerpt 2b, we reenter the conversation when the teacher calls on Jenny, whose hand has been raised for a while (see line 10). Excerpt 2b displays a turn in the conversation when Jenny, based on the teacher's spider example, invokes a reference to Spider-Man. Jenny wants to know whether one of Spider-Man's superpowers—the ability to produce gossamer—is caused by the transferal of the spider's genes into Spider-Man through a bite. Jenny's giggling and characterization of her Spider-Man reference as "perhaps a bad example" (line 38) can be interpreted as a way of signaling that she understands others might think this is a strange comparison or a peculiar question. Nevertheless, her persistence in keeping her hand raised from the point when the teacher introduced the spider example indicates that she finds the topic intriguing. Jenny asks, "Did he get the spider's genes inside him then so he could produce gossamer?" Although not using the scientific term, she is addressing *horizontal gene transfer*, or the lateral movement of genetic material between unicellular or multicellular organisms, which for instance, constitutes the primary mechanism for the development of antibiotic-resistant bacteria. We take the fact that the other students quickly fall silent and turn their attention to the teacher to indicate that they are eager to hear his response (lines 43–45).

The teacher responds with a rhetorical question, asking whether eating an apple will result in the apple's genes entering their bodies (lines 46–47). By addressing the whole class, not only Jenny, he invites all the students to share their opinions. He then emphasizes that Jenny's question is interesting (line 51). The energy rises again, as several students speak together and suggest answers to the teacher's question (line 52). By raising his voice, Paul gets in a word and suggests that genes "don't mix" (line 56). Without validating Paul's suggestion, the teacher turns to Jenny and asks her what she had for lunch, to which Jenny answers that she had a sandwich. The teacher then makes use of an eliciting strategy by posing a series of cued questions to

Excerpt 2b

Teacher: Jenny
Jenny: Uhm:: one thing (0.2) the thing you said about spiders
and genes uh::m well perhaps a bad example but Spider-
Man that we've seen (0.3) he was bitten by a spider
((giggles like she is bit embarrassed)) did he get the
spider's genes inside him then so he could produce
gossamer?
((several students giggle or laugh when Jenny asks her
question, then fall silent and turn their attention back
to the teacher))
Teacher: eat an apple (0.2) do you get the genes from the apple in
you? ((looks at the class))
Knut: Sort of
Truls: Yes in a way
Jenny: ((shrugs))
Teacher: Yes that's an interesting question Jenny
((several students speak all at once providing
suggestions))
Teacher: ((talks loud to be heard above the students)) I only
responded with a question back to you
Paul: They don't mix do they?
((several students continue to speak all at once))
Teacher: ((laughs)) What did you eat during today's lunch break
((addresses Jenny))
Jenny: Uhm:: a sandwich
Teacher: A sandwich yes (0.3) what types of genes did you eat then?
Jenny: (0.7) U:::hm proteins uh::m (0.3) well (0.1) yes
Teacher: Yes you ate grain then (0.4) grain is heredity material
(0.1) isn't it? Those plant cells?
Jenny: Yes
Teacher: Yes (0.2) so you ate a bunch of genes (0.2) you ate a bunch
of cells and in other words you ate a bunch of genes cells
and in other words you ate a bunch of genes
Jenny: That I do not understand (0.1) how can the different=
Teacher: But you can think of that you cook that recipe (0.4) you
burn the
library of life in your cells (0.2) right (.) but (.) (.)
the heredity material does not become a part of you (0.5)
then we constantly would've turned into what we eat
((several students speak all at once))

Teacher: (3.0) Yes that would've been fun ((laughs)) what did you say? ((looks at Jenny))
Jenny: Yes but (.) how can he produce gossamer then?
Truls: ((looks at Jenny)) It's a comic character Jenny ((laughs)) ((several students respond at the same time))
Teacher: Well sh:::: ((silencing the students)) it's an interesting question indeed ((points at Jenny and then looks at the class)) (0.7) and the answer is not as simplistic as I give the impression of now (.) uh::m but it's first of all- but in nature like plants and bacteria and so on genes (.) hereditary material can move uh:m between organisms (0.4) that can happen (0.3) but with higher organisms that's not happening this is an interesting question we'll address this issue when we come to the topic evolution okay?
Jenny: ((Nods))

Jenny (lines 61, 63–64 and 66–68) and following up Jenny's responses with reformulations and inferences based on her answers. The teacher guides Jenny and the class by constructing a scientific account; food, such as a sandwich, contains grain (line 63), which is to be seen as "hereditary material" (line 63). Consequently, Jenny ate "a bunch of genes" for lunch (line 66). At this point, Jenny bursts out that she does not understand (line 69).

The teacher tries to elaborate by referring to an analogy he had previously introduced where he compared a DNA molecule with a cooking recipe. In the teacher's utterance "you burn the library of life in your cells, right, but the hereditary material does not become a part of you" (lines 70–73), he makes use of gene consumption (i.e. eating and digesting genetic material in food) as a resource for arguing against Jenny's implicit inferences that genes from the spider entered and changed Spider-Man's genetic material. By opening her following response with "Yes, but," (line 78), Jenny signals that she acknowledges the teacher's scientific counterargument but still wants an explanation of Spider-Man's ability to produce gossamer. At this point Truls addresses Jenny and in a humoristic tone saying that Spider-Man is only a comic character. Other students, however, enthusiastically raise their hands and talk between themselves, giving the impression that the theme is not exhausted. While silencing the class, the teacher once again emphasizes the relevance of Jenny's question. Then he pursues Jenny's reintroduced Spider-Man question by explaining that genetic material can be exchanged between plants and bacteria but not between higher organisms (lines 86–89). Then, he rounds off by saying that they will get back to the issue when they discuss evolution (lines 90–91).

Seeing the Sequence 2 interactions in light of conceptual and positional framing (van de Sande & Greeno, 2012) sheds light on how the invoked student resource became a mediational means. The analysis displays that Jenny and the teacher assumed diverging *conceptual framings*. In her inquiry, Jenny kept returning to whether transfer of genetic material from the spider might have resulted in Spider-Man's ability to produce gossamer. Without using the technical terms, her inquiry implicitly invoked and foregrounded the issue of horizontal gene transfer as a conceptual framing. Jenny constructed a rather complex reasoning related to the principle of horizontal gene transfer, displaying it for her peers and the teacher. By formulating her inference as a question, she tested her ideas about gene transfer and asked the teacher to validate her comprehension of a complex scientific concept. The teacher's response to Jenny's Spider-Man example shows that he adopted and advocated a different conceptual framing. By invoking eating and digesting genetic material in food as a resource for arguing against Jenny's implicit inference about horizontal gene transfer, the teacher oriented the students' attention toward an alternative conceptual framing, which he might have seen as more valid and relevant. Even though Jenny accepted the internal logic in the teacher's conceptual framing, she did not let go of her own conceptual framing. She kept redirecting the teacher's attention to the issue of horizontal gene transfer. In his response, the teacher provided reasoning within Jenny's conceptual framing while refuting her reasoning by providing a short authoritative account about the principles of horizontal gene transfer among higher order species. The fact that neither Jenny nor her peers followed up the teacher's authoritative response might indicate that the students either accepted the teacher's conceptual framing as the most valid or dismissed Jenny's conceptual framing.

Regarding the social dimension of the Sequence 2 conversation, the analysis reveals that Jenny's superhero example, which the teacher acknowledged as an interesting case, sparked the students' engagement, scientific curiosity, and active participation. Multiple students talked among themselves and raised their hands, eager to participate and share their input. Still, seeing the ongoing interaction in light of their positional framing provides some nuance with regard to the authoritative roles that the participants assumed. By formulating her Spider-Man reference as a question, Jenny placed the teacher in the source position while taking on a listener position herself. In his response, the teacher accepted the source position by responding to Jenny's reasoning as he oriented their shared conceptual sensemaking toward his suggested conceptual framing. Even if the teacher eventually provided reasoning within Jenny's conceptual framing, he sustained his source position by refuting her reasoning about horizontal gene transfer. Furthermore, the analysis shows another social dimension of whole-class conversations. Not all resources and conceptual framings invoked by one student were seen as relevant or valid by other students, as voiced by Jenny's peer Truls. In other words, peers are not necessarily willing to position their fellow students as sources in settings where students bring in their everyday resources.

Summing up, the analysis displays that the student resource became a mediational means in the sense of enabling students to explicate, construct, and present a complex scientific idea about gene transfer to their teacher and peers. The student resource also became a mediational means that triggered students' engagement, scientific curiosity, and active participation. For the teacher, the student resource became a mediational means for introducing an alternative conceptual framing about gene transfer—perhaps a conceptual framing he viewed as more valid and relevant. The student's and the teacher's different framings created a conceptual and positional tension that the teacher tried to alleviate by assuming an authoritative source position. The analysis shows that the teacher, as also seen in Sequence 1, was positioned in and assumed the "traditional" role of the provider of information, whereas the students were positioned as listeners. The interaction revolving around Jenny's Spider-Man reference makes us wonder if the teacher missed a golden opportunity when he chose to pursue his own conceptual framing instead of pursuing the somewhat peculiar, but still valid and rather complex scientific matter raised by a student. Thus, the analysis points to some of the challenges that emerge when the teacher's conceptual framing is presented as the most valid or preferred perspective.

Sequence 3: Student resources as mediational means promoting authoritative and accountable student participation

In the following, we analyze a sequence deriving from a whole-class conversation where the class was presenting their results from a group assignment on nature versus nurture during which student groups categorized various human characteristics. Using a digital drag-and-drop resource on the interactive whiteboard, appointed students were asked to place characteristics (e.g., musicality, religion, eye colour, short hair) into three containers labeled "inheritance," "environment," and "inheritance and environment." We enter the setting when Trond is invited up to the whiteboard and places "short hair" in the "environment" container. In the conversation that follows, the students assume differing conceptual framings when explaining issues that determine hair length. These conceptual framings are challenged and nuanced when a student invokes a story about the hair of a famous soccer player. Furthermore, the sequence shows that the teacher assumes a different position in the instructional work compared to the previous sequences, leading to productive interactions.

In Excerpt 3a, we enter the conversation when Trond is about to justify his group's choice of putting "short hair" under the category "environment."

Excerpt 3a

Trond: Short hair is determined by the environment because:::
(0.3) you can imagine that if all (0.3) in a place (0.4)
have short hair (0.4) then it won't then you would in
general also want short hair so you fit in in a way.
Teacher: Like having long hair at Hillside ((the name of the
school)) (1.7) have you seen one girl at Hillside with
short hair? ((Several of the students say "yes"))
Teacher: It's not many. ((Some small talk occurs between teacher
and the students))
Nina: We don't agree.
Teacher: You don't agree with this?
Chris: No:::.
Teacher: No (0.3) u:hm (1.7) I guess that many of you have put it
where Trond's group has put it (1.1) right that it is more
like that's environment u::hm (0.2) right (1.0) norms
right that we are influenced by our surroundings u::hm
(0.6) et cetera (1.2) norms for how our looks should be and
stuff (0.3) Nina you didn't agree.
Nina: U::hm no because it might be that you have those genes (0.2)
that causes your hair not to grow
Teacher: Yes?
Nina: So you might have short hair
Teacher: ((walks between the students)) Some of you start to get
rather long hair (0.3) I saw some girls earlier Sol doesn't
have that super long (0.4) Heidi starts to::: (1.4) Ella
you have long hair.
Ella: Yes?
Teacher: Do you have the longest hair in the class?
Ella: I don't know
Teacher: Like (0.3) Maren and Frida and Ina they have started to get
really long hair (0.6) but Anne in the other class (.) she
said that she (0.3) she doesn't get that long hair (0.5)
even if she lets it grow (2.2) so maybe that applies to some
of you also that don't get that super long hair (0.7) but
here we talk about short hair by all means.

Trond places "short hair" in the environment category and argues that hair length concerns people wanting to "fit in" (lines 1–4). The teacher acknowledges his contribution and backs Trond's claim by acknowledging that most female students at the school have long hair (lines 5–7). Nina interjects, stating that her group reached a different conclusion (line 10). Before nominating Nina, the teacher acknowledges Trond's environmental position, saying that many groups probably have reached the same conclusion as Trond's group (lines 13–18). The teacher also introduces academic formulations and concepts, like "influenced by our surroundings" (line 16) and "norms" (lines 15 and 17). Then, the teacher invites Nina to elaborate on her group's differing conclusion. Nina justifies her group's heredity position by saying that genes may cause an individual's hair not to grow long (lines 19–20 and 22). Instead of agreeing with either position, the teacher highlights the few female students with short hair, indirectly assuming the environment position. He then mentions a female student, Anne, in a parallel class who claims that her hair never grows long (lines 30–35). By invoking this example, he holds a possibility open for the heredity position. By building on the students' contributions, the teacher acknowledges both positions as relevant and important for the classroom community.

In Excerpt 3b, we reenter the conversation when the teacher invites Frode to share something overheard during the preceding group-work activity. In his response to the teacher's invitation, Frode brings in Wayne Rooney as an example of someone unable to grow long hair (lines 36–37). Soccer was popular among many students, and Rooney was a soccer legend and celebrity at the time. This example from the students' everyday lives clearly triggers student engagement and interest, where several students raise their hands, talk together and simultaneously share their thoughts. In response to Frode's Rooney reference, Arne notes that hair length can be related to age (lines 42–43 and 45), bringing nuance to the discussion. Following up on Frode's Rooney reference and backing up Frode's heredity position, Tom adds that Rooney has hair implants (line 44). Frode states that, since Rooney spends a considerable amount of money on implants, his short hair cannot be by choice and consequently "it has to be because of heredity" (lines 50–52). The teacher responds by emphasizing the complexity of the topic under discussion. By saying "this is not as clear as we perhaps might think" (lines 62–63), he is opening up a space in which the students can provide multiple perspectives. Then he calls on Elsa, who introduces the perspective that hair length is related to the place people grow up. She elaborates that people in India can get "really long hair" because their hair is very "strong," while others cannot have long hair even if they try because it "gets very worn" (lines 65–69). Even though the scientific basis of Elsa's argument is somewhat implicit and unclear, she positions herself in favor of a heredity position. Her statement that "it has to do with heredity too" (line 71) adds nuance to her stance and signals her reaching back to Tom's environmental position voiced earlier (lines 1–4) to acknowledge both an environmental and a heredity position. In his response, the teacher wraps up the discussion. By concluding that the heredity factor determines "how long the hair gets" whereas environmental factors determine "short hair," the teacher acknowledges and builds on the contributions and perspectives that the students brought into the discussion.

Seeing the interactional work in Sequence 3 in light of conceptual and positional framing (van de Sande & Greeno, 2012) provides insight into how the student resources became mediational means in the whole-class conversation. The analysis of Excerpt 3a displays two competing *conceptual framings*, one favoring an environment position voiced by Trond's group and another favoring a heredity position voiced by Nina's group. In Excerpt 3b, the reasoning within the two conceptual framings is elaborated on and nuanced. Within this context, Frode's Rooney example became a mediational means in several ways. First, it appears to have stimulated student engagement, active participation, and curiosity, resulting in many students actively sharing their ideas. Second, the Rooney example opened up opportunities to collaboratively explore more nuanced understandings of heredity-related factors while explaining and arguing for their stances. For instance, some used Rooney's hair implants to build an argument that nuanced the environment position and sparked a discussion about the

Excerpt 3b

Frode: Yes there is a soccer player who doesn't yes who doesn't get
longer hair than this this [long. ((shows with his fingers))
Teacher: [Yes like this. ((shows with his
fingers))
Erik: Rooney?
Frode: Yes Rooney doesn't get longer hair than [this,
Arne: [It has something
to do with age.
Tom: He used like implants.
Arne: Perhaps it has something to [do with age.
Frode: [Yes he used implants.
Arne: Yes.
Frode: So [::
Erik: [Iniesta too.
Frode: It can't be just because (0.2) he doesn't do that on purpose
(0.2) then he wouldn't have used a lot of money on implants
(0.3) then it has to be because of heredity.
Teacher: It's not just because he has like frizzy curls.
Frode: No no he has like these small stubbles on his head. ((shows
with his fingers))
Teacher: Uhum (1.0) yes perhaps the age i:::s involved
[here uh::m?
Frode: [He is twenty-six: uhm: twenty-seven or something (.)
don't know (0.2) something like that (0.4) he has never had
much hair on his head (0.3) never.
Teacher: [Twenty-six yes he's not older.
Teacher: No (0.4) it's an interesting u::hm case that one (0.6) this
is not as clear as we perhaps might think (0.4) Elsa did you
have some inputs?
Elsa: Uhm yes (.) yes I was about to say that u::hm it depends on
where you're from like for example, in India you get really
long hair because the hair is so strong (0.6) but others
(0.4) grow their hair but it gets very worn (0.2) so it
doesn't get much longer.
Teacher: Yes?
Elsa: It has to do with heredity too.
Teacher: So if we think (0.8) if we nuance a little bit how long the
hair gets (0.4) then a heredity factor is present (0.8) but
if we just think short hair like:: Truls or Erik right (0.7)
then (0.2) we agree that (1.0) we are where (0.4) Trond is.
((points to the category "environment" on the
whiteboard))

relevance of age and dissimilar hair qualities based on location. Furthermore, the teacher did not clearly front a specific conceptual framing and used open-ended questions. He refrained from providing the “correct” answer and validating the students’ argument; instead, he prompted students to respond to each other’s input. Concerning the participants’ *positional framing*, the teacher’s orchestration in Sequence 3 also contrasts with earlier sequences. In Sequence 3, he refrained from providing his own conceptual framing, explicitly invited the students to share their resources, and prompted them to argue for their perspectives. The teacher refrained from taking a source position and positioned himself as a listener, while the students in this setting were positioned as and took on roles as sources. Their positioning as sources is evident in the fact that their input was in the form of arguments, clarifications, or counterarguments to their peers’ input, rather than inquiries formulated as questions to be validated by the teacher, as seen in Sequences 1 and 2. Another essential aspect of the teacher’s positional and conceptual framing is displayed toward the end of the sequence when the teacher wrapped up the discussion. His way of summing up the two main positions advocated by the student groups shows that the teacher tried to accomplish an alignment between the students’ conceptual framings and interactionally develop common ground and achieve mutual understanding.

Summing up, the analysis shows that the student resources became mediational means that enabled the teacher to orchestrate a learning situation in which the students assumed different conceptual framings for engaging with the topic of nature and nurture that stimulated reasoning and reflection. The student resources became mediational means that enabled them to nuance and elaborate their conceptual sensemaking within these frames. Furthermore, the student resource appears to have triggered students’ engagement, scientific curiosity, and active participation. Most importantly, the analyses of Sequence 3 display that the student resources became mediational means that enabled the teacher to position students as accountable and authoritative contributors in the whole-class conversations, such as when inviting Frode to share a resource he had introduced earlier in the project. The teacher then invited the other groups to elaborate on their counterargument instead of taking on the role as a provider of counterarguments, thereby positioning the students as sources while assuming a listener position. In contrast to Sequences 1 and 2, the teacher acknowledged the different conceptual framings introduced by the students and tried to align these in working toward a nuanced common understanding of the topic. Furthermore, when the teacher reinstated himself as a source when wrapping up the conversation, he simultaneously positioned the students as “co-sources” by foregrounding their differing conceptual framings. Thus, the Sequence 3 interaction displays the potential that student resources hold as mediational means that enable students to assume roles as sources—providers of accounts, arguments, and reasoning—in whole-class conversations about complex scientific issues.

Discussion

This article aims to show how resources from students' everyday lives become mediational means for engaging in whole-class science conversations and to examine what opportunities and challenges teachers face in this type of instructional work. We have provided a theoretical framework for conceptualizing student resources from a sociocultural perspective of learning and teaching. Combining an analytical focus on conceptual and social dimensions of learning and teaching, we have examined in detail how student resources were made sense of and made relevant in the ongoing interactional work carried out by students and the teacher during whole-class conversations about genetics in a naturalistic setting. This examination provides an opportunity to identify some critical factors for how teachers can devise productive strategies to invite and build on the resources that students bring into whole-class science conversations. We will now discuss our main findings and end with possible implications for instructional design.

Enabling students to express and test out their conceptual understanding and scientific reasoning

Researchers focusing on students' science learning have emphasized the importance of allowing students to make their scientific ideas, reasoning, and understanding visible to their peers and teachers (Berland & Hammer, 2012; Engle, 2006). Educational dialogs, specifically whole-class conversations, might provide rich opportunities for such activities (Berland et al., 2020; Clarà, 2019; Howe et al., 2019; Kovalainen & Kumpulainen, 2007). Several studies have shown how teachers' use of carefully planned instructional designs targeting students' everyday experiences can form a pivotal basis for supporting and guiding students' development of conceptual understanding (Elby & Hammer, 2010; Hammer, 2000; Luna, 2018). This study adds to this literature and extends the findings from previous studies. By focusing on examples from students' everyday lives (e.g., soccer, popular culture) that they themselves spontaneously invoked during whole-class conversations, we explored how such resources became means in students' inquiry and sensemaking of science concepts.

Orienting our analytical focus toward the participants' conceptual framing (van de Sande & Greeno, 2012) enabled us to display and examine the more or less implicit scientific reasoning embedded in the resources invoked by the students, as well as how the teacher responded to their reasoning. In turn, we can see how the resources emerged as conceptual mediational means in the whole-class discourse. Concerning the students, the analyses showed that the invoked examples and experiences became mediational means that enabled students to verbalize, visualize, and test out their conceptual framings—their understanding of science concepts, ideas, and principles—in the classroom community. Furthermore, as displayed by the Rooney reference in Sequence 3, the student resources also became a mediational means that enabled students to argue for their own stances and conceptual framings. Of equal importance, the invoked resources enabled the students to display and articulate their conceptual challenges and misunderstandings. While their conceptual framing is not always aligned with authorized versions of science or uttered with the correct vocabulary, students still have rather advanced scientific ideas and assumptions. The analysis of Sequence 1 and 2 show this to be true even when the resources are unexpected, as seen in the references to the current-resistant man and Spider-Man.

Design-based research studies have shown that planning for mobilizing students' everyday experiences and language might enable students to engage in advanced conceptual reasoning in science (Rosebery et al., 2010; Varelas et al., 2008; Warren et al., 2001). Our findings add to this literature by contributing knowledge about the complexities of this type of instructional work. Regarding the teacher, our analyses showed that the student resources became mediational means enabling the teacher to gain insight into the students' understanding and reasoning. As seen in Sequences 1 and 2, the teacher used the resources invoked by students as means for explaining and elaborating on ideas and underlying principles embedded in these contributions. At the same time, the analyses also displayed that the students and the teacher occasionally made use of different, sometimes conflicting conceptual framings. Sequence 1, which concerned the current-resistant man, illustrates how teachers must manage what they view as a less relevant or erroneous conceptual framing put forward by students while acknowledging the conversational contribution provided by each student. Sequence 2 also displays a tension between a conceptual framing put forward by the student Jenny and the teacher—a tension the teacher tried to alleviate by assuming an authoritative source position. Considering that the student's reasoning implicitly addressed a central scientific principle regarding gene transfer, it might be argued that the teacher missed a golden teaching opportunity when he chose to put forward his own conceptual framing.

Despite the conundrums that can occur as a consequence of tensions between conceptual framings as illustrated in Sequences 1 and 2, the analysis of Sequence 3 revolving around the Rooney reference shows that teachers can use differing conceptual framings—in this case voiced by students—to demonstrate the complexity of science issues and highlight how scientific reasoning involves the capacity to apply and combine different conceptual framings. In other words, teachers can use student resources as mediational means to create dialogic relationships between different conceptual framings present in science-related whole-class conversations. Overall, the analyses display the importance of teachers being sensitive toward and curious about the underlying scientific ideas and reasonings that students aim to address when invoking examples and experiences from their everyday lives. By prompting students to provide elaborations and clarifications, the teacher can elicit these underlying issues and make them available as resources for the classroom community to reason with.

Promoting student participation, engagement and curiosity in science learning

Learning sciences researchers have emphasized the importance of facilitating varied forms of engaged participation (Azevedo, 2013; Bricker & Bell, 2014; Engle & Conant, 2002; Nasir & Hand, 2008). In a case study, Engle and Conant (2002) displayed that passionate involvement constitutes the core of students' productive disciplinary engagement. Likewise, Jaber and Hammer (2016) argued for the importance of directing instructional attention toward students' "epistemic affect," as affective engagement is an essential aspect of both classroom disciplinary practices and professional researchers' practices. Furthermore, studies have shown the importance of creating learning environments in which students are willing to contribute to science discourses (Barton & Tan, 2009; Brown, 2011; Tabak & Baumgartner, 2004). Many students are often reluctant to participate verbally in whole-class discussions (Sedlacek & Sedova, 2017; Sedova & Navratilova, 2020), making it challenging for teachers to activate multiple students in whole-class conversations (Lemke, 1990; Myhill, 2006; Myhill & Brackley, 2004; Pimentel & McNeill, 2013).

Our empirical findings indicate that invoking student resources might have a positive impact on students' participation and engagement in whole-class conversations. For example, the initial identification and coding of student references showed that 67 of the 77 student references were invoked in conversation sequences involving the teacher and multiple students. Although we cannot ascertain a causal relationship between invoking student resources and increased participation, this finding indicates a relationship between high student participation and discussion of student resources. Affect, engagement, and motivation within disciplinary practices can be difficult targets for investigation as they occur in situ and often play out bodily or by gesticulation rather than verbally (Goodwin, 2007; Jaber & Hammer, 2016). Our analyses of the participants' interactions in the three sequences shed light on how such engagement can unfold in learning conversations in which student resources are invoked. First, the analyses show that the introduction of everyday examples by the students and the teacher seemed to spark interest in the ongoing conversations about genetics. When these resources were invoked, the classroom atmosphere elevated and multiple students became activated, raised their hands, and joined the conversations. Seen in light of the fact that several students provided their input simultaneously with raising intonations and cutoffs, as seen in Sequences 2 and 3, we interpret this as an indication of positive "epistemic affect" (Jaber & Hammer, 2016). The students' engagement and curiosity were directed to their peers' examples and the science topic under consideration. As such, this study shows that facilitating whole-class conversations that activate student resources can contribute to students' willingness to engage in academic discourse. Students used these resources to join dialogues about complex science issues.

Second, science learning implies not only the capacity to understand scientific concepts and processes, but also the willingness to position oneself according to co-existing perspectives and participate in scientific argumentation (Engle & Conant, 2002; Strømme & Furberg, 2015; van de Sande & Greeno, 2012). The analysis shows that the students were willing to share their perspectives on scientific issues while daring to make risky references to everyday experiences (e.g., Jenny's Spider-Man reference in Sequence 2 and Tom's current-tolerant man references in Sequence 1). Most importantly, in Sequence 3, by prompting students to invoke their everyday experiences as resources to construct arguments, the teacher facilitated a learning situation in which the students were able to assume different positions in whole-class conversations and engage with each other's perspectives about complex science issues. As such, resources from students' everyday lives inherit a significant potential as mediational means that can support student participation and curiosity in conversations about science.

Promoting students as authoritative and accountable participants in whole-class science conversations

Learning sciences researchers have addressed the difficulties in creating learning designs that balance canonical versions of science with students' personal experience (Kapon et al., 2018; Russ & Berland, 2019). In secondary classrooms, learning science inevitably involves appropriating the tools used by science experts and the canonical, or authoritative, ways of reasoning in science (Aguiar et al., 2010; Lemke, 1990; Scott et al., 2006). However, teachers must offer learning opportunities that are sensitive to students' orientations and interests, where student resources can serve as more than starting points toward canonical forms of knowing, reasoning, and inquiry. According to Berland and McNeill (2012), teachers should give students time and the opportunity to introduce their own experiences when inquiring into new science topics, without immediately adjusting these experiences to academic discourses. Furthermore, scholars have highlighted the problem of only superficially referring to students' everyday experiences and knowledge in instructional work. This problem arises when the everyday experiences are not made relevant and integrated in the co-construction of knowledge about the science issue under consideration (Bronkhorst & Akkerman, 2016; Polman, 2006; Silseth, 2018).

Orienting our analytical focus on the participants' positional framing as sources and listeners (van de Sande & Greeno, 2012) has revealed that the meaning of student resources and how they become mediational means depends on the distribution of authoritative roles between students and the teacher in whole-class dialogues. Although the teacher in our study facilitated learning situations inviting students to bring in their own examples to engage in science conversations, some resources were not investigated in detail or seen as irrelevant. For example, in Sequence 2, the teacher did not use the Spider-Man example as an opportunity to discuss horizontal gene transfer as a potential conceptual framing that the students' reference could have opened for. Although acknowledging the student resources as interesting, the teacher assumed a source position, placing the students in the listener position (Sequences 1 and 2).

Most importantly however, is that the analyses also show that conversations revolving around resources invoked by students have the potential to change this traditional conversation pattern. This is displayed by Sequence 3, where the teacher positioned the students as sources—accountable providers of information—and by that he facilitated and supported productive forms of student engagement. The students provided arguments and counterarguments to a much greater extent than in the other sequences. The teacher's guidance was characterized by open-ended questions, and he refrained from providing the "correct" answer as he invited several students into the conversation, prompting them to respond to each other's input. In light of the notion of communicative approaches (Scott et al., 2006), the teacher employed a dialogic approach and refrained from entering an authoritative source position. The students were positioned as sources and co-sources, or as "authoritative and accountable" participants (Greeno, 2006a), in a whole-class conversation in which the participants tried to develop common ground and achieve mutual understanding. Thus, a significant finding of our study is that student resources may become mediational means to change traditional conversation patterns and promote students as authoritative, accountable participants in whole-class science conversations.

Although we cannot make causal inferences between conceptual and positional framings, the analyses make us wonder about the relationship between these two framings. In the sequences where the conceptual framings were not explicitly aligned, the students were positioned as listeners. In the sequence where the students were positioned as sources, the conceptual framings of the students were allowed to co-exist and illuminate each other. This finding points to the importance of a teacher that invites and encourage students to bring in ideas and assumptions about science from their everyday lives, as well as enabling them to assume the roles of sources with authority over their ideas while also supporting them in making connections between their ideas and scientific concepts. Thus, a teacher's openness to students' conceptual framings that they put forward when invoking their resources may realize shifts in the students' role in educational dialogues toward becoming authoritative and accountable participants.

Implications for instruction

Whole-class conversations provide unique opportunities to engage students in learning situations where they can verbally clarify their ideas and reuse each other's contributions when inquiring into science-related topics. This study shows how student resources can help create engagement and participation to support students as learners in whole-class conversations. However, we also note possible challenges that teachers might face. First, teachers must be attuned to the interpretation and negotiation work that students undergo in their conceptual sensemaking processes. It is valuable to devise dialogic moves that explicitly elicit sensemaking in the intersection between everyday and traditionally scientific ways of engaging with subject matter. Second, teachers should be aware of and orient toward the often implicit conceptual framings offered by students when invoking experiences from their everyday lives. Students do not always have the correct scientific terms but might have rather advanced scientific ideas that can be built upon in meaningful ways. Third, teachers should take time to dwell on the students' resources brought into the conversations. If they only superficially mention the students' resources, they risk simply aligning them with their own conceptual framings. By planning for instructional designs and discussions that are sensitive to students' orientations and interests, teachers can ensure that student resources serve as more than starting points toward more canonical forms of knowing, reasoning, and inquiry. Most importantly, striving to position students as sources when introducing examples from their own lives as resources for learning is valuable. Doing so might lead to learning situations in which students feel true engagement and ownership, enabling the classroom community to meaningfully engage with each other's interests, ideas, and experiences in a common enterprise of learning science.

Concluding remarks

The emerging aspect of how student resources can become productive resources in classroom conversations refers to the relational process where the invoked everyday experiences are picked up, addressed, and made relevant during ongoing dialogues. Even though student resources may become productive mediational means that support science learning and engagement, these resources are not ready-made. They must be made relevant and productive in the interactions. The activation of student resources is enacted in situated activities, and we need to pay attention to both the conceptual and social dimensions of these conversations. This study points to the importance of educators—teachers, researchers, designers—understanding student resources as woven together with the scientific content and the social contexts of the classroom. To support students in everyday school science settings, teachers must be sensitive to the student resources spontaneously brought into science conversations and the shared effort required for these resources to become mediational means.

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Appendix A

Table A1. Transcript conventions.

[]	Start and end points of overlapping speech
(# 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
:::	Prolongation of a sound
((text))	Annotation of non-verbal activity