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Bridging group work and whole-class activities through responsive teaching in science education

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Abstract

Previous studies have shown both benefits and challenges of group work and whole-class activities in educational settings. One overall finding in the existing literature is that it is challenging for teachers to facilitate whole-class conversations that realise the rich potential of student discussions and undertakings during group work. This article investigates how teachers can facilitate productive consolidating whole-class conversations building on students' group work experiences by enacting responsive teaching practices, implying foregrounding students' experiences and ideas, and pursuing the substance of the students' experiences and ideas in instructional work. Based on a sociocultural perspective, we analyse sequences of classroom interactions where students' experiences from their lifeworld are invoked in a) settings where student engage in small group activities and b) teacher facilitated whole-class conversations. The educational context is a science project about genetics involving lower secondary school students and their science teacher. Our analysis shows that in group work settings, students' everyday experiences are invoked but are seldom picked up on and pursued in group conversations as resources for engaging with science matters. In whole-class conversations facilitated by the teacher, especially in situations in which the teacher assumed a responsive teaching approach, students' everyday experiences were more often realised as resources for shared meaning making and engagement with scientific concepts and ideas. We discuss this study's implications for teachers designing productive learning activities that combine group work and whole-class activities.

Keywords Responsive teaching · Group work · Whole-class conversations · Sociocultural · Interactional analysis

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Introduction

In this article, we examine how an instructional sensitivity to student resources – the experiences, ideas and assumptions about science matters that students bring to school – when facilitating consolidating whole-class activities can contribute to building on and refining student discussions and undertakings during group work. Decades of research on group work and whole-class conversations have provided valuable knowledge about the productive aspects of student collaboration and group-work activities. For instance, student collaboration in group work settings provides students with the opportunity to engage in shared knowledge construction, making scientific reasoning explicit and making ideas available for negotiation (Barron, 2000; Howe & Abedin, 2013; Webb & Mastergeorge, 2003). However, some studies have also found that students' conversations during group work are often characterised as being cumulative and disputational rather than explorational (Mercer & Littleton, 2007), groups are more inclined to perform the task at hand rather than engage in deeper conceptual sensemaking (Strømme & Furberg, 2015), and that group work, for some students, may evoke negative emotions and create motivational challenges (Baker et al., 2013; Furberg & Arnseth, 2009; Han & Gutierez, 2021). Regarding whole-class conversations, research has shown that teachers can provide students with conceptual support in the form of elicitation, contextualisation and revoicing that enables learners to produce more sophisticated and extended accounts of their ideas and position them as more actively engaged participants (Howe et al., 2019; Kumpulainen & Rajala, 2017; O'Connor & Michaels, 1993). Nevertheless, other studies have emphasised that, for various reasons, students might be reluctant to engage in these types of educational dialogues characterised by multiple participants (O'Connor et al., 2017; Sedova & Navratilova, 2020). From a teaching perspective, teachers face challenges in orchestrating such dialogues in ways that are meaningful to all members of the class and support reasoning and learning (Lehesvuori et al., 2013; Lemke, 1990; Pimentel & McNeill, 2013).

Thus, the opportunities and challenges of educational dialogues in both group work and whole-class settings have been the subject of much research. However, it has been argued that we need more knowledge about the relationship between activities across these settings (Frøytlog & Rasmussen, 2020; Galton et al., 2009; Howe & Abedin, 2013; O'Connor et al., 2017), as well as how teachers can orchestrate consolidating activities where connections between group work and whole-class conversations are realised (Howe & Mercer, 2017; Webb, 2009). In this article, we aim to investigate this aspect in the context of school science. More specifically, we set out to investigate how teachers can facilitate consolidating whole-class activities for the purpose of building on and refining student discussions during group work through practices of *responsive teaching* (Jaber et al., 2021; Robertson et al., 2016). These instructional practices imply that teachers are attuned and sensitive to the experiences, ideas and assumptions about science matters that students bring to school, which we argue represent a promising way to enact supportive consolidating whole-class activities.

By employing a sociocultural approach to learning and responsive teaching (Hatano & Wertsch, 2001; Vygotsky, 1978), we scrutinise how teachers can facilitate whole-class conversations by mobilising, taking up, and refining students' experiences and ideas emerging in preceding group work activities. To empirically examine this issue, we analyse sequences of classroom interactions where students' experiences from their lifeworld are invoked in a) settings where student engage in small group activities and

b) teacher-facilitated whole-class conversations. The educational context is a science project about genetics involving lower secondary school students (aged 15–16 years) and their science teacher. The purpose of analysing collaboration during group work is to display and explore the role of students' everyday experiences and ideas in peer science conversations. The purpose of analysing the whole-class conversations is to examine how the teacher, in and through a responsive teaching event, contributes to the creation of productive connections between the group work and the whole-class conversations. In the following sections, we discuss previous studies on group work and whole-class conversations in science education settings and outline our conceptual framework.

Learning and teaching in group-work and whole-class settings in science education

Research on students' engagement in group work activities

In the learning sciences, there is a fair consensus to the notion that peer collaboration and group work provide a valuable basis for student learning across different knowledge domains and school subjects (Baines et al., 2007; Fung, 2022; Howe, 2014). In the context of science education research, many studies have revealed the importance of student collaboration in small-group settings and its positive aspects regarding student learning and engagement in science education. For instance, group work provides students with opportunities for shared knowledge building, sense-making and making their scientific reasoning and ideas explicit and available for negotiation (Berland & Reiser, 2009; Furberg & Arnseth, 2009; Gillies, 2003). Furthermore, group work allows students to practise and develop their scientific argumentation skills (Evagorou & Osborne, 2013). Other studies point to the positive socio-emotional aspects of group work. For instance, it can contribute to establishing and strengthening social bonds among students (Sullivan & Wilson, 2015), as well as providing opportunities for students to become meaningful contributors to the classroom community (Esmonde, 2009). Students might also be more motivated to engage with the subject matter when working together than when working individually (Slavin et al., 2003).

However, some studies have also shown that the quality of group work varies considerably among students (Barron, 2003), and students often encounter conceptual, procedural and socio-emotional challenges during group work (Berland & Reiser, 2011; Han & Gutierez, 2021; Sohr et al., 2018). For example, conversations between students during group work is often characterised as being cumulative and disputational rather than explorational (Mercer & Littleton, 2007), and students' focus tends to be more oriented towards procedural aspects of performing the task at hand (as quickly as possible) rather than engaging in deeper conceptual sensemaking (Furberg & Arnseth, 2009). Regarding socioemotional challenges, competition among group members can contribute to an unproductive learning environment (Sullivan & Wilson, 2015). Peer collaboration can evoke negative emotions and cause motivational challenges to arise when students' characteristics, goals and demands conflict (Baker et al., 2013; Han & Gutierez, 2021). Students often spend more time and effort dealing with socio-emotional conflicts instead of conceptual issues and problems (Andriessen et al., 2013; Isohätälä et al., 2018).

Research on teachers' facilitation of whole-class conversations

Over the years, scholars have argued for the significance of teacher-facilitated *consolidation activities* following group work activities to realise the rich potential and quality of student discussions and undertakings during group work (Kaendler et al., 2015; Klette, 2020; MacQuarrie, 2013). Whole-class studies show the significance of teachers' conceptual support by eliciting students' understanding, contextualising students' utterances and accounts and revoicing and re-phrasing students' utterances through the application of more scientific terms (Howe et al., 2019; O'Connor & Michaels, 1993). By using follow-up questions and discourse moves that stimulate extended accounts from students, the teacher can enable them to make more sophisticated and elaborated contributions (Kovalainen & Kumpulainen, 2007; Oliveira, 2010). Consolidation activities are also important in the sense of sharing the experiences and insights gained by groups with the larger classroom community (Kaendler et al., 2015).

However, some studies have also revealed that whole-class conversations can be challenging for both students and teachers. Students can experience participation in whole-class conversations as socially, cognitively and emotionally challenging (Sedlacek & Sedova, 2017; Sedova & Navratilova, 2020). Due to their fear of revealing lack of competence in the subject matter or deviating from expectations in the peer culture, many students might be reluctant to participate in consolidating whole-class conversations after group activities. Moreover, the participant structures might not give all students in the class equal opportunities to contribute their perspectives and ideas, thereby hindering authentic reasoning and inquiry (Lehesvuori et al., 2013; Lemke, 1990). As to teachers, studies have also shown that even if teachers know about the importance of dialogic-oriented teaching, they might lack the competence, dialogic skills and expertise required to establish this type of instructional approach (Myhill, 2006; Pimentel & McNeill, 2013). Furthermore, facilitating consolidating conversations, where the different perspectives and interests that students bring into the dialogue are made meaningful to all members of the class, entails complexities and challenges (Pimentel & McNeill, 2013; Silseth & Erstad, 2022; Wells & Arauz, 2006).

Our review of previous research reveals some of the benefits and challenges associated with group work and whole-class conversations. However, it is also clear that we need more knowledge about how teachers can facilitate consolidating whole-class activities that can realise the rich potential and quality of student discussions and undertakings during group work (Frøytlog & Rasmussen, 2020; Galton et al., 2009; O'Connor et al., 2017; Webb, 2009). In Howe and Mercer's (2017) words, "a crucial educational issue is how teachers should draw on the outcomes of small-group discussions in the whole-class setting" (p. 85). The balancing act of introducing students to disciplinary scientific content, making learning relevant to students, and finding ways to engage them more personally might contribute to this complex and challenging aspect of whole-class conversations. We argue that one productive way of creating connections between group work and whole-class activities, an area that existing research on consolidating activities has not explicitly addressed, is for teachers to engage in responsive teaching practices. In the next section, we outline our sociocultural approach to learning, instruction and responsive teaching.

A sociocultural approach to learning, instruction and responsive teaching

From a sociocultural perspective, learning is understood as a dynamic meaning making activity enacted in negotiations between and among interacting participants (Danish & Gresalfi, 2018; Vygotsky, 1978). Furthermore, the mediating role of semiotic and cultural tools is emphasised. Above all, language is considered the most important tool for making sense of the world and of human practices and ideas, as well as a tool that mediates thinking and reasoning (Hatano & Wertsch, 2001). From a sociocultural perspective, two closely related features of meaning making are deemed central. The first concerns *the situated character* of dialogues. A dialogue represents a social practice in which actors interact and communicate, and individual contributions cannot be understood as separated from where and in what ways they are produced. Every utterance, act or turn made by one of the participants in a dialogue is made sense of in the context in which it is embedded (Goffman, 1981; Greeno, 2006b). Second, meaning making is deeply social and interactional in nature and a matter of *joint construction*. In social interactions, meaning neither belongs to nor is it a product of a single individual (Bakhtin, 1986; Linell, 2009). The collective construction of meaning and learning is made possible by the mutually coordinated social interactions among participants in specific settings and practices (Hall & Stevens, 2016; Silseth et al., 2023; Valsiner, 2007).

Building on these assumptions about learning—perceived as meaning making—the idea of teaching in the form of guided participation has been important in the sociocultural tradition. Moreover, the significance of teacher support in the form of dialogue facilitation has been emphasised (Collins, 2006; Mercer et al., 2019). Much attention has been paid to how teacher support can be provided by means of orchestrating talks and dialogues that can contribute to enhancing students' development of their conceptual understanding (González-Howard and McNeill 2019; Howe et al., 2019; Michaels & O'Connor, 2015). Through strategies such as eliciting student contributions, building on and expanding student accounts, revoicing students' sometimes unclear and unfinished contributions, and inviting and enabling them to build on one another's contributions, teachers can support student reasoning and participation in educational dialogues. In addition to focusing on the facilitation of students' development of their conceptual understanding, scholars in the sociocultural tradition have accentuated the importance of establishing dialogic classroom settings where multiple perspectives and the free interchange of multiple voices are made possible (Bakker et al., 2015; Silseth & Arnseth, 2022). More specifically, some researchers have argued for the importance of creating dialogic learning settings in which students are positioned as authoritative and accountable participants and allowed authorship in the co-construction of knowledge (Engle & Conant, 2002; Furberg, 2016; Greeno, 2006a; Kumpulainen & Rajala, 2017). An important teacher strategy for guiding student participation in such educational dialogues in school science is to invite students to share their own knowledge and experiences regarding scientific concepts and ideas and together with their peers, realise such contributions as meaningful resources for reasoning and inquiry (Brown, 2011; Furberg & Silseth, 2022; Muller Mirza et al., 2014; Rosebery et al., 2010; Varelas et al., 2008).

In this article, we argue for the significance of instructional practices that have recently been referred to as *responsive teaching*, which is based on the assumption that students come to the classroom with a wealth of knowledge, understandings, experiences and ideas about science that might be intuitive and raw but remain the basis on which scientific knowledge can be built (Hammer et al., 2012; Luna, 2018). Responsiveness involves foregrounding the attention to students' experiences and ideas, recognising their disciplinary connection and pursuing the substance of the students' experiences and ideas in instructional work. Responsiveness to the resources that students bring into the science classroom should be accompanied by the belief that students should learn to become and experience being agents of their own learning (Robertson et al., 2016). Jaber et al. (2019) describe responsive teaching in this way:

> [...] an instructional approach centred on listening closely to students' ideas, interests, and questions, to identify and build on the productive beginnings in their thinking. In responsive classrooms, teachers adapt objectives and activities within their lessons while still working toward larger learning goals. (p. 85–86)

This juxtaposition of responsibilities associated with responsive teaching represents a possible tension in instructional work because teachers need to balance their commitment to introducing students to scientific versions of concepts and the learning goals defined by the curriculum as well as to creating learning settings where student resources are valued and put to the fore (Ball, 1993; Berland et al., 2020). However, an important assumption in the responsive teaching approach is that teachers have the capacity to both focus on the resources that students bring into the classroom, adjust the intended instructional design to these resources and keep an eye on the overall science content, learning goals and curriculum.

The present study

Previous research has underscored the importance of providing more knowledge about how teachers can facilitate consolidating whole-class activities that can realise the rich potential and quality of student discussions and undertakings during group work. In the present study, we aim to provide deeper insights into how students' everyday experiences become resources for engaging with science matters during group work and whole-class conversations. Furthermore, we seek to examine how teachers can facilitate consolidating whole-class conversations for the purpose of building on and refining student discussions during group work through practices of responsive teaching. Such instructional practices imply that teachers are attuned and sensitive to the experiences, ideas and assumptions about science matters that students bring to school. By adopting a sociocultural and interactional approach, we further investigate this issue by analysing classroom interactions in naturalistic school science settings. Our empirical context is comprised of group-work and whole-class conversations that took place within a science project about genetics involving lower secondary school students and their teacher. The following research questions guide our analyses:

- How are everyday experiences invoked by students, addressed and responded to by collaborating peers in group work settings?
- In what ways does the teacher contribute to developing and refining students' everyday experiences and undertakings during group work in whole-class conversations?

Research design

Participants and educational setting

The analysed data were produced during a science project about genetics. The participants consisted of one class comprising 38 lower secondary school students (aged 15–16 years), with an even distribution of boys and girls, along with their science teacher. The public school in which the project took place was situated on the outskirts of Oslo, Norway, and the majority of students came from the surrounding neighbourhoods. When initiating contact with the school, we asked the principal to suggest a teacher who would be willing to participate in the research project. The designated teacher was in his late thirties and had served as a science teacher for the past 11 years. To prepare for the data collection, the research team (led by the second author) met with the teacher and assembled information about the instructional design, learning activities, instructional materials and time schedules. The teacher was not provided with any specific instructions regarding his role as a teacher in the project or information on how to facilitate classroom conversations. Thus, the teacher was not instructed to engage in responsive teaching. During the science project, the teacher was fully responsible for implementing the instructional design without interference or guidance from the observing researchers. The project consisted of several instructional units related to the theme of genetics, such as genetic material, cell division, and environment and heredity. The school project lasted 11 h and was organized through both group-work and whole-class sessions.

Data and analytical procedures

The main data material constitutes a total of 11 h of transcribed video recordings of three student groups' interactions during the group work activity and student–teacher interactions in whole-class sessions. Classroom observation notes, teacher-developed instructional materials and student products provided supplementary contextual data for the analyses of the participants' interactions (Derry et al., 2010). The three video-recorded student groups were selected with the teacher's help based on the criterion of being verbally active. According to the teacher, the students were average- to high-level achievers in science. To address the research questions and provide a fine-grained analysis of students' and teachers' meaning making, four interaction sequences were selected and analysed in detail: two sequences from group activities and two sequences from a whole-class activity facilitated by the teacher, focusing on consolidating the students' experiences from group work. The two sequences from the group work settings were selected for the purpose of illustrating what we identify as typical interactional patterns in settings where students bring in experiences, ideas or resources from their everyday lives during small group conversations without a present teacher. The two whole-class sequences enabled us to examine in detail how the teacher engaged in an event of responsive teaching that built on the students' work in groups. Furthermore, it enabled us to display and explore the opportunities that responsive instructional approaches offer when students are invited to share their experiences and ideas in consolidation-oriented whole-class settings. The two whole-class conversation sequences have been analysed for a different purpose in one of our previous articles (Furberg & Silseth, 2022). In the current article, the whole-class sequences are re-analysed according to our current focus on the relationships between group work, whole-class conversations and responsive teaching.

The applied analytical procedure is interaction analysis, which involves sequential analysis of talks and interactions among the participants (Hall & Stevens, 2016; Jordan & Henderson, 1995). In a sequential analysis, each utterance is analysed as part of multiple chains of utterances, in which each utterance is considered in relation to previous and future utterances in the ongoing conversation (Linell, 2009). Attending to details in interactional exchanges between and among the students and their teacher enables us to provide a fine-grained analysis of how the participants co-construct meanings and their activities, as well as what kinds of resources they mobilise in these efforts (Enyedy & Stevens, 2014). See the Appendix for transcript conventions. The conversations were originally in Norwegian, and the excerpts were translated into English by the authors.

Results

When reviewing the video data, we found that student resources were invoked in both group-work and whole-class settings. However, after comparing the interactions in both settings, it became clear that the everyday experiences were met and responded to differently. During group work, the students introduced experiences from their own lives or examples from everyday practices when working on different tasks related to the overall topic of genetics. Our analyses also show that these everyday experiences were seldom picked up and pursued in group conversations as resources for engaging with science matters. During whole-class conversations facilitated by the teacher, students' everyday experiences were invoked by both the students and the teacher. Our analyses also found that the everyday experiences were more often realised as resources for engaging with science matters, especially in situations where the teacher assumed a responsive approach in the sense of foregrounding the attention to students' ideas and pursuing the substance of these resources in the ongoing conversations. In the following subsections, we present and analyse four sequences that emerged during the school project. Sequences 1 and 2 were selected from the different groups' interactions while performing group tasks. Sequences 3a and 3b were selected from a consolidating whole-class conversation, together with their teacher, where the student groups presented their results from a group assignment. Our analysis has a twofold overall aim. First, we intend to display and explore how student's experiences and assumptions become resources in their discussions about science during group work. Second, we aim to display and explore how the teacher enacted a responsive approach in a consolidating whole-class conversation by being sensitive to the resources that the students brought in during group work. Analysing these sequences enables us to investigate the relationship between the group work and the whole-class activities and what kinds of resources are activated by the teacher to accomplish the connections between these activities and support student learning about genetics.

Sequence 1: Exploring trait heritability through group work

Sequence 1 is derived from an activity in which the groups enquired into the topic of trait heritability. The group members were seated around a table with their notebooks, a copy of two pages from another textbook, an iPad and a mobile phone that one of the students brought to the table. The students were asked to make a Punnett square diagram in order

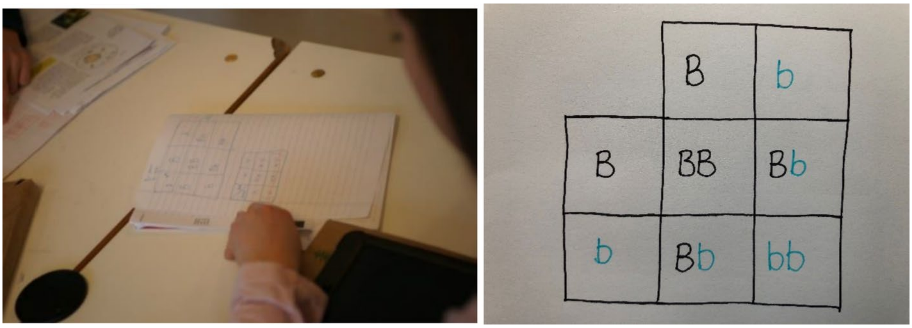

Fig. 1 Left: Students making a Punnett square diagram. Right: Representation of the students' Punnet diagram showing the probability of eye colour.

Anne: Hereditary characteristics (.) genes can influence (.) gender
related heredity (.) Linus (.) you're not red green
colourblind (.) you see like?
Linus: Yeah (.) I see it [colours]
Anne: But you were colour blind before?
Linus: Well (.) my parents meant that I was when I was younger
Anne: ((*looking at the eye colour Punnet diagram*)) Gender
Linus: It's fifty-fifty there
Anne: No
Linus: How can it not be?
Anne: Because that results in brown ((*points at the BB-square in the*
Punnet diagram)) (.) that results in in brown ((*points at*
the Bb-square)) (.) that results in brown ((*points at the second*
Bb-square)) and that results in blue ((*points at the bb-square*))
(.) it is only when two small ((*refers to two small b's*)) that
it results in blue
Linus: Okay
((*the group continues to work on the task*))

Fig. 2 Exploring trait heritability through group work

to calculate the probability of offspring's eye colour in a situation in which one parent has blue eyes and another has brown eyes. Scientifically, the task addressed the principle that two heterozygote brown-eyed parents statistically have a 25% chance of conceiving a child with blue eyes. In the diagram, the dominant brown allele was signified as "B," whereas the recessive blue allele was signified as "b" (See Fig. 1, right).

We zoom in on the activity just when Anne, one of the students, has finished drawing their eye colour diagram (see Fig. 1 Left). She suddenly turns to Linus and asks him about his *colour blindness* (Fig. 2).

In a discussion prior to the previous group work, Linus shared that he had suffered from colour blindness when he was younger. In the beginning of Sequence 1, Anne attunes the other group members to the process of how genes can influence human characteristics (line 1). Then, by referring back to Linus' previous account of colour blindness, Anne asks him if he struggles with differing red and green (line 2). In his response, Linus confirms that he can but does not elaborate. Anne holds on to the issue and asks Linus if he was colourblind earlier in his life (line 5). As such, Anne makes visible her interest in colour blindness as a phenomenon and whether such human characteristics can change during a person's life trajectory. Linus does not have a simple answer to this enquiry but explains that his parents have told him that they suspected he was colour blind as a young boy. In line 7, we see that Anne orients their visual attention and conversation back at the eye colour Punnet diagram. By this, the students leave the issue of colour blindness as a genetic predisposition and Linus' personal experience behind. In line 8, Linus suggests that there is a fifty-fifty chance that the child will have blue eyes. Anne corrects him, and by using the diagram as a visual resource, she promptly goes through the four squares, concluding that Linus' suggestion is wrong but without providing an explanation or elaboration (lines 11–16). In line 17, Linus signals that he agrees with her conclusion, but he does not encourage Anne to provide an elaborated account, and the group continues with the task.

Our analysis of Sequence 1 reveals that one of the students invoked another's student personal experiences regarding the condition of being colour blind. Here, the student invoked some experiences that Linus has shared prior to this event, related to the possibility that human characteristics can change during an individual's lifetime. However, even though this personal story could be a vibrant resource for engaging with the complexities of human characteristics, it was not picked up and further explored, and the student group returned to the task in a more cumulative manner. In addition, the analysis shows that the students performed the task quickly and when disagreements or diverging suggestions were expressed, they were not subject to elaboration or discussion. In the next section, we analyse a sequence where, to some extent, the group members verbalise contrasting perspectives and where a real-world example is invoked by one group member. We also see the potential that lies in such experiences in the context of science education but is not realised as resources for reasoning about science matters.

Sequence 2: Exploring human traits through group work

Sequence 2 is derived from an activity where the groups were to classify a variety of human traits (e.g., eye colour, musicality and religious affiliation) according to the following categories *only heredity-dependent*, *only environment-dependent* or *heredity- and environment-dependent*. In the group work activity, the student groups were provided with a paper handout in which they were to draw lines between a set of human traits and the three category containers (see Fig. 3).

This sequence is from another group that, to some extent, verbalised the members' disagreements and contrasting perspectives. In their efforts to solve the assignments, one of the group members attempted to invoke a real-world example as a reasoning resource for the group. Here, we zoom in on the activity when the group has arrived at the human characteristic *agility* (Fig. 4).

When Hans concludes that agility should be categorised as being dependent on heredity and environment (line 2), Paul promptly agrees (line 3). Both Sven's and Bert's accounts (lines 4 and 5, respectively) might be interpreted as tokens of their uncertainty about whether agility is determined by both heredity and environment. Hans responds with an argument for why agility can be determined by the environment by stating, "Maybe they all like to jump all the time, right?" – implying that frequent jumping practice will cause highly developed agility (line 6). Bert picks up on Hans's argument, concluding that agility is a matter of training. His suggestive tone indicates that he wants others' feedback on his reasoning (line 7). Paul responds by confirming Hans' training suggestion, concluding that agility should then be categorised as determined by environment (line 8). Hence, Paul

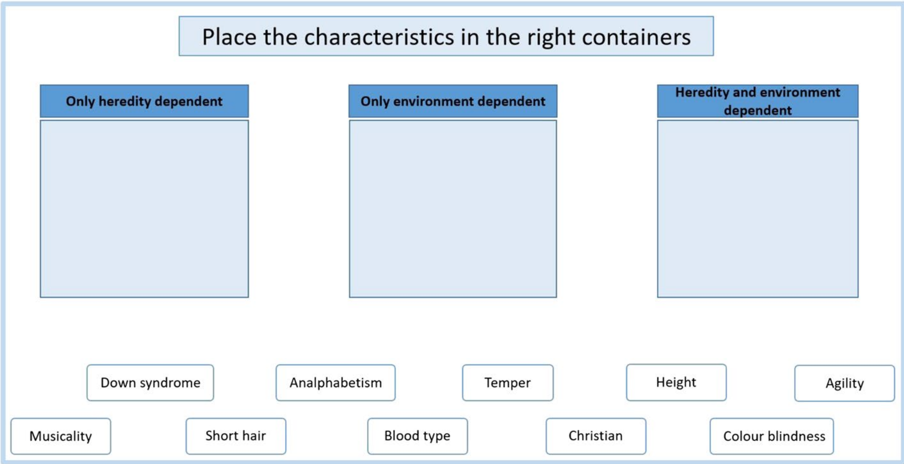

Fig. 3 A reproduced and translated version of the handout used in the group activity and the whole-class activity

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Paul:  Agility that is (.)
Hans:  Heredity and environment
Paul:  I think heredity and environment
Sven:  U::hm?
Bert:  Agility?
Hans:  Yeah but maybe they all like to jump all the time right?
Bert:  That's (.) oh:: (.) so only training then?
Paul:  Yeah (.) no (.) it's environment (.) environment (.) yes
Hans:  Environment (.) and heredity
Sven:  It's something to (.) u::hm: (.) it's something to do
       with u::hm
Bert:  Yeah (.) it can have something to do with bone structure
Hans:  Yes
Paul:  Bone structure?
Bert:  Physique
Paul:  Yes okay
Sven:  Yes (.) then it's heredity and environment
Paul:  Yes (.) But if
Sven:  YES (.) then we should put
Paul:  LISTEN
Sven:  A line here ((draws a line from "agility" to the
       "heredity and environment" container))
Paul:  If I'd been an u:hm athlete
Sven:  Like you're not ((laughs))
Paul:  Then my children would've become like (.) athletes
Sven:  Not necessarily
Hans:  Not necessarily
Paul:  Yeah but (.) in some cases
Sven:  In some cases
Paul:  If I'd succeeded I'll bet that they would've started with it
Hans:  Height (.) is heredity right? ((points at the handout)) We
       all agree on that one? ((looks at the others))
All:   Yes ((Hans draws a line from height to the heredity box,
       and the group moves on to the next trait))
```

Fig. 4 Exploring human traits through group work abandons his previous suggestion that agility is determined by heredity and environment, as expressed in line 3. It turns out that the rest of the group members disagree with Paul's position on environment. Hans contributes by emphasising that agility is determined by environment *and* heredity (line 9). Bert confirms this and argues for the heredity factor by pointing to the connection between agility and bone structure (line 12). Hans immediately confirms Bert's suggestion, but Paul prompts Bert to elaborate (line 14). Bert reformulates his suggestion by using the term "physique" (line 15), and Paul seemingly confirms this. Sven then concludes and draws a line from the *agility* trait to the *heredity and environment* category (lines 17, 19 and 21–22). While Sven draws the line, Paul interjects, explicitly asking for the others' attention (line 20). Clearly, he is not yet ready to leave his position on environment behind, and he wants the others to hear him out. Paul then provides a real-world example as a resource for sharing his reasoning with the group. He argues that if he had been an athlete, his children would become athletes as well (lines 23 and 25). With a humourous tone, the other group members start to tease Paul by emphasising that he is not an athlete and then adding that they do not entirely agree with his reasoning. Paul keeps pushing his argument by emphasising "yeah, but in *some* cases" (line 28) and then elaborates that if he had been a successful athlete, "I'll bet that they would've started with it" (line 30). From an analytical perspective, Paul's last utterance in line 30 can be perceived as ambiguous, and it is difficult to determine whether he actually argues in favour of an environment or an environment and heredity position. Either way, the discussion is put to a halt when Hans directs their attention to another trait on the list – height. He draws a line between height and the heredity box, and they all confirm their agreement (line 33). They then move on.

This sequence shows that, to some extent, the students verbalised their disagreements and contrasting perspectives. However, the accounts and arguments were not elaborated upon or expanded by the contributing students. Nonetheless, it is interesting that Paul invoked a real-world example in which he places himself in the role of a successful athlete. He mentions the probability that his prospective children would follow in his footsteps. However, as revealed by the analysis, this potential reasoning resource and its embedded argument were stalled when one of the students directed their attention to the next trait. Hence, the group members managed to provide some perspectives and resources that could be used to reason about how the trait of agility can be categorised, but these were not picked up and pursued in their further discussion.

Sequence 3: Reasoning about human characteristics in a whole-class setting

In this part of our analysis, we shift our focus from group work to a whole-class session in which the teacher facilitates a consolidating activity. Sequences 3a and 3b show how students' everyday experiences can be realised as resources for engaging with science matters when teachers assume a responsive approach by foregrounding the attention to students' ideas and pursuing the substance of these resources in the ongoing conversations.

In the following sequence, the teacher used a digital drag-and-drop resource on the interactive whiteboard, similar to the design of the paper handout from the group work setting. The teacher appointed one student from each group to come up to the whiteboard and place the traits (e.g., musicality, religion, eye colour, short hair) into three containers labelled *only determined by heredity*, *only determined by environment* and *determined by heredity and environment*. Then he asked the rest of the group members whether they agreed or have come to a different conclusion. In cases of differences, he asks the students to provide an account of their decisions. In the sequence that we examine, Trond has been invited by the teacher to share his group's work. Trond picks the trait *short hair* and drags the label into the *only determined by environment* container. We enter this conversation as Trond is about to justify his group's categorisation choice (Fig. 5a).

Trond places the trait *short hair* in the *only determined by environment* container and provides an argument for the group's decision. He argues that the length of people's hair is determined by their desire to fit in (lines 2–4). The teacher's response can be read as supporting the group's decision. In his response, he rhetorically asks the students whether they know of "*one*" female student with short hair, and when some students confirm that there are some, he replies, "There aren't many" (lines 5–6 and 8). Another student, Nina, sees the opportunity to report that her group has reached a different conclusion. Before giving the floor to Nina's group, the teacher revoices the first group's ideas about people's desire to fit in and explains that this argument is about how people are influenced by their surroundings and particular social norms (lines 15–17). Then, Nina advocates the heredity position by arguing that short hair or hair loss can be caused by certain genes (lines 19–20 and 22). In his response, the teacher acknowledges the second group's ideas, and once more, he backs a student's account by referring to another student, Ann, in an earlier session on the same day, explaining that her hair does not grow very long, even if she lets it grow (lines 31–35).

a

Trond: Short hair is determined by the environment because::: (.)
you can imagine that if all (.) in a place (.) have short
hair (.) 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*))
(.) 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 among the students and the teacher*))
Nina: We don't agree.
Teacher: You don't agree with this?
Frode: No:::
Teacher: No (.) u:hm (.) I guess that many of you have put it where
Trond's group has put it (.) right that it is more like
that's environment u::hm (.) right (.) norms right that we
are influenced by our surroundings u::hm (.) et cetera (.)
norms for how our looks should be and stuff (.) Nina you
didn't agree
Nina: U::hm no because it might be that you have those genes (.)
that causes your hair not to grow
Teacher: Yes
Nina: So you might have short hair
Teacher: ((walks among the students)) Some of you start to get rather
long hair (.) I saw some girls earlier Sol doesn't have that
super long (.) Heidi starts to::: (.) Ella you have long
hair
Ella: Yes
Teacher: Do you have the longest hair in the class?
Ella: I don't know
Teacher: Like (.) Maren and Frida and Ina they have started to get
really long hair (.) but Anne in the other class (.) she
said that she (.) she doesn't get that long hair (.) even
if she lets it grow (.) so maybe that applies to some of you
also that don't get that super long hair (.) but here we
talk about short hair by all means

Fig. 5 Reasoning about human characteristics in a whole-class setting

b

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 (.) he doesn't do that on purpose (.) then he wouldn't have used a lot of money on implants (.) 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 (.) yes perhaps the age i:::s involved here uh::m
Frode: He is twenty-six: uhm: twenty-seven or something (.) don't know (.) something like that (.) he has never had much hair on his head (.) never
Teacher: Twenty-six yes he's not older
Teacher: No (.) it's an interesting u::hm case that one (.) this is not as clear as we perhaps might think (.) 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 (.) but others (.) grow their hair but it gets very worn (.) so it doesn't get much longer
Teacher: Yes
Elsa: It has to do with heredity too
Teacher: So if we think (.) if we nuance a little bit how long the hair gets (.) then a heredity factor is present (.) but if we just think short hair like:: Truls or Erik right (.) then (.) we agree that (.) we are where (.) Trond is ((*points to the category "only determined by environment" on the whiteboard*))

Fig. 5 (continued)

Thus, in Sequence 3a, the teacher acknowledges and builds on the students' ideas and ways of doing the assignment in the group work, but refrains from choosing sides regarding the categorisation of the characteristic. Through this responsive approach, the teacher creates a social space in which the introduction of student ideas and understandings from group work are welcomed and built on in the ongoing co-construction of knowledge about nature versus nurture.

In Sequence 3b, we re-enter the conversation as the teacher invites Frode, a member of Nina's group, to share something he overheard during the preceding group work activity (Fig. 5b).

When Frode cites the example of Wayne Rooney, a soccer star with whom many of the students are familiar, several students engage in the conversation. The references to Rooney triggers Arne to contribute with the idea that hair length can be influenced by age (line 41). Tom elaborates further on Rooney, stating that Rooney uses hair implants (line 42). The implant information is picked up by Frode, who uses the information to back his group's claim that short hair can be determined by heredity (lines 48–50). After engaging with the students' Rooney example for a while, the teacher concludes that "short hair" in fact is very interesting and not as evident as one might anticipate (lines 59–61). He then invites more students to share their perspectives. Elsa brings in an example of people living in other parts of the world, arguing that the ability to grow long hair depends on the quality of the hair and is a matter of genetics (lines 62–66). However, when the teacher acknowledges her ideas and perspectives, she asserts that she is open to both the environment and the heredity position (line 68). The teacher concludes the whole-class episode by summing up what they have discussed by acknowledging both positions and the complexity that this topic entails. Once more, he contextualises the issue by explicitly referring to the hair characteristics of the students present in the whole-class setting (lines 69–74).

We now highlight some important aspects of the teacher's enactment of a responsive teaching approach in this whole-class conversation. The first aspect concerns the teacher's foregrounding of student resources—in this case, a reference to a famous soccer player's hair implant, initially introduced by a student during the group work session. The teacher himself introduced resources familiar to the students, mentioning that few female students in school have short hair and referring to a previous discussion in the parallel class where a female student admitted her inability to grow her hair long even if she tried. Second, by inviting and encouraging the students to share their everyday experiences, as well as by providing some experiences himself, the teacher signalled his acknowledgement of the student resources as a valid basis for problematising the nature versus nurture position. Thus, viewed in light of responsive teaching, the teacher recognised the disciplinary connection between the student resources and the conceptual issues in focus as well as pursued the substance of the students' experiences and ideas in the ongoing instructional work. On this basis, what can we say about the participants' interactional achievements in this session, in which the student resources constitute an interactional centre?

First, by inviting the students to share resources initially introduced during the group work sessions, the teacher *made the resources available to the whole class* as relevant resources to build arguments and discuss the disciplinary topic. These resources were then picked up by the students in the consolidating activity and become shared reasoning resources for inquiring about and discussing the complex relationship between nature and nurture. Second, by prompting the students to respond to one another's ideas and positions, the teacher created an educational dialogue in which students' contributions become acknowledged resources for voicing *contrasting perspectives* on the topic of nature versus nurture. Third, by pursuing the groups' ideas about what determines hair length through pointing to members of the different groups as examples of human characteristics and students' knowledge about soccer celebrities, the teacher *contributes to the students' willingness to participate in the disciplinary science conversation* that builds on the group work. Finally, and most importantly, the analyses show that the teacher does not explicitly favour a specific conceptual standpoint and that he uses open-ended questions. He also refrains from providing the correct answer and validating the students' arguments; instead, he prompts them to respond to one another's input. Through his responsive approach, the teacher contributed to positioning students as accountable and authoritative contributors in the whole-class conversation.

In sum, the analyses show that through his responsive moves, the teacher creates connections between group work activities and whole-class conversation. The students share and appropriate resources from prior learning events and engage in discussions characterised by verbalising disagreements and contrasting perspectives, where the accounts and arguments are elaborated or expanded by the contributing students. Stated differently, the teacher's responsive approach contributes to creating a consolidating whole-class conversation where the students' ideas, experiences and sensemaking that emerged earlier during the group assignment become resources that position the students as accountable and authoritative contributors in the whole-class conversation.

Discussion

As found in the literature review, previous research has provided important and valuable knowledge about the opportunities and challenges of group work and whole-class conversations. Nevertheless, there is a need for more knowledge about the complex relations between activities in these settings (Frøytlog & Rasmussen, 2020; Galton et al., 2009; Howe & Abedin, 2013; O'Connor et al., 2017), as well as how teachers can facilitate consolidating whole-class activities where connections to group work activities are realised in ways that support student learning (Howe & Mercer, 2017; Webb, 2009). By taking a sociocultural and interactional approach, we aim to provide deeper insights into how teachers can facilitate consolidating whole-class activities, whose purpose is to build on and refine student discussions during group work through responsive teaching practices. We now discuss some of our analytical points in relation to theory and prior research on group work and whole-class settings.

A sociocultural and interactional approach to meaning making and learning enables us to investigate in detail how students participate in group work in a science unit about genetics. Here, we unpack some of the challenges that students might face when collaboratively engaging in science learning in group work. These findings not only resonate with those of prior research (Barron, 2003; Berland & Reiser, 2011; Sohr et al., 2018) but also extend our current understanding of challenges in group work. Our analyses of peer interaction during group work activities show that the observed groups often take a task-oriented approach when doing the assignment. This might be interpreted as the groups focusing on procedural aspects of the assignment (Furberg & Arnseth, 2009; Mercer & Littleton, 2007) and refraining from engaging in conceptual aspects of this work. Willingness to engage in science discourse is an important aspect of learning school science (Brown, 2005). In Sequence 2, we observe how one of the student groups, to some extent, demonstrates contrasting perspectives and positions when engaging in discussions about different human characteristics. Thus, to a certain degree, students were willing to engage in science discourse. However, the group members did not elaborate on one another's accounts and were unwilling to require explanations or arguments.

One of our positioning arguments in this article is that the activation of resources from students' everyday lives can become powerful tools for engaging in science learning (Hammer, 2000; Rosebery et al., 2010; Varelas et al., 2008). Our analyses of the interactions during group work and whole-class conversations indicate that student resources were activated in both settings. Starting with the group work setting, our analysis of Sequence 2 reveals that a real-world example is activated by a student in an attempt to build an argument for a particular position and to provide the group with a relevant resource to reason with. However, our analysis also shows that the group did not realise the example as a potential resource to reason about science matters. The act of realising these types of examples as resources to reason with is a collaborative effort. Even if such resources embed the affordances of becoming valuable tools to reason with, we might assume that students sometimes need guidance when making sense of and appropriating these resources in shared conceptual sensemaking.

How, then, can responsive teaching contribute to further developing and refining students' experiences and undertakings during prior group work when later discussed in whole-class conversations? Research within the sociocultural tradition has emphasised the importance of facilitating learning spaces where students' contributions are recognised, participants listen to one another and teachers and students build on each other's perspectives, enabling students to elaborate and expand their views and propositions (Bakker et al., 2015; Enyedy et al., 2008; Silseth & Arnseth, 2022). However, prior research on whole-class conversations shows that some students find it socially, cognitively and emotionally challenging to participate in consolidating whole-class conversations (Sedlacek & Sedova, 2017; Sedova & Navratilova, 2020) and that students are not necessarily given equal opportunities to contribute (Lehesvuori et al., 2013; Lemke, 1990). In our context, this means that a teacher might face challenges on at least two levels: engaging students in whole-class conversations and creating connections between students' group work and whole-class activities.

One of the central assumptions regarding responsive teaching approaches is that being sensitive to and appropriating the resources that students bring into science conversations can potentially make student's agents of their own learning (Robertson et al., 2016). For this to occur, teachers need to foreground students' experiences and ideas, orienting the students to their disciplinary connections as well as pursuing the underlying assumptions in students' ideas in the instructional efforts (Hammer et al., 2012). Our analyses of Sequences 3a and 3b show that by orienting to and foregrounding students' ideas and experiences from both the group work and their everyday lives, the teacher contributed to transforming these into shared reasoning resources for engaging with the disciplinary topic of nature versus nurture. This contributes to creating a learning situation where students gain access to multiple resources to reason within the ongoing co-construction of knowledge and engagement. Our analyses also reveal that by paying attention to and pursuing the different ideas about what determines hair length, which had emerged earlier during the group work, the teacher manages to create a learning situation in which students are willing to both share their reasoning from the group work and engage in discussions about nature versus nurture based on these ideas and perspectives.

Scholars within the sociocultural tradition have accentuated the importance of creating dialogic classroom settings where multiple perspectives and the free interchange of multiple voices are made possible (Bakker et al., 2015; Enyedy et al., 2008). More specifically, researchers have argued for the importance of creating dialogic learning settings in which students are positioned as authoritative and accountable participants and allowed authorship in the co-construction of knowledge (Engle & Conant, 2002; Furberg, 2016; Greeno, 2006a; Kumpulainen & Rajala, 2017). Our analyses of Sequence 3a and 3b demonstrate that by prompting the students to respond to one another's ideas and positions emerging from the group work, the teacher manages to establish an educational dialogue where students' contributions become resources for expressing contrasting perspectives on the disciplinary topic of nature versus nurture. We have found that the teacher's responsive teaching approach creates an educational setting that promotes students' use of their experiences, ideas and assumptions from their everyday lives and group work. They are willing to test their conceptual understandings, participate actively in answering difficult questions and reason about the disciplinary topic of nature versus nurture. This ultimately leads to positioning students as authoritative and accountable learners who become agents in their own and one another's learning.

Implications for instruction

The current study provides knowledge that can be useful for teachers and teacher educators in designing productive learning activities that combine group work and whole-class activities. Concerning the facilitation of group work activities, our study demonstrates the importance of formulating *assignments* that explicitly prompt students to retrieve, activate and link resources from a variety of sources – both authorised learning resources and experiences from their everyday lives. Advising students to activate resources from their everyday lives can seem trivial. However, students might need to hear that the teacher explicitly values and acknowledges their own or their peers' everyday experiences in formal school settings in order to recognise the relevance of such resources.

Shifting the focus to whole-class settings, what are the potential implications for teachers' facilitation of whole-class conversations aimed at developing, refining and sharing students' experiences and undertakings during prior group work? Our study highlights the importance of *teachers actively mobilising students' everyday experience*s and *providing conversational opportunities for students to invoke their everyday ideas and understandings*. Such strategies might contribute to enabling students to work on and explore possible connections between their everyday ideas and their understanding of science and more canonical versions of it. Furthermore, our empirical findings emphasise the significance of *designing consolidating whole-class dialogues that explicitly invite multiple students to initiate and share their concerns, interests and inquiries*. This might lead to learning situations in which students become willing to engage in science discussions and discourses, as well as share ideas and insights from group work that contribute to building a community of learners with a shared interest in reasoning together.

We believe that enacting practices of responsive teaching – being attuned and sensitive to the experiences, ideas and assumptions about science matters that students bring to school – will eventually provide a valuable foundation for sharing, building on and refining student group work conversations in consolidation-oriented whole-class settings.

Appendix: Transcription Conventions

Sign	Explanation
(.)	Pause during speech.
<u>word</u>	Underlining indicates emphasis on words and expressions.
:::	Colons indicate the lengthening of a word or a sound.
°word°	Indicates that the word or the sound is softer than the surrounding talk.
((looks up))	A sentence that is enclosed in double parentheses describes actions.

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Declarations

Conflict of interest There is no conflict of interest.

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Current themes of research:

Well situated in the sociocultural tradition, Silseth and Furberg have in their research focused on meaning making, learning and teaching as interactional phenomenon's, and have recently published articles about a wide range of topics relevant for the field of Psychology of Education, such as science education, technology-enhanced learning and instruction, game-based learning, student resources, assessment practices, teachers digital competences and learning identity.

Most relevant publications:

Furberg, A. (2016). Teacher support in computer-supported lab work: bridging the gap between lab experiments and students' conceptual understanding. *International Journal of Computer-supported Collaborative Learning*, 11, 89–113.
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