



Teachers' Coordination of Dialogic and Authoritative Discourses Promoting Specific Goals in Socioscientific Issue-Based Teaching

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Abstract

The integration of socioscientific issues (SSI) into science teaching requires that teachers manage classroom discussions in which various perspectives are considered and students' contributions are recognized. The present study aimed to provide knowledge of how classroom discussions on SSI can be structured and implemented to pursue specific teaching purposes. In this study, two secondary science teachers' employment of *communicative approaches* during four discussions on SSI was analysed. In the studied context, communicative approaches can be described as involving various or only a single perspective on SSI and as being either interactive or non-interactive. The results elucidate how teachers can make purposeful use of different communicative approaches to facilitate students' decision-making while promoting complexity in their reasoning. The results also show how teachers can promote *cumulativity*, in terms of their recognition of students' contributions to discussions. It is proposed that teachers can use the concept of communicative approaches as an analytical tool to reflect on and develop aspects of teaching practice in relation to the goals that they wish to achieve.

Keywords Classroom discussions · Secondary science teachers · Socioscientific issues · Teacher-student interactions

Introduction

An aim of science education is for students to develop scientific literacy that includes knowledge and skills vital to decision-making on socioscientific issues (SSI), that is,

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issues that involve a science dimension and raise a range of societal, political, economic, and ethical considerations (Ratcliffe & Grace, 2003). Research indicates that SSI-based teaching, in which SSI are used as contexts for teaching and learning, can promote knowledge integral to the development of informed perspectives on SSI (Rudsberg, Öhman, & Östman, 2013; Zeidler, Sadler, Applebaum, & Callahan, 2009). SSI-based teaching typically involves the consideration of tentative scientific knowledge, conflicting values and various interests (Nielsen, 2013; Oulton, Dillon, & Grace, 2004; Sadler, Barab, & Scott, 2007). An emphasis often is placed on discourse-based activities in which students' contributions are valued because such activities provide opportunities for students to consider diverse perspectives on SSI to develop reasoning skills (Chung, Yoo, Kim, Lee, & Zeidler, 2016; Ratcliffe & Grace, 2003). Thus, SSI-based teaching requires that teachers be skilled in managing open-ended discussions in which various perspectives, alongside scientific knowledge, are considered, and students' contributions are recognized. At the same time, this is recognized as a complex task. Research indicates that science teachers tend to focus on disciplinary content (Hofstein, Eilks, & Bybee, 2011; Sadler, Amirshokoohi, Kazempour, & Allspaw, 2006; Tidemand & Nielsen, 2017), thereby leaving little space for students' perspectives in the classroom discourse (Lyons, 2006; Osborne, Duschl, & Fairbrother, 2002). It also has been reported that teachers often lack skills or feel ill-prepared to moderate discussions on contentious issues (Bryce & Gray, 2004; Lee, Abd-El-Khalick, & Choi, 2006; Oulton, Day, Dillon, & Grace, 2004). This may prevent teachers from implementing discussions on SSI in their teaching.

A few studies involve detailed investigations of teachers' discursive practices in SSI-based teaching. Dawson and Venville (2010) investigated teaching strategies to promote students' argumentation skills in the context of a decision-making task on an SSI entailing genetics. The teacher's facilitation of students' argumentation was described by means of codes related to, for example, how the teacher defines an argument, values different positions, checks evidence and prompts justification. The results indicate that the teacher's facilitation promoted the quality of argumentation and students' consideration of different opinions. Mork (2012) analysed a science teacher's interventions in a role-playing debate about wolves. She presented descriptions of different types of teacher interventions and the characteristics of the debate causing the interventions. The interventions concerned, for example, ensuring accuracy with respect to content, extending the topic range and involving as many students as possible in the debate. Puig and Jiménez-Aleixandre (2011) examined two teachers' instructional practices during lessons devoted to explanations of genetics concepts in the context of an SSI entailing biological determinism. They suggest that the character of teacher-student interactions is significant for the pursuit of SSI-based teaching aims. Instructional practices, in which the teacher takes account of students' ideas, have the potential to encourage students to participate in classroom discourse and express their thinking. Furthermore, they suggest that teacher-student interactions in which various perspectives are addressed support students' understanding of the complexity of SSI.

These studies provide valuable descriptions of teaching practices that can promote the consideration of different perspectives and invite students' ideas. However, a need exists to explore further how teacher-student interactions can play out throughout lessons involving open-ended discussions on SSI so that different perspectives, including scientific knowledge, are introduced and considered. Moreover, a need also exists

to gain a deeper understanding of ways in which students' contributions can be recognized in this context. The present study aims to explore further how teachers' discursive practices can facilitate students' decision-making on SSI, as well as recognize students' contributions in open-ended discussions. The purpose is to provide knowledge of how classroom discussions on SSI can be structured and implemented to pursue specific teaching purposes.

Background

In science education research, the structure and function of teacher-student discourse have been analysed by employing a range of frameworks and methods. An increasing number of studies has focussed on how different perspectives are taken into account in the science classroom. These studies have characterized teacher-student interactions along a continuum between dialogic and authoritative by drawing on concepts from *dialogism* (Bakhtin, 1935). The present study follows this line of research, which will be outlined further below.

Dialogic and Authoritative Classroom Discourse

From the perspective of dialogism, any discourse intrinsically is dialogic in nature because each utterance in some way responds to past utterances and anticipates potential responses (Wertsch, 1991), and because any discourse is structured by the interaction among participants' diverse perspectives (Nystrand, 1997). However, discourses differ in "their openness to counter positions" (Wells, 2007, p. 255). Bakhtin (1935) distinguished between *authoritative* discourse, which demands acceptance and in which meaning is not negotiable, and *internally persuasive* discourse, in which meaning is negotiable (Wells, 2007; Wertsch, 1991) implying that the discourse is open to alternative perspectives and interpretations.

With respect to classroom discourse, scholars from diverse fields of education have translated the distinction described above to make definitions useful for empirical investigations of classroom discourse. Classroom discourse in which a range of ideas, including students' perspectives, is represented has been defined as *dialogic* (Mortimer & Scott, 2003; Nystrand, 1997) or *ideologically dialogic* (O'Connor & Michaels, 2007). In contrast, classroom discourse in which attention is paid to a specific perspective and ready-made knowledge is conveyed has been defined as *authoritative* (Mortimer & Scott, 2003), *monologic* (Nystrand, 1997) or *ideologically monologic* (O'Connor & Michaels, 2007).

Features of authoritative and dialogic classroom discourses have been described based on the definitions presented above and on results from classroom studies. Authoritative discourse typically is characterized by dominance of "test questions" (Nystrand, 1997), that is, questions to which the teacher already knows the answers. Moreover, authoritative discourse typically includes explicit teacher evaluation of students' contributions (Nystrand, 1997; Scott, Mortimer, & Aguiar, 2006) and often is played out through a teacher initiation-student response-teacher evaluation (IRE) pattern (Mortimer & Scott, 2003). In this way, the teacher maintains tight control over the classroom discourse while being positioned as the primary source of knowledge. In contrast, dialogic discourse is

characterized by teachers' use of "genuine" (Scott et al., 2006) questions, that is, questions that aim to elicit students' thinking, and by absence of direct teacher evaluation (Almahrouqi & Scott, 2012; Mortimer & Scott, 2003; Scott & Ametller, 2007; Scott et al., 2006). Instead, teachers often use students' contributions by incorporating their responses into subsequent questions, a process referred to as *uptake*, or by elaborating on new perspectives brought forth by students (Nystrand, 1997). In this way, students are positioned as significant contributors to classroom discourse.

However, classroom discourse cannot be characterized as dialogic or authoritative based on analyses of single utterances, such as the teacher's questions or evaluations. For example, a test question may initiate a dialogic exploration of students' understanding, as demonstrated by O'Connor and Michaels (2007). As illustrated above, the features of authoritative and dialogic classroom discourse are tied closely to expectations of and opportunities for students to contribute to and influence the content and direction of discourse. Therefore, it has been argued that the ultimate characteristic of dialogic teaching is that students are positioned as thinkers and significant contributors to classroom discourse (Nystrand, 1997; O'Connor & Michaels, 2007; Wells, 2007). Alexander (2008) describes such classroom practices as *cumulative*, which means that the participants build on each other's contributions. Thus, dialogic teaching requires that teachers recognize and make meaningful use of students' contributions.

Interplay Between Dialogic and Authoritative Discourses in Science Teaching

Empirical investigations suggest that efficient teaching implies alternating between dialogic and authoritative classroom discourses to align with different teaching purposes (Mortimer, 1998; Mortimer & Scott, 2003; Nystrand, 1997; Scott & Ametller, 2007; Scott et al., 2006). Thus, teachers need to consider the character of classroom discourse in relation to the educational goals that they wish to achieve. Regarding the teaching of scientific concepts, Mortimer and Scott (2003) have demonstrated that dialogic discourse fits with the purpose of engaging students with the content and exploring students' everyday ideas about a concept. There is evidence to support that dialogic discourse characterized by "genuine" (Scott et al., 2006) questions and a lack of explicit teacher evaluation can lead to students' sharing ideas and elaborating on their thinking in the science classroom (Almahrouqi & Scott, 2012; Chin, 2006; van Zee, Iwasyk, Kurose, Simpson, & Wild, 2001). In contrast, authoritative discourse fits with the purpose of introducing and focussing on the "scientific story" (Mortimer & Scott, 2003, p. 18), for example, the scientific meaning of concepts. In this context, the classroom discourse is characterized by a "pressure towards univocality" (Mortimer, 1998, p. 79), because teaching's overall aim is to establish a shared understanding of the authoritative discourse of science. Accordingly, dialogic discourse mainly implies openness to and exploration of students' prior understandings and experiences with scientific phenomena under consideration, that is, a "dialogue between scientific and everyday discourses" (Mortimer, 1998, p. 80). Classroom studies reported by Mortimer and Scott (2003) and Scott and Ametller (2007) demonstrate that effective classroom discourse often follows a rhythm. The classroom discourse initially can be described as dialogic, as the teacher explores students' ideas about the content. The discourse then shifts towards an authoritative mode as the teacher works on aspects of the content "through shaping, selecting and marking ideas" (Mortimer & Scott, 2003, p. 69) and

finally summarizes key points and reviews progress. In other words, dialogic discourse calls for subsequent authoritative discourse in which the teacher intervenes to clarify the scientific perspective (Scott & Ametller, 2007).

SSI-based teaching differs in important ways from teaching authoritative science content. SSI are unsettled because they often are subject to ongoing investigations, and the scientific evidence is sometimes incomplete, contradictory or open to multiple interpretations. Consequently, teachers are likely to receive questions that they cannot answer, which is why “teachers have to position themselves as /.../ knowledge contributors on par with their students” (Sadler, 2011, p. 367). This means that teachers are not necessarily positioned as primary sources of knowledge in negotiations of SSI. Thus, it seems reasonable to suggest that SSI-based teaching can provide extensive opportunities for dialogic classroom discourse, in which students contribute their perspectives and influence discourse content and direction. Moreover, because SSI are cross-disciplinary and often involve contradictory interests, not only scientific evidence but also social, political, economic and ethical considerations might be involved in the negotiation of such issues (Nielsen, 2013; Ratcliffe & Grace, 2003; Sadler et al., 2007). Thus, it is possible to arrive at different conclusions regarding how to best deal with a certain issue. Consequently, SSI-based teaching implies opportunities for discourse that is dialogic not only with respect to the inclusion of students’ ideas but also with respect to being open to various disciplines, evidence interpretations, knowledge sources and potential solutions.

At the same time, research indicates that students need basic science content knowledge to engage with SSI (Lewis & Leach, 2006) and that content knowledge is an important prerequisite for high-quality reasoning on SSI (Sadler & Zeidler, 2005; Wu & Tsai, 2007). Thus, to facilitate students’ decision-making on SSI, the teacher must ensure that students have sufficient science-content knowledge relevant to the issue at hand. This means that authoritative classroom discourse may be needed to introduce and establish a shared understanding of science content.

Thus, both dialogic and authoritative classroom discourses seem to be relevant to facilitate students’ negotiation of SSI and provide space for students’ contributions. However, research shows that authoritative classroom discourse, in which the teacher directs discussions with an emphasis on covering science content, tends to be dominant (Kilinc, Demiral, & Kartal, 2017; Levinson, 2004; Levinson & Turner, 2001; Osborne et al., 2002; Ratcliffe & Millar, 2009). This means little space is available to consider diverse perspectives on issues and recognize students’ perspectives. Therefore, the teaching does not provide students with sufficient opportunities to develop understanding of the complexity of SSI and develop informed perspectives on issues. Thus, knowledge of how teachers can use dialogic and authoritative classroom discourse to pursue SSI-based teaching aims seems urgent.

Analytical Framework

The present study will use the definitions of *dialogic* and *authoritative* classroom discourses developed by Mortimer and Scott (2003). According to their definitions, classroom discourse is dialogic when space is allotted for a range of ideas to be represented, specifically students’ ideas about the content. As described above, SSI-based teaching implies opportunities for discourse that is dialogic, not only with respect to

the inclusion of students' ideas but also with respect to being open to various disciplines, evidence interpretations, knowledge sources and potential solutions. In dialogism, *voice* can involve many dimensions, ranging from the "speaking subject's perspective" (Wertsch, 1991, p. 51) to a "generalized perspective /.../ tied to a group of sense-makers" (Linell, 2009, p. 116). Accordingly, the concept of *voice* can encompass a variety of perspectives, both personal or tied to a group of people or a discipline, that are represented by the teacher's and students' contributions to classroom discourse in SSI-based teaching. Thus, the following distinction can be made between dialogic and authoritative classroom discourses: In *dialogic discourse*, various voices are represented and taken into account, while in *authoritative discourse*, different voices are not taken into account, and attention is focussed on one specific perspective. Moreover, Mortimer and Scott (2003) point out that classroom discourse can be either *interactive* (speakers taking turns) or *non-interactive* (speakers not taking turns, with one person speaking). Consequently, for purposes of the present study, four *communicative approaches* were defined (see Table 1): interactive/dialogic (I/D), non-interactive/dialogic (NI/D), interactive/authoritative (I/A) and non-interactive/authoritative (NI/A).

However, empirical investigations have shown that segments of classroom discourse typically display both dialogic and authoritative characteristics (Al-Mahrouqi, 2010; Mortimer, 1998; Tytler & Aranda, 2015). To enable more subtle descriptions, the discourse's *voicedness* and *coerciveness* (Linell, 2009) can be considered. Voicedness concerns whether the discourse is *multi-voiced*, in the sense that several voices on a topic is taken into account, or *one-voiced*, implying that only one voice is taken into account. Coerciveness concerns whether the discourse is *dialogical*, in the sense that it is open for a wide range of understandings, or *authoritarian*, as it "tries to impose on the addressee only one possible way of understanding" (Linell, 2009, p. 168). These distinctions also were employed in the present study's analyses.

Aim and Research Questions

Teachers need to consider their communicative approach choices in relation to specific teaching purposes. This study aims to elucidate ways in which teachers can use different communicative approaches to pursue SSI-based teaching aims. Significant

Table 1 Definitions of communicative approaches employed in this study, adapted from Mortimer and Scott (2003)

	Dialogic (D)	Authoritative (A)
Interactive (I)	Interactive/dialogic (I/D) The teacher and students take turns, with various voices represented and taken into account	Interactive/authoritative (I/A) The teacher and students take turns, with various voices not taken into account and attention focussed on one perspective
Non-interactive (NI)	Non-interactive/dialogic (NI/D) The teacher and students do not take turns, with various voices represented and taken into account	Non-interactive/authoritative (NI/A) The teacher and students do not take turns, with various voices not taken into account and, attention focussed on one perspective

SSI-based teaching aims are that students develop understanding of SSI complexities and get opportunities to develop informed perspectives on issues.

Specifically, the present study's purpose is to provide knowledge that can be useful in structuring and leading classroom discussions on SSI in which multiple perspectives are considered and students' contributions are recognized. This purpose is achieved by examining two teachers' use of communicative approaches during classroom discussions on SSI.

The following research questions guide this study:

1. In what ways do teachers facilitate students' decision-making on SSI?
2. In what ways do teachers promote the recognition of students' contributions?

Method

Participants and Educational Context

The research took place at a public upper secondary school with approximately 900 students in a small Swedish city. Two science teachers and three of their classes (comprising 15- and 16-year-old students) at the Social Science Programme participated in the study. The three-year Social Science Programme prepares them for higher education, and the students specialize in social sciences. Each of the participating classes comprised 30–32 students and was heterogeneous with respect to students' genders and academic achievement levels, as measured in grades from compulsory school. The students were invited to participate in accordance with Swedish ethical guidelines for social science research (Vetenskapsrådet, 2011). Thus, the students were informed about the research's overall purpose. Their participation was voluntary, they were informed that they could withdraw from the study at any time and they were given confidentiality guarantees. Written approvals were obtained from the students and their parents. One student declined to participate, and this student's group was not recorded.

The participating teachers hold teaching degrees in natural sciences and geography (Teacher A) and natural sciences and biology (Teacher B). At the beginning of the study, they had three and 10 years of teaching experience, respectively. Their experience with SSI-based teaching was limited, but the year before the study, they participated in a university course for practising teachers on SSI in science teaching. The university course included planning and implementation of an SSI unit in which discourse-based activities were included. However, frameworks for describing classroom discourse's structure and function were not introduced during the course. The teachers' participation in the research project was voluntary and motivated by their interest in implementing SSI-based teaching.

The teachers were integrating SSI-based teaching into the course Science Studies, which is compulsory for all students in the Swedish upper secondary school who do not specialize in science or technology. It comprises about 90 h and typically is taught throughout an academic year, covering aspects of sustainable development, human sexuality and relationships, individual health and lifestyle, and biotechnology and its implications. Some of the course's aims are that the students "develop an understanding of how scientific knowledge can be used in both professional life and everyday

situations” and that they are enabled “to make personal choices and form their views” (Skolverket, 2011, p. 1). The two teachers typically dealt with the different subject areas of the course for several weeks, and an SSI was addressed in some way in conjunction with each subject area, although not in every lesson.

Data Collection

As part of a 2-year research project that focussed on various dimensions of teaching and learning in the participating teachers’ classrooms, a part of the data set comprised recordings of 20 lessons (40–60 min each) made in naturalistic classroom settings, containing discussions defined as “an opportunity for students to express their understanding and ideas to other students” (Ratcliffe & Grace, 2003, p. 67). For purposes of the present study, audio and video recordings from four lessons were selected for analysis. (Further information on the lessons is provided in Table 2.) The specific lessons were selected to provide variation in the data, in the sense that lessons from both teachers were used, and the SSI addressed during each lesson were different. Research indicates that different content requires different types of teacher interventions (Mortimer & Scott, 2003). Therefore, it was assumed that different SSI would contribute to variety in the teachers’ discursive practices, for example, because the students hold stronger personal perspectives on some issues than on others. To ensure variation, repeated discussion activities implemented by the same teacher in different classes were excluded.

In the selected lessons, the discussions can be described as open-ended. The students discussed different perspectives without needing to arrive at an agreed-upon position. Both teachers organized the discussions mainly so that the students first discussed the issues in small groups. Occasionally, the teachers intervened in the group discussions. The students then presented the results of their discussions to the class. In some instances, the presentations turned into whole-class discussions in the sense that the teacher asked for elaborations or clarifications, or the students reacted in some ways to each other’s ideas. The recordings comprise both whole-class instruction and the student groups’ concurrent discussions with occasional teacher interventions.

Data Analysis

The recordings were transcribed verbatim. The parts of the transcripts that were related to the discussions were excerpted for analysis. Thus, activities such as taking attendance or returning graded assignments were not included. The discussions’ characteristics and the data collected and analysed are presented in Table 2.

The first author analysed the excerpts using an iterative process that involved engaging with the data and extant research literature. It also involved a continuous discussion of interpretations with the second author, as well as with other science education researchers in the faculty. In total, faculty members scrutinized 10% of the excerpted transcripts and associated interpretations on five different occasions until agreement was reached on all interpretations.

Table 2 The discussions' characteristics and collected and analysed data

Lesson	Topic and purpose of the discussion	Classroom activities ^a related to the discussion
Lesson 1 40 min Teacher A	Topic: risks and benefits associated with the use of prenatal diagnosis Purpose: provide an opportunity for the students to practice reasoning and critical thinking by discussing an issue with social and ethical dimensions	(Students' individual reading); <i>teacher lecture; teacher initiation of group discussions; (group discussions without teacher facilitation); whole-class discussion facilitated by teacher.</i> In total, 27 min of data were analysed
Lesson 2 40 min Teacher A	Topic: arguments held by different stakeholders for increasing or reducing the Swedish wolf population Purpose: Introduction to a sequence of lessons in which the students first will write an essay explaining their personal positions on the issue, then collaboratively, with the whole class, write a letter to the Swedish Minister for the Environment, conveying their stance on the issue	<i>Teacher lecture; teacher initiation of group discussions; group discussions with occasional teacher facilitation; whole-class reporting of results from group discussion; teacher recapitulation of discussion.</i> In total, 56 min of data were analysed
Lesson 3 40 min Teacher B	Topic: Potential future developments in the area of gene technology Purpose: Introduction to a sequence of lessons in which the students will explore perspectives on GMO held by different interest groups	<i>Teacher lecture; teacher initiation of group discussions; (group discussions without teacher facilitation); whole-class reporting of results from group discussions; teacher initiation of group discussions; (group discussions without teacher facilitation); whole class reporting of results from group discussions.</i> In total, 25 min of data were analysed
Lesson 4 60 min Teacher B	Topic: norms and expectations regarding femininity and masculinity Purpose: Introduction to a sequence of lessons in which the students will examine norms and expectations in relation to sexuality and relationships and work in groups on topics involving dilemmas, for example, abortion or HIV-positive individuals having children	<i>Teacher initiation of group discussions; (group discussions without teacher facilitation); whole class reporting of results from group discussions; teacher initiation of group discussions; (group discussions without teacher facilitation); whole-class reporting of results from group discussions; teacher initiation of group discussions; (group discussions without teacher facilitation); whole-class discussion facilitated by teacher; teacher recapitulation of discussion.</i> In total, 27 min of data were analysed

^a The classroom activities written in italics involved the teacher, and these were analysed. Classroom activities in parentheses did not involve the teacher, so these were not analysed

The analysis was done in three steps. First, the communicative approaches (see Table 1) used by the teachers throughout each episode involving teacher talk were coded. This involved dividing episodes of teacher talk into segments based on considerations of changes in topic, the teacher's explicit introduction of a new task or teaching purpose, or shifts in interactivity. A non-interactive segment of discourse was considered as shifting to interactive if there were at least two turn-taking sequences involving the teacher and the students. Thus, a single teacher question during the course of a

lecture, for example, “Are you with me?”, that the students responded to was not considered a shift to interactive discourse. Conversely, an interactive discourse segment was viewed as shifting to non-interactive if the teacher interrupted it by introducing and elaborating on a perspective that the students did not address, but not if the teacher provided an extended explanation in response to a student’s question. Each segment then was coded initially as I/D, NI/D, I/A or NI/A.

However, as part of efforts to apply the codes to the data, interactive discourse segments were identified that could be characterized as containing both dialogic and authoritative features. Different voices in terms of the students’ views were taken into account, while the teacher’s purpose seemed to be to focus attention on one specific perspective. Here, the discourse could be considered multi-voiced, as various voices were taken into account. At the same time, it was authoritarian, as it tried to impose a specific understanding of the SSI under discussion. These segments subsequently were coded as interactive/dialogic-with-fixed-end (I/DF). Thus, five different communicative approaches were defined and employed in the analysis, as shown in Table 3.

In the second step of the analysis, the ways in which the teachers used the various communicative approaches were examined. This was done through an inductive process. Teaching purposes, as interpreted by the researchers, were noted tentatively for each communicative approach throughout the episodes. Commonalities or distinguishing features of these noted teaching purposes then were explored to identify and describe final themes (Robson, 2011).

The third step of the analysis aimed to explore how the teachers’ discursive practices promoted the recognition of the students’ contributions to the discussions. The segments of discourse that were coded as I/D were examined to identify ways in which the teachers used the students’ contributions.

Discourse excerpts that are representative of the results were translated into English and presented together with notes on the analysis in the Results section to elucidate the interpretations that the researchers made, as recommended by Miles and Huberman (1994). Digressions that were judged irrelevant for the purpose of the analysis are omitted. The following markings are used in the excerpts: An ellipsis with backslashes (/.../) indicates part of the transcript was omitted; notes between square brackets ([]) indicate clarification by the researchers; and an ellipsis (...) indicates an interruption in speech. The students were given aliases.

Results

Facilitating Students’ Decision-Making on SSI

The teachers’ use of different communicative approaches that may facilitate students’ decision-making on SSI will be presented as belonging to two major themes. In the first theme, the teachers are shown to provide content and context knowledge using authoritative communicative approaches. In the second theme, we present how they elucidated the complexity of SSI using dialogic communicative approaches. The results will be presented chronologically in order to elucidate the teaching purposes of different communicative approaches during the lessons.

Table 3 Definitions employed in this study to categorize the teachers' communicative approaches

	Dialogic (D)	Dialogic-with-fixed-end (DF)	Authoritative (A)
Interactive (I)	Interactive/dialogic (I/D) The teacher and the students take turns, with various voices represented and taken into account	Interactive/dialogic-with-fixed-end (I/DF) The teacher and the students take turns, with various voices taken into account and attention focussed on one perspective	Interactive/authoritative (I/A) The teacher and the students take turns, with various voices not taken into account and attention focussed on one perspective
Non-interactive (NI)	Non-interactive/dialogic (NI/D) The teacher and the students do not take turns, with various voices represented and taken into account		Non-interactive/authoritative (NI/A) The teacher and the students do not take turns, with various voices not taken into account and attention focussed on one perspective

Providing Content and Context Knowledge Using Authoritative Communicative Approaches

The teachers used authoritative communicative approaches, both NI/A and I/A, to provide science content knowledge. Moreover, they used the I/A communicative approach to provide *context knowledge*, in terms of some understanding of the issue itself and certain considerations relevant to it.

When preparing the students for the discussions, the teachers used the NI/A communicative approach by giving lectures in which they conveyed science content knowledge relevant to the issue under consideration. During lectures, the teachers occasionally shifted to the I/A communicative approach to review and check science content knowledge with which the students were supposed to be familiar.

When facilitating the discussions, the teachers used the I/A communicative approach to provide context knowledge. The students occasionally asked questions that did not concern the science relevant to an issue. In response to this, the teachers provided explanations as a way of promoting students' understanding of the issue. In this way, further discussion on the issue was facilitated. The following excerpt from Lesson 1, concerning prenatal diagnosis, illustrates this.

Excerpt 1, Lesson 1, Teacher A, I/A communicative approach Interpretation

Adam:	There was a thing in the article	Here, the teacher conveys ("Well it's more like") to the students what is known about how parents in Sweden tend to decide when it comes to children with Down's syndrome. This represents the I/A communicative approach because the teacher responds to Adam's and Emilia's questions (the teacher
Teacher:	Yes?	
Adam:	They say that probably the last child with Down's syndrome will be born around 2030	
Teacher:	Mm	
Adam:		

Excerpt 1, Lesson 1, Teacher A, I/A communicative approach Interpretation

	I don't understand exactly how they think because it's a genetic disorder that can occur anywhere /.../	and the students are taking turns) while he pays attention to one specific perspective, namely the decisions that most parents make.
Emilia:	Will they ban it, that you're not allowed to give birth to children with Down's syndrome? /.../	
Teacher:	Well it's more like, imagine that all women are examined and that you look specifically for Down's and if you find it then the parents will presumably get to choose /.../ and so far we've seen that in Sweden, people who get to ... parents who find out that the child you're expecting suffers from Down's and then almost everybody in Sweden has an abortion but not everyone does the test that you do for Down's syndrome	
Anna:	But I think that's quite good /.../	

Elucidating SSI Complexity Using Dialogic Communicative Approaches

The teachers used dialogic communicative approaches (NI/D, I/D or I/DF) to elucidate SSI complexity. When preparing the students for the discussions, the teachers used the NI/D communicative approach by giving lectures in which they presented different voices relevant to an issue. This is illustrated by the excerpt below.

Excerpt 2, Lesson 2, Teacher A, NI/D communicative approach Interpretation

Teacher:	In Sweden, there's a public debate regarding whether we should have wolves or not, and there's the Sami people or the reindeer keepers, for example, that don't want to have any wolves because they the wolves eat reindeers and then they lose money. The Swedish Society for Nature Conservation and the Swedish Carnivore Association [non-profit NGO:s], of course, want to keep the wolves	The teacher elucidates the wolf issue's complexity by describing different interest groups (reindeer keepers, Swedish Society for Nature Conservation and Swedish Carnivore Association) and different perspectives regarding whether to increase or reduce the wolf population. This represents the NI/D communicative approach because the teacher and students are not taking turns, while various voices (interest groups and opinions) are represented.
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When facilitating the discussions, the teachers used the NI/D communicative approach to open up voices for consideration that the students had not yet addressed. This was accomplished through insertion of short lectures into ongoing discussions that functioned to further the discussion so that additional voices were addressed. By definition, these lectures represent the NI/D communicative approach because the teacher and students were not taking turns while different perspectives on the issues were represented. For example, towards the end of the discussion about prenatal diagnosis (Lesson 1), Teacher A introduced a question that had not yet been addressed, namely, whether all parents should be *offered* the test or need to *ask for* the test. He described it as an issue that is influenced by both values

and economic concerns that Swedish doctors do not agree upon. In this way, the teacher introduced multiple voices as being relevant to the issue.

Similarly, the teachers sometimes used the I/D communicative approach to encourage the students to consider additional perspectives. The following excerpt from the discussion about the Swedish wolf population (Lesson 2) illustrates this. In the excerpt, the students are discussing the issues in small groups, and this particular group of students reports to the teacher that they have nothing more to discuss.

Excerpt 3, Lesson 2, Teacher A, I/D communicative approach Interpretation

Teacher:	You mean you've solved the problem?	This discourse is interactive because the teacher and the students are taking turns. The students are taking one perspective into consideration, namely the problem with inbreeding. By asking "what about the reindeer keepers then?", the teacher introduces another perspective on the issue – in this case, that the reindeer keepers are negatively affected by the wolves. The students then consider this perspective as they suggest that fences could be a solution. In this way, different perspectives on the issue are considered. Thus, the discourse is dialogic.
Erik:	Yes, we think that the wolves should be preserved /.../	
Victor:	Because they're inbred now, you have to have...	
Erik:	Well you can't redu... it feels strange to reduce if they're inbred now, reduce to 180 that won't solve the problem. It'll...	
Teacher:	No, it won't	
Erik:	The problem with inbreeding will only increase then	
Teacher:	But what about the reindeer keepers then?	
Erik:	Can't they...	
Teacher:	They complain now that there are...	
Erik:	Can't they, like, ... can't they get better fences? [Student group discussion continues]	

Finally, the I/DF communicative approach, illustrated by the excerpt below, was used to elucidate a dilemma or controversy underlying a certain issue. By means of the I/DF approach, the teachers took account of students' contributions while specifically drawing attention to a dilemma or conflicts of interests.

Excerpt 4, Lesson 3, Teacher B, I/DF communicative approach Interpretation

Teacher:	OK then, what do you think?	The interaction is multi-voiced because various students' voices are taken into account. The teacher builds on the students' responses by checking interpretations and asking follow-up questions. However, the interaction is authoritarian. The teacher seems to have a predetermined agenda, namely to elucidate a dilemma. The conclusion that "it's not so easy to decide what's right and wrong" is based on the teacher's contributions, for example, "in some cases it's OK but not in others?", and not on the students' contributions. Rather, the students do not seem to perceive a dilemma.
Sara:	Well, like, it's not good to design people like because (inaudible)	
Sophie:	But we think that if someone's ill	
Teacher:	So in some cases it's OK but not in others?	
Sophie:	Yes, but not like if two parents want to have a child, they can say, well, the eyes should be blue and it should be blond, and, like you said, be good at soccer, but, like that's not how it should be	
Teacher:	So that's not OK to you?	
Sophie:	No, it should be like, natural	
Teacher:		

Excerpt 4, Lesson 3, Teacher B, I/DF communicative approach Interpretation

OK, and who's gonna decide then where the limit is for what's natural?

Emma: Illness or what, if you're ill then (inaudible)
/interaction continues/

Teacher: This whole area called genetic engineering is full of such ethical dilemmas, you call it like where it's not so easy to decide what's right and wrong

When summarizing and closing the discussions, the teachers used the NI/D communicative approach to make comparisons and point out similarities and contrasting perspectives put forward by the students. Finally, the teachers recapitulated specific voices that had been considered in the discussions, thereby elucidating the issue's complexity.

Promoting Recognition of Students' Contributions

Discursive practices that may promote the recognition of students' contributions to classroom discourse will be presented as belonging to two major themes. First, we present how the teachers elicited the students' voices by means of dialogic communicative approaches. The presentation is chronological to elucidate in what ways the students' voices were recognized during the lessons. Second, we present how the teachers built instruction on the students' contributions in seemingly purposeful ways.

Eliciting Students' Voices through Dialogic Communicative Approaches

The teachers used dialogic communicative approaches to elicit the students' voices during the lessons. While lecturing to prepare the students for the discussions, the teachers shifted to the I/D communicative approach to elucidate the students' prior knowledge or experiences in a certain area. This can be seen in the excerpt below in which the teacher explores the students' prior knowledge about people who have been important to the development of science.

Excerpt 5, Lesson 3, Teacher B, I/D com- Interpretation
municative approach

Teacher:	Are you familiar with Aristotle?	The discourse is interactive because the teacher and the students
Students:	[multiple yes and no answers]	are taking turns. It is dialogic because the teacher invites
Teacher:	Have you heard the name?	different student voices, by asking about their prior
Students:	[multiple yes and no answers]	knowledge about Aristotle. The questions "Are you familiar
Teacher:	OK, some of you have heard it, what have you heard?	with Aristotle?", "Have you heard the name?" and "What
Students:	[murmuring]	have you heard?" are all genuine in the sense that the teacher
Michaela:	Not so much	does not know the answers to them. Specifically, the
Teacher:	OK, you have just heard the name?	question "What have you heard?" opens up a space for the
		students to contribute with their knowledge

When initiating the whole-class discussion during Lesson 1, Teacher A used the I/D communicative approach. He asked for the students' perspectives or suppositions through genuine questions like "*Is it [prenatal diagnosis] right or wrong? What do you think?*"

When facilitating discussions, the teachers used the I/D communicative approach to elicit the students' voices and invite the students to share their thoughts. They assigned speakers, checked interpretations and asked for clarifications and elaborations.

In summarizing the content of group discussions in the whole class, the teachers used the I/D communicative approach to collect the students' contributions, for example, by asking questions like, "*Group one, you had an idea. How did you think? Can you explain?*" [Lesson 2]. In that way, they opened up a space for the students' voices to be represented.

Building Instruction on Students' Contributions

The examination of the ways in which the teachers used students' contributions in I/D discourse segments showed that they built their instruction on the students' contributions in two different ways.

First, they used the students' contributions to introduce scientific terminology, which can be illustrated through the following excerpt drawn from Lesson 4. Before the beginning of this excerpt, the students discussed in groups why differences exist between men and women, and the teacher is now collecting the ideas from the different groups.

Excerpt 6, Lesson 4, Teacher B, I/D discourse interrupted by an authoritative utterance Interpretation

Emma:	Well, it's like, if five boys are playing soccer, and one girl wants to do it, but not the others, then I think she'll probably leave /.../	The teacher interjects an authoritative utterance that makes a connection between the situation that the student describes in everyday language and the scientific term "cultural sex". The utterance is authoritative because attention is focussed on one specific perspective: "here comes the first". He recognizes the student's contribution by using it to introduce scientific terminology. After this single authoritative utterance, the I/D discourse is resumed by the teacher inviting further student contributions by asking "anything else?"
Teacher:	OK, it's in the culture, so to speak – what's feminine and masculine? Well then here comes the first, there's a cultural sex [gender] /.../ kind of unwritten laws	
Emma:	Mm	
Teacher:	Yes, anything else? No? What do you think then? [turns to another group of students]	

Second, the teachers built their instruction around the students' contributions by structuring discussions so that students' ideas in the first part of a discussion became the focus of a subsequent discussion. The following excerpt from Lesson 3, in which the students were encouraged to discuss potential future directions in gene technology, illustrates this.

Excerpt 7, Lesson 3, Teacher B, I/D communicative approach Interpretation

Teacher:	Well, it seems like you have got some ideas /.../ What do you think?	The discourse is interactive because the teacher and the students are taking turns. It is dialogic because different student voices are represented. First, the teacher summarizes the discussions so far by collecting the suggestions from the different student groups by means of the genuine question "What do you think?". Subsequently, the teacher allows the students' contributions, "all this", that he has written on the board, to become the focus of a subsequent discussion in which the students' contributions are once again invited. By incorporating the students' contributions into a subsequent discussion, the students' contributions are recognized as important to this instructional activity
Amir:	A new species /.../	
Teacher:	A new species. OK, that you can create it? [writes on the board] Um what do you think? [turns to another group]	
Sophie:	Like, that it'll be possible to make a human like he made an artificial...	
Teacher:	Like a new human species or a new human...	
Sara:	No, like to decide how...	
Maria:	Yeah, the eye colour and stuff	
Teacher:	OK, to design?	
Sophie:	Yes, kind of /.../	
Teacher:	Well, then, let us say that all this is possible, let us say let us imagine that it's possible, then there's another question to you /.../ is it desirable to be able to create new species? Is it desirable to be able to design humans?	
Students:	[The students begin to discuss this in groups]	

Discussion

Methodological Discussion

Sample Size

The sample analysed in this study is small with respect to the number of participants, as well as the number of lessons observed and the number of SSI under consideration. Thus, it exists for further investigations to gain more profound knowledge on how teachers can use communicative approaches (Mortimer & Scott, 2003) for specific teaching purposes in SSI-based teaching and how cumulativity (Alexander, 2008) can be promoted in this context. Nevertheless, the present study can be considered a first step in this direction because it shows that the concepts communicative approach and cumulativity are useful tools for examining features of teaching practice in the context of SSI-based teaching. Further studies may well contribute with additional communicative approaches that can further our knowledge on interactions within SSI-based teaching.

Data Analysis

There is a challenge associated with determining the unit of analysis that needs to be acknowledged. It is potentially possible to divide teacher-talk episodes into segments in different ways, based on, for example, changes in topic. This may result in different analytical levels, which may lead to different interpretations (Ødegaard & Klette, 2012). The way that interactivity shifts were defined in the present study enabled a

micro-level analysis of how the teachers coordinated different communicative approaches for different teaching purposes while ignoring, for example, considerations of the dominant communicative approach in their teaching. To enable readers to judge our interpretations' credibility, examples are provided in the Results section.

Coordination of Communicative Approaches to Facilitate Students' Decision-Making on SSI

The present study's results show that the teachers coordinated authoritative and dialogic communicative approaches that served different purposes with respect to facilitating students' informed decision-making on SSI.

The teachers used the NI/A or I/A communicative approaches to introduce or review science content and context knowledge relevant to the forthcoming discussions. This suggests that authoritative classroom discourse served an important role in the pursuit of specific learning goals, such as students' learning of disciplinary content. This is similar to the purpose of introducing and focussing on the "scientific story" reported by Mortimer and Scott (2003) to fit with authoritative communicative approaches. However, in SSI-based teaching, students' learning of disciplinary content is not just an end in itself but also a prerequisite for students' engagement in decision-making on SSI (Lewis & Leach, 2006; Sadler & Zeidler, 2005; Wu & Tsai, 2007). In contrast to Mortimer (1998, p. 79), the present study shows that authoritative communicative approaches (NI/A and I/A) in the SSI classroom can be used to support students' dialogic discourse, instead of resulting in a "pressure towards univocality" (see Excerpt 1). Consequently, the two teachers' use of authoritative discourse primarily early on in the lessons laid a foundation for students' participation in the discussions and their decision-making on SSI by means of dialogic discourse.

The teachers used the NI/D communicative approach to elucidate complexity in terms of diverse perspectives on an issue, both in preparing for, facilitating, and closing a discussion. Thus, the NI/D communicative approach seems to play an important role in pursuing the goal of SSI-based teaching, namely, that students recognize SSI complexities and the various perspectives that are relevant to the issues. Extant research has shown that both primary (Byrne, Ideland, Malmberg, & Grace, 2014), secondary (Patronis, Potari, & Spiliotopoulou, 1999) and university (Sadler & Zeidler, 2004) students tend to draw extensively on personal experiences and values when negotiating SSI. Through the NI/D communicative approach, the teacher can maintain control over the discussion and ensure that diverse perspectives are considered. Thus, the use of the NI/D communicative approach seems crucial for teachers' possibilities to promote students' engagement with multiple SSI perspectives successfully.

The teachers also used the I/D and I/DF communicative approaches to elucidate the complexity of an issue, but these communicative approaches seemed particularly useful for responding to opportunities that occurred during the course of the discussions to address diverse perspectives on issues, when the teachers noticed that the students took only a limited range of perspectives into account. Specifically, the I/DF communicative approach was used to elucidate a dilemma or controversy underlying an issue. By means of it, the teachers drew attention to a dilemma or conflict of interest, while taking students' contributions into account. Thus, the I/DF communicative approach seems particularly important for SSI-based teaching, as it provides teachers with the possibility to guide

students towards further elucidation of the SSI at hand without preventing students' ownership of the task. It provides a means to pursue specific learning goals – in this case, elucidating the complexity of an issue – while promoting cumulativity. However, it should be noted that there may be a fine line between making meaningful use of students' contributions to pursuing specific learning goals and what have been described as “instruction-in-disguise” (Hand & Levinson, 2012), in which the students' contributions are not valued in their own right. Thus, the I/DF communicative approach presents a means to scaffold students' reasoning on SSI but presents challenges that teachers need to overcome to sustain students' engagement and agency in relation to the task.

Promoting Cumulativity in the Context of Classroom Discussions on SSI

The teachers in the present study opened up a space for the students' voices in terms of their prior knowledge and experiences, as well as their perspectives on certain SSI, by yet another way of using the I/D communicative approach. Genuine questions (Scott et al., 2006) were used as starting points for I/D segments of discourse, in which opportunities existed for the students to contribute through their ideas. This is in line with results from studies dealing with the teaching of scientific concepts that show that the teaching purpose of exploring the students' ideas fits with the I/D communicative approach (Mortimer & Scott, 2003).

Extant research in this context further suggests that I/D discourse often is followed by authoritative discourse to clarify the scientific perspective (Scott & Ametller, 2007). A similar result was found in the present study and represents an example of a way of supporting students' learning of specific content in SSI-based teaching while promoting cumulativity. The two teachers used the students' contributions expressed in everyday language to introduce scientific terminology relevant to the discussions. In other words, they initiated a “dialogue between scientific and everyday discourses” (Mortimer, 1998, p. 80). This way of making connections between the students' contributions and disciplinary content can be a means for teachers to direct classroom discourse to promote students' learning of content specified in their curricula by means of dialogic teaching. Such means seem important when it comes to encouraging science teachers to implement discussions on SSI, given that science teachers often attach great importance to covering disciplinary content (Hofstein et al., 2011; Sadler et al., 2006; Tidemand & Nielsen, 2017).

However, in contrast with the findings presented by Scott and Ametller (2007), the present study's results show that in SSI-based teaching, I/D discourse in which students' voices are represented need not be followed by authoritative discourse. The two teachers built on the students' contributions to the discussions by allowing these to become the focus of subsequent discussions, thereby promoting cumulativity (see Excerpt 7). Such subsequent discussions were initiated by genuine questions that related to the ideas that the students had elicited. This way of using students' contributions resembles the uptake process, in which “the teacher validates particular students' ideas by incorporating their responses into subsequent questions” (Nystrand, 1997, p. 6). However, while uptake requires that the teacher be responsive to individual students' contributions in moment-to-moment interactions, the way of initiating further discussions based on students' contributions identified in the present study is something that teachers may plan for when structuring discussions.

Table 4 Summary of teaching purposes and related communicative approaches identified in this study

Teaching purposes	Communicative approaches
Students' learning of disciplinary content Prerequisite for decision-making on SSI	Non-interactive/authoritative
Students' learning of disciplinary content Promote cumulativity Prerequisite for decision-making on SSI	Interactive/authoritative
Elucidate complexity Promote engagement with multiple perspectives	Non-interactive/dialogic
Elucidate complexity Promote cumulativity	Interactive/dialogic-with-fixed-end
Open up a space for students' voices	Interactive/dialogic

Conclusion and Implications

The present study's results elucidate ways in which teachers can manage open-ended discussions on SSI so that different perspectives are introduced and considered while students' contributions are recognized. The results illustrate that management of classroom discussions on SSI requires the teacher to alternate between and make purposeful use of both authoritative and dialogic, as well as interactive and non-interactive, communicative approaches. On the one hand, a teacher can maintain firm control over classroom discourse to ensure that multiple perspectives on an issue are addressed by using the NI/D communicative approach when preparing for a discussion. However, this way provides little room for students' perspectives. On the other hand, if the teacher leaves it solely to students to introduce different perspectives, the issue's complexity may not be explored sufficiently. To avoid this, teachers can promote students' exploration of an issue's complexity by using the I/DF communicative approach, as well as by being responsive to opportunities to address different perspectives during the course of a discussion by using the I/D communicative approach.

Consequently, in the context of SSI-based teaching, no specific communicative approach is more appropriate than another per se. Instead, teachers need to consider their choices of communicative approaches in relation to specific teaching purposes. The descriptions of teaching practices provided in this study can facilitate reflection on choices of communicative approaches to fit with teaching purposes relevant to SSI-based teaching and ways to promote cumulativity. This seems urgent, given that teachers' lack of knowledge on how to structure and lead discussions on contentious issues (Bryce & Gray, 2004; Lee et al., 2006; Oulton, Day, et al., 2004) may prevent them from implementing such activities. The teaching purposes and related communicative approaches identified in this study are summarized in Table 4.

We suggest that the concepts' communicative approach and cumulativity can provide tools that teachers can use to analyse their teaching practices and their development in the context of SSI-based teaching. An analysis of teachers' use of different communicative approaches throughout lessons can provide an overview and indicate the extent to which students' contributions are invited into classroom discourse, while attention to cumulativity may lead teachers towards consideration of

ways to make meaningful use of these contributions. Engaging teachers in such analyses of their discursive practices and analysing such processes' outcomes seem like an important direction for further research, given that a need exists among many science teachers to develop strategies to manage classroom discussions on SSI.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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