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Use of dialogue to scaffold students' inquiry-based learning

Abstract

This paper suggests a set of theoretical principles to guide teachers' use of dialogue to scaffold students' inquiry-based learning. To find out how teachers might make use of dialogue, six documents presenting instructional models of IBST are analysed. The document analysis and the identification of theoretical principles are guided by Dewey's concept of a complete act of thought, Bakhtin's theory of dialogism, and the concept of authenticity in use of language. All analysed documents suggest the use of dialog, but are only specified for certain phases of the inquiry process. Only three documents provide arguments for the relevance of dialogue using theories of language and learning. Two documents argue that language use that is personally meaningful to the individual is important for the learning process. The suggested theoretical principles includes six basic types of learning dialogues suitable for stimulating learners to enter different phases of reflective thinking needed to develop deep understanding.

Introduction

Inquiry-based science teaching (IBST) is advocated by many educational organizations and science curricula (Pellegrino & Hilton, 2012). IBST, where students design hypotheses and perform experiments to test these, holds the potential for making science accessible to more students, foster deep learning, and enculture students into critical thinking and scientific ways of thinking (Duschl, Schweingruber, & Shouse, 2007). At the same time, some researchers are claiming that inquiry-based teaching is less effective than direct instruction (Hattie, 2009; Kirschner, Sweller, & Clark, 2006). However, responses to such criticism points out that approaches providing extensive scaffolding and guidance to students are effective. (Alfieri, Brooks, Aldrich, & Tenenbaum, 2011; Hmelo-Silver, 2007; Minner, Levy, & Century, 2010; Schmidt, Loyens, van Gog, & Paas, 2007). Appropriate scaffolding thus seems to be fundamental to successfull inquiry-based teaching.

The purpose of this article is to explore how science teachers may use dialogue to scaffold students' reflective thinking during IBST, and to suggest a set of theoretical principles indicating how teachers can engage students in relevant types of dialogues during IBST. The basic idea is to use Dewey's

(1909) model of a *complete act of thought* to identify different types of thinking a teacher may need to stimulate in students during inquiry, and identify uses of dialogue in six documents presenting instructional models of IBST with relevance for these types of thinking. Dewey's model does not include an explicit analysis of the role of dialogue and collective reasoning involved in learning. Moreover, the use of group and whole class discussions in teaching does not necessarily lead to kinds of dialogue associated with learning (Alexander, 2006; Mercer & Littleton, 2007; Wegerif, 2013). Consequently, theories describing the role of language and dialogue in learning are included in the theoretical framework for this paper. Teachers often seems to struggle with increasing the number of students engaged in learning dialogues; creating and sharing ideas and points of view. Thus, Wallace's (2004) concept of *authenticity of language use* and Nystrand's (1997) concept of open or *authentic questions* will be discussed. The paper does not discuss how teachers and students might learn the practical use of dialogue in the classroom. The aim is to hypothesize a set of theoretical principles which can guide teachers when designing for situations stimulating learners to enter into relevant individual and collective reasoning processes throughout an inquiry process.

These hypothesized theoretical principles are general and does not describe specific activities or how to design these. The set of principles might be denoted as a *high-level conjecture*. Discussing design-based research, Sandoval (2013) identifies a high-level conjecture as "a theoretically principled idea of how to support some desired form of learning, articulated in general terms and at too high a level to determine design". The hypothesized theoretical principles are intended as a starting point for design research and a guide for identification of specific dialogic activities

Verbal dialogue and learning

Deep learning (Pellegrino & Hilton, 2012), a main purpose of IBST, implies the development of new ways of acting, thinking and talking, i.e. new mental functions. Vygotsky (1978) claims that mental processing can occur not only within individuals, but also between people on the intermental plane. Individual mental functioning has social origins, as summarized in the following well-known citation:

> *Every function in the child's cultural development appears twice, on two levels. First, on the social, and later on the psychological level. (p.128)*

One possible interpretation of Vygotsky's theory is that the learner has to participate in a relevant social arena in order to develop new ways of thinking. Moreover, language plays a key role as it provides the means for generating new ideas, and for thinking together (Mercer & Littleton, 2007; Wells & Arauz, 2006). According to Vygotsky (1978) and Dewey (1909), the use of signs, e.g. words and figures, enables humans to clarify, coin and memorize abstract ideas. Signs are abstractions, and for those who are not familiar with a sign, it will not carry any precise meaning. This is a basic challenge for teachers and learners, and explains why metaphors like *active construction* and *creation of meaning* are often used to describe learning. The meaning of signs (e.g. scientific concepts), and students' tentative construction of interpretations of these, therefore has to be negotiated using written or oral dialogue (Wallace, 2004).

A characteristic of utterances in dialogues, impinging on such negotiating processes, is that linguistic communication is potentially ambiguous (Wells & Arauz, 2006). Words and sentences are imbued with the speaker's meaning, which is based on his or her perspective on the topic under consideration (Bakhtin, 1981). Consequently, individual participants in a dialogue interpret and speak about the topic from different perspectives, based on their previous knowledge and experiences and current concerns. This results in what Bakhtin calls *multi-voiced* dialogues, where multiple views are present. Thus, although one might assume that a speaker and a listener make the same interpretation of an utterance, this can only be clarified through further dialogue. Clarifying dialogue presupposes active mutual responses, using text and language as *thinking device* (Wells & Arauz, 2006).

Bakhtin (1981) uses the concept *interanimation* to describe the process were dialogue partners expose their views to each other. If the dialogue partners inspect, compare and contrast each other's ideas, the dialogue involves a high level of interanimation (Scott, Mortimer, & Aguiar, 2006). If views are presented but not worked on, the level of interanimation is low. In reality, dialogues might of course involve any intermediate levels of interanimation, making this a continuous scale. The concept of high level of interanimation maps directly into Mercer's concept of *explorative dialogue* (Mercer & Littleton, 2007), shown to be effective for students' learning. Dialogue involving interanimation is denoted by Scott et al. (2006) as *dialogic discourse*, but will in this paper only be denoted as dialogue. Consequently, the concept of dialogue denotes situations where dialogue partners share points of view (Wegerif, 2013). In this paper oral dialogue is in focus. Thus the term *dialogue* is taken to denote situations were views are shared orally between dialogue partners. Consequently, the concept includes teacher-led, whole-class dialogue as well as group dialogues with or without the teacher present as a supervisor. Situations where one person, e.g. the teacher, only repeats different views of others, what Scott et al. (2006) conceptualises as *noninteractive dialogic*, are not included. Taking the continuous scale between high and low levels of interanimation into account, this definition implies that situations where views are shared without being compared and contrasted are also regarded as dialogues, e.g. brainstorming activities. The term *discussion* will be used as a broad term to include talking and writing about a subject, whether characterised by interchange of views between different voices or not.

There are indications that oral interaction is common in school science (Wells & Arauz, 2006; Ødegaard & Arnesen, 2010), making effective ways of learning through dialogue important to understand. In addition to enable immediate access to feedback on one's tentative ways of thinking and talking about an issue, oral dialogue has several additional pedagogical advantages and possibilities. One is the tentative clarification of one's own emerging thoughts through articulation in a communicative situation. Another is the access to the dialogue partners' thoughts and ideas, which provides a broader knowledge base for ones' own thinking (cf. distributed knowledge). Also, it can give students a voice as a participant in dialogues (Wegerif, 2013).

Authenticity of language use in dialogues

There is an ongoing concern that students, and also science teaching, focuses on ability to recall facts on demand rather than ability to explain and apply knowledge connected and organized around important concepts (Bransford, Brown, Cocking, Donovan, & Pellegrino, 2000; Duschl et al., 2007). Also, many studies have identified the initiation – response – evaluation (IRE) type of question and response as a common type of teacher-student dialogue in science teaching (Duschl et al., 2007; Scott et al., 2006). Two characteristic features of IRE-dialogues is a focus on facts and the teacher's evaluation of the student's answer. Consequently, there is a risk that students' aims to memorise and reproduce definitions and facts, partly using words and language they do not understand (Mestad & Kolstø, 2014). Consequently, it is important to create a culture in the science classroom emphasising deep learning instead of recall.

Wallace (2004) states that the development of a language reflecting subject matter authenticity presupposes the learner's *authentic use of language* during the learning process. By authentic use of language, Wallace means language use which is personally meaningful to the utterer. Thus, in order for students to move from vernacular authenticity to subject matter authenticity, the learners need to express themselves using language which is personally meaningful, although tentatively stretching out for new concepts and ways of talking, during the learning process. Personal meaningful use of language is also necessary for the student's response to others' utterances to become a resource for own learning, involving "*the internally persuasive* word" (Bakhtin, 1981, p.345) and ability to "*populate it with his own intention*" (Bakhtin, 1981, p.293). Language authenticity is important also because learning not only involves the acquisition of new concepts but also new uses of language and

new ways of discussing (Wallace, 2004). This view is also consistent with the Vygotskian understanding, stating that concept and language learning cannot be separated because they develop as a whole (Vygotsky, 1978). Consequently, it is necessary to focus on the importance of stimulating students to use language in personal meaningful ways during learning processes.

As research on IRE-dialogues indicates (Duschl et al., 2007; Scott et al., 2006), the type of questions used by the teacher might have an impact on the type of responses you get from students. Studying US classrooms, Nystrand (1997) developed the concept of *authentic questions* as questions where the teacher does not hold the answer. Consequently, such question calls for students' views, interpretations and knowledge contributions. The defining core of authentic questions is that the teacher expresses interest in the students' ways of thinking and talking. In classrooms where teachers used authentic questions, Nystrand found students expressing themselves using personally meaningful language.

In the analysis of documents describing IBST instructional models, the concepts of authenticity of language use and authentic questions will be used to identify described practices, e.g. task and questions reflecting these concepts, and arguments for the importance of such practices.

Dewey's concept of a complete act of thought

Dewey's (1909) concept of a *complete act of thought* is one of the intellectual origins of the 5E instructional model (Bybee et al., 2006) and of Kolbs' (1984) well-known experiential learning cycle. It has had a longstanding influence on educational theories on IBST. In his theory, Dewey (1909) described a mechanism, denoted as *double movement of reflection*, by which individuals develop their thinking further, i.e. learn. For these reasons, Dewey's (1909) five elements involved in a *complete act of thought* is used in this study for identifying possible purposes of dialogue in different phases of inquiry in analysed models of IBST:

> *(i) a felt difficulty; (ii) its location and definition; (iii) suggestion of possible solution; (iv) development by reasoning of the bearings of the suggestion; (v) further observation and experiment leading to its acceptance or rejection; that is, the conclusion of belief or disbelief (Dewey, 1909, p.73).*

The core of this description is the double movement of reflection. Confronted with a problematic situation (i), an individual may use his or her knowledge and creativity to come up with a tentative interpretation of observations and information encountered (element iii). This is an inductive (sometimes called abductive) step. In itself it will not imply new insight, as it is only a guess. However, the induction is followed by deductive and observational phases where the tentative interpretation is tested against further evidence (element iv and v). If the tentative interpretation is consistent with the new evidence gathered, the interpretation has gained merit. However, if the tentative interpretation is not consistent with available evidence, one may repeat the process. From this conception of inquiry-based learning, it follows that a main purpose of teaching is to stimulate such *reflective thinking* in students.

Stage (ii) includes a clarification of the specific character of the problem. The inductive leap leading to an interpretative idea draws upon facts, concepts and preliminary observations the situation brings to the mind of the learner. Consequently, the learner's prior knowledge and experiences enables and constrains the interpretative inferences to be generated. Stage (v) contains in fact two aspects; to identify further observations (e.g. through experiment) and to make a conclusion on whether the new observations are consistent with the proposed solution or interpretation. For clarity, these two aspects are separated in the analytical framework.

Research question

The purpose of this article is to explore the possibility for the teacher to initiate dialogues stimulating elements of reflective thinking relevant in different phases of students' learning process in IBST. This possibility will be explored first by analysing documents presenting instructional models of IBST, based on the following research question:

> How, and why, might teachers use dialogue to scaffold students' reasoning and learning processes during different phases of inquiry-based learning?

A second purpose is to ask how insights from the document analysis and the theoretical framework presented might be combined into tentative theoretical principles for the use of dialogue to scaffold students' inquiry-based learning.

Method

There are many examples of instructional models for IBST in the science education literature. To make it possible to include in this paper some details from the analysis, only six models were selected. These instructional models were selected as they state partly different pedagogical aims and means, potentially enabling the detection of various ways of emphasising dialogue and authentic use of langue. Partly these were selected because this author has had a long-standing interest in these models. Of specific interest is the BSCS 5E instructional model with its long history of use and the POLLEN-project discussed in the Rocard report (Rocard et al., 2007) as reference project for Europe. Other instructional models could have been selected, but these six, and the selected documents presenting them, are believed to be sufficiently well-known and cited to justify inclusion. The following documents presenting models of IBST was selected for analysis (citations in Web of Science/Google scholar at the 11th of January 2018 in parenthesis):

The BSCS 5E Instructional Model *(*Bybee et al. 2006, 15/981)
The Science Writing Heuristic (Keys et al. 1999, 123/421)
POLLEN Methodological Guide (Saltiel 2006)
Argument-Driven Inquiry (Sampson et al. 2011, 54/169)
Constructing Representations (Hubber et al. 2010, 64/156)
The modelling method (Wells et al. 1995, 104/431)

To facilitate comparison across models, the analysis of the instructional models was structured using the slightly modified version of Dewey's description of a complete act of thought. This model was chosen for several reasons. In addition to being one of the intellectual origins of inquiry-based learning, Dewey claims that the model applies to everyday thinking and learning as well as the thinking involved in developing scientific knowledge. Hence it is relevant also for school projects aimed to imitate scientific ways of working, and for learning progression over an extended period of time. Thus all six models were inspected for descriptions and recommendations of dialogic activities during the following phases of inquiry:

1. **Problem:** impinging in students a felt problem
2. **Preliminary observations and prior knowledge:** observations and prior knowledge relevant to the problem
3. **Tentative explanations:** the development of tentative explanation
4. **Implications:** the development of possible testable implications of the tentative explanation
5. **Testing**: the testing of such implications through further collection of data and information
6. **Consistency**: concluding on the consistency of proposals with all available information

Through thematic analysis (Guest, MacQueen, & Namey, 2011) the presence and particularities of specific types of content were identified. The six documents were first coded for sections describing activities involving any of the six specified phases of inquiry. Secondly, two sets of keywords potentially indicative of sections discussing or describing dialogic activities and authentic use of language were inductively identified from the documents. The purpose was to enable subsequent search through the documents for identification of all relevant sections, taking into account the variability in ways language can express ideas.

Following this line of thinking, two intertwined aspects in the definition of dialogue in the theoretical framework was explicated: The presence of views (1) in a collective situation (2). The 32 keywords identified as potentially indicative of dialogic activities could therefore be sorted into two clusters: 1. words indicating elicitation of views (e.g. *questions, ask, elicit*), expression of views (e.g. *explain, articulate, describe, formulate, present, orally*) and interchange of views (e.g. *debate, listen, exchange, reply, defence, negotiation*), and 2. words indicating collective situations (e.g. *group, peer, collaborative, collectively, class*).

Similarly, two intertwined aspects of authenticity in students' use of langue, as described in the theoretical framework, was explicated: The articulation of an idea or interpretation (1) developed through the student's own reflection (2). The 31 keywords identified as potentially indicative of authenticity of use of language and authentic teacher questions could therefore be sorted into two clusters: 1. words indicating students' interpretations and constructions versus focus on correct answer (e.g. *make, construct, invent, interpret, suggest, comparing, ideas, viewpoint, opinion, model,* and *incorrect, right, given, fail*), and 2. pronoun focusing on students' own reflections (e.g. *you, your, I, own, my, their, peers*).

Finally, these lists of identified keywords was used to search all documents systematically to ensure identification of all relevant sections. When a keyword from one of the lists of keywords were present, the section were inspected and coded if judged to involve oral dialogue, authentic questions or authentic use of language. Also, all documents were inspected for *arguments* in support of dialogue activities and the importance of authenticity of students' use of language.

Analysis of documents presenting instructional models of IBST

The BSCS 5E Instructional Model

The BSCS 5E instructional model (5E) was developed in 1987 by the Biological Sciences Curriculum Study in US and consists of 5 main phases: *Engagement, exploration, explanation, elaboration* and *evaluation* (Bybee et al., 2006). In the analysed document, the presence and order of the three first phases is discussed as crucial to successful inquiry-based learning.

The teacher's use of questions is suggested for all main phases. For the engagement phase, it is suggested that the teacher seeks to make students engaged in a problem, e.g. by "*asking a question*" (p.8). It is also suggested that the teacher "*Elicits responses that uncover what the students know or think about the concept or topic*" (p.34). In the exploration phase the teacher should "*Asks probing questions to redirect the students' investigations when necessary*" (p.34) and "*Asks for justification (evidence) and clarification from students*" (p.34) when results are presented. In the explanation phase the teacher "*Encourages the students to explain concepts and definitions in their own words*" (p.34).

To facilitate clarification and transfer of concepts, students are to present, defend and receive feedback in class on ideas developed during group discussions, thus testing their ideas against others'. In the evaluation phase "*students should receive feedback on the adequacy of their explanations*" (p.10).

In this phase, the use of open-ended questions such as, "*Why do you think …?*", "*What evidence do you have?*", "*What do you know about x?*" and "*How would you explain x?*" (p.34) are suggested.

Two arguments related to the use of dialogue in IBST were found. First, it is stated that "*the BSCS 5Es views learning as dynamic and interactive*" (p.11) and that conceptual development involves interaction with the environment and other individuals. Second, it is stated that "*cooperative learning*" (p.12) is incorporated into the exploration and elaboration phases.

Concerning authenticity of students' use of language many examples of questions to use ask for students' views and include the personal pronoun *you*, as in the examples above. When talking about students tentative explanations, the phrase "*in their own words*" (p.34) was included. Explicit arguments for stimulating students in this direction were not found in the analysed account of the 5E model.

The Science Writing Heuristic

The Science Writing Heuristic (SWH) is a heuristic tool for learning from laboratory activities in secondary science developed by Keys, Hand, Prain, and Collins (1999). Their stated aim is to build on insights from research on *writing to learn* and the importance of making students think about how claims are developed and supported by evidence in science. It offers one template for the teacher and one for the students for guiding teaching and learning activities.

The teacher template suggests the use of individual or group concept mapping for students' exploration of their pre-knowledge. Also, it is suggested that questions for students' inquiry, and also lists of terms relevant for the topic in focus, is generated using whole-class brainstorming.

The template also suggests "*collaborative group discussions*" (p.1065) where students test their tentative explanations by negotiating understandings of concepts and data with peers, e.g. "*sharing and comparing data interpretations*" (p.1068). Suggested questions for the students in such group discussions are "*What can I claim?, How do I know?, Why am I making these claims?*" (p.1069).

Concerning authenticity of students' use of language, these and other questions for the students include the personal pronoun *I*. The teacher template suggest that students write "*personal meanings*" (p.1068) as the first step following laboratory activity.

The analysed document provides detailed arguments for the use of writing and how the SWH is grounded in the epistemological frameworks. They state that negotiation of meaning is essential, and should be done not only through discussions but also through reading and writing texts.

POLLEN Methodological Guide

The Pollen project (PP), running from 2006 to 2009, aimed to stimulate and support IBST in primary schools. The methodological guide (Saltiel, 2006) analysed states, as an essential feature, that one is to "*allow children to build up the knowledge desired by helping them express their ideas, expose their reasoning, test their hypotheses and strive to be exacting*" (p.9), thus explicating students expressing of own ideas is indispensable.

The guide has a special section discussing the importance of group discussions (the term dialogue is not used), e.g. stating that debate on students' ideas, observations and facts can come into play in all phases of IBST. Also, it is argued that group discussions "*give the students an opportunity to realise that ideas other than their own exist and that those ideas can be rooted in facts that they had not considered*" (p.14). Concerning the quality of group discussions, it is stated that "*the students work in groups can be especially enriching if the students are encouraged to discuss, compare their*

viewpoints and try to agree on a common conclusion" (p.18) and that reports to full class should explain how claims are substantiated.

It is suggested that during presentations of group reports in full class, students might get ideas from each other. It is also suggested that records of students' work might sometimes be developed jointly in class.

Concerning authenticity of students' use of language, the guide includes discussions on "*What questions should be asked of the children and how to ask them*" (p.15). For instance, it states the importance of encouraging students to express their ideas orally or in writing and taking them all into consideration without making value judgements. The focus on students expressing own ideas is reflected in a range of examples of possible teacher questions, all including phrases like "*what do you see…?*", "*In your opinion, …*" etc., consistent with the idea of *authentic use of language*. It is argued that this focus on students' wordings and thinking supports the emergence of new understandings based on new observations and ideas.

Argument-Driven Inquiry

The ADI instructional model aims to develop students' conceptual understanding as interrelated to their ability to understand and participate in scientific argumentation and knowledge building (Sampson, Grooms, & Walker, 2011). Key activities in the model are the students' production, critical discussion (the term dialogue is seldom used) and improvements of an argument consisting of a tentative explanation and supporting evidence.

In the second and third step in the model (after teacher introduction of topic and tasks), the students work in groups generating data and a tentative argument. How to facilitate group work, e.g. dialogues, is not discussed.

In the fourth step in the model, the core activity is a class dialogue where "*small groups share their arguments with the other groups and critique the work of others to determine which claim is the most valid or acceptable*" (p.220). Class discussion is also one of several alternatives suggested used to introduce or reinforce important content.

The three final steps include creation, peer review and revision of a report, but the use of verbal dialogue to scaffold these activities is not mentioned.

Concerning authenticity of students' use of language, students are required to answers questions like *"What is your argument?*" (p.222) when writing reports. There is also a general call for students to construct and discuss arguments. The use of dialogue is supported by an argument stating that "*students learn more when they are exposed to the ideas of others, respond to the questions and challenges of other students, articulate more substantial warrants for their views, and evaluate the merits of competing ideas*" (p.220).

Constructing Representations

Emphasising induction into the practices of science discourse, Hubber, Tytler, and Haslam (2010) extend the inquiry principle of exploration and student generation of preliminary explanations with the notion that "*learning involves the recognition and development of students' representational resources*". Thus the term "*Constructing representations*" (CR). In their teaching sequence, students co-develop explanations and representations, e.g. drawings, graphs, symbols and 3D models.

Regarding the use of dialogue, students' prior knowledge and everyday words on the topic in focus are elicited at the outset, e.g. through a whole-class brainstorm activity. A class discussion is also included

as a first step: Students' everyday words on the topic are collected, and new categories are collectively identified. The document states "*there should be explicit discussion and evaluation of the adequacy of representations in generating meaningful understandings*" (p.10). In addition to empirical adequacy of representations, the evaluation of consistency of students' ideas also includes comparison across the groups' explanations and representations.

Concerning authenticity of students' use of language they state, as a principle, that "*students should be encouraged and supported to generate their own representations*" (p.10). They supported this principle by referring to cognitive research on learning and how application of own resources, including language and representations, are important for engagement and learning. The emphasis on discussions and negotiations is described as important practices, and supported by an argument stating that "*induction into the practices of science discourse can enhancing student conceptual growth*" (p.7).

The modelling method

The modelling method (MM) (Wells, Hestenes, & Swackhamer, 1995) was developed in the early nineties at Arizona State University for high school physics. An essential feature is the focus on stimulating students to engage in "*extensive discussions of qualitative reasoning and representational tools*" (p.608) as they develop, present, defend and improve a model representing a concrete experimental situation.

As a first step, the teacher demonstrates an experimental setup before the students work on their own in groups of three. Through a class discussion (the term dialogue is seldom used) where the teacher elicits from students possible variables, including arguments for their suggestions, a consensual description of the setup is established.

Repeatedly during the modelling activity, students are required to present in class an explicit model on a small whiteboard. Using questions like "*Why did you do that?"* and "*How do you know that?*" the teacher challenges the presenter to explain how the model are consistent with theory and experimental data. Also, students are challenged to question each other's ideas, providing answers, and explain how various representations cohere in their interpretations.

Concerning authenticity of students' use of language, the document states the importance of "*developing techniques for improving the quality of student discourse*". One technique suggested is to do grading by selecting one report at random from each group and selecting different members of the group to defend different aspects of that report, thus "*instilling a sense of shared responsibility for the knowledge*" during group work. Also, instead of providing answers when students are perplexed, it's suggested that the teacher asks them to check out what other students are doing.

In general, it is suggested to use questions stimulating students to come up with suggestions and to articulate their reasoning. It is also suggested, that the teacher avoid the role of authority, allow students to fail, and encourage students to evaluate their ideas in collaborative discourse with other students, i.e. strategies consistent with the idea of authentic use of language.

In support for the use of dialogue, the developers states that the quality of student discourse is a key, that students must be actively engaged, and that scientific discourse should be a common practise in the classroom.

Table 1 provides an overview of findings from the analysis of the six instructional models, visualising how dialogue was included in the different phases of the inquiry process. With one exception, dialogic activity was found for all phases of inquiry. The empty horizontal row in table 1 shows that a description of dialogue about possible testable implications of students' tentative explanations, and how to test these, was not found in any of the instructional models.

Table 1: Overview of findings about suggested uses of dialogue in the six documents on instructional models. In the category about testing, ideas related to improvement and renewed testing are also included. The illustrative short phrases are formulated using words and phrases close to those used in the analysed documents.

	The BSCS 5E	Science Writing Heuristic	The POLLEN project	Argument-driven inquiry	Constructing Representations	The modelling method
Identify an engaging problem	Teacher raises questions to engage students and define a problem	Students develope questions within a topic, e.g. from brainstorming	Questioning through demonstration with contrasting observations			
Identify relevant prior knowledge	Elicit responces to uncover what the students know or think	Expressing prior knowledge, e.g. collective concept	Teacher elicit pre-conceptions and students see other ideas		Eliciting in class the students' everyday action words they used	Identification of relevant variables in a class discussion
Clearify observations or information leading to the problem	Students record observations, the teacher asks probing					
Develope tentative explanatory ideas	Encourages students to work together and explain in their own		Students express ideas orally, realise ideas e.g. contradictory with others		Class discussion categorising everyday words	
Identify implications, plan experiment and identify observations						
Testing own ideas using data and/or discussions	Teacher asks for justification and clarification: Why?	Negotiate understandings of data with peers	Teacher arrange discussions. Compare with established fact	Students share ideas and evaluate the mirits of competing ideas	Representations discussed and evaluated in whole class discussion	Challenging students' models using probing questions («why?»)
Improving ideas and renewed testing		Comparing own science ideas to printed resources, e.g. writing group notes	Groups report in class and listen to each others ideas		Remake representations and repeat discussions of adequcy	
Evaluate consistency and conclude	Teacher asks the students what they think and what evidence they				Different meanings of improved respresen-tations discussed	Preparing agreed upon model for presentationand

Discussion

The analysis revealed that all six documents suggested dialogic activities in several phases of IBST. The activities can have low level of interanimation, e.g. brainstorming, or a high level of interanimation, e.g. debates on tentative explanations.

All models includes the use of *class discussions* e.g. for elicitation of students prior knowledge and ideas or *testing* and provide feedback on tentative explanations and arguments made during group work. In three models *group discussions* are explicitly suggested as an arena were students develop and/or negotiate explanatory ideas (SWH, PP, MM). All models suggest that students work in groups to develop and test explanatory ideas. None of the six models suggests the use of dialogue for all phases of inquiry.

All six documents include the personal pronoun *you* or *I* in examples of questions and tasks teachers might use. Also, all texts state that students should express their ideas *in their own words*. Two texts explicate that the teachers should allow students to fail without the teacher making value judgements (PP, MM). In support of the focus on authenticity of students use of language, one document points to cognitive research and the role of language in learning (CR) and one on how students' wordings and thinking supports learning (PP).

In support of the use of dialogue, all documents in essence states its importance for conceptual growth or that conceptual development involves interaction with the idea of others'. In addition, one text points to research on cooperative learning (5E). All documents discussed the importance of specific aspects of the model (e.g. focusing on order of phases, writing to learn, scientific argumentation, representations, modelling). Only one provided separate discussions on how to ask questions and to facilitate group discussions (PP). Consequently, this limited analysis suggests there is room for improvement in communication of arguments and practical advices for how to use dialogue to scaffold students learning process in IBST.

Scaffolding different phases of the inquiry process

As shown in table 1, the use of dialogic activities is recommended in several documents for all phases of inquiry, except for the phase about possible implications and ways of testing these. Based on the analysis of the six instructional models, we might ask how the use of dialogue is suggested for different phases of inquiry.

Problem: To bring about in students an interest in a problem, three texts suggests a whole class *brainstorming* (SWH) or questions based on an experiment presented (5E, PP). However, the use of teacher initiated dialogue in groups or whole class about what students observed and what they found surprising (Thorsheim, Kolstø, & Andresen, 2016) was not found.

Preliminary observations and prior knowledge: Three of the instructional models (5E, PP, CF) suggests that the teacher elicit prior knowledge and everyday conceptions using questions in whole-class. Two of the documents discuss the use of dialogue to clarify relevant observations or other contextual elements needed to clarify the problem discovered (5E, MM). Examples of teacher questions for such dialogues is discussed by Østergaard (2012).

Tentative explanations: The mentioning of dialogue during students' construction of tentative explanations was found in two document (5E, PP, CF). A general model for how a teacher led dialogue might be used to generate and elicit ideas for students' subsequent testing are developed by van Zee and Minstrell (1997) based on their classroom research.

Implications and plan for testing of these: The second phase in Dewey's double movement of reflection, to think through implications of a tentative explanation and how one might go about to test these, was not discussed as an explicit phase in any of the six documents. It might be regarded as implicit in activities where students test their tentative explanations, but this does not imply that it is not possible, or not profitable for some students, to scaffold this reasoning process. The Predict-Observe-Explain model, first suggested by White and Gunstone (1992), exemplifies how one might support students to think through possible empirical implications of an explanatory idea before a relevant test is designed and implemented.

Testing: The use of dialogic activities as a way of testing tentative ideas and interpreting new data is described in all six documents. Dialogic activity aiming to support identification of new observations or observations was not found.

Consistency: Three of the accounts include a whole class dialogue with presentations and teacher led debate on ideas/explanations/models (5E, CR, MM) developed and tested by students. However, dialogic activities categorised as testing in table 1 might also be taken to include a focus on consistency.

Theoretical principles for planning dialogic activities during IBST

Taking all six documents into account, the above discussion shows that dialogic activity is suggested for all phases of inquiry except from the phase with identification of possible empirical implications and tests. Moreover, the use of authentic types of questions is suggested through teacher led dialogues. However, none of the documents suggest dialogic activities for all phases of inquiry, and the use of dialogue and authentic questions are sparsely backed by theoretical reflections. Also, the educational potential of dialogue based on conflicting or diverging voices for reflective thinking and conceptual development (Wegerif, 2007) are not discussed explicitly in the documents analysed, although inherent in processes were students negotiate (SWH), compare (PP), critic (ADI) and evaluate adequacy (CR) of views.

The use of dialogue implies that conflicting views and ways of talking are made socially accessible, enabling *explorative dialogue* (Mercer & Littleton, 2007) and interanimation of views (Bakhtin, 1981; Scott et al., 2006). This way dialogues might scaffold the development of students' ways of thinking and talking. According to Bakhtin's (1981) theory on dialogue, students' views and interpretations, i.e. their answering words, will always be idiosyncratic and multivoiced. However, authoritarian situations can foster mimicking responses. Thus, to ensure engagement in reflective thinking, it is important to ensure authenticity in learners' use of language (Wallace, 2004). Moreover, by using open or authentic questions (Nystrand, 1997), the teacher can stimulate students to express own thoughts, thus enabling the subsequent analysis and interanimation of ideas (Scott et al., 2006) through extended explorative dialogue (Mercer & Littleton, 2007). In practical terms, the need to involve all students' views and at the same time allocate time for feedback and teacher guidance, calls for a thoughtful alternation between dialogue in groups and whole class dialogue (Thorsheim, Kolstø, & Andresen, 2016; Wallace, 2004).

Inspired by the theoretical framework discussed and the inclusion of dialogue in the analysed instructional models of IBST, I propose two theoretical principles for planning dialogic activities during inquiry projects. These principles are based on the assumption that deep learning occurs when the learner works his/her way through *complete acts of thoughts* (Dewey, 1909), and that these different acts of thought needs scaffolding through dialogue. By formulating guiding questions explicitly focusing on different elements involved in reflective thinking, the teacher might guide learners to consider these aspects. Obviously, group and class dialogues are not the only ways to scaffold students' reflective thinking in different phases of inquiry. However, I believe that the analysis of instructional models supports the hypothesis that dialogues might be used to scaffold students' learning, and at the same time indicates that a more thorough theoretical grounding for the use of dialogue in IBST is needed.

The first resulting principle is that tasks and questions stimulating dialogic activities should take into account the function or aim of the different phases of inquiry learning. Using Dewey's concept of *a complete act of thought* as a reference point, six different phases of inquiry can be identified. Figure 1 gives a visual representation of the six elements. Other descriptions of inquiry learning might identify different phases.

The second hypothesised principle is to plan for *multi-voiced* dialogues and learner's *authentic use of language*. Again using Dewey's concept of *a complete act of thought* as a reference point, corresponding guiding types of questions for the six elements in figure 1 are formulated in table 2.

The main idea in the hypothesised principles is to suggest the use of dialogue to scaffold all phases of a complete act of thought, as defined by Dewey's account of inquiry-based learning. Consistent with the six elements in a complete act of thought, the hypothesised principles suggests the use of six types of dialogues aiming to activate these elements of reflective thought in students.

As exemplified in several of the analysed documents, the teacher can indicate interest in the students' knowledge and thinking, in contrast to an anticipated correct answer, e.g. by using the personal pronoun *you*. However, students should not be led to believe they have to be convinced and able to defend all ideas put forward. As in the Pollen instructional model, it needs to be communicated that only the ideas themselves are to be in focus, irrespectively of its source. Also, a focus on students' interpretations and ideas, instead of correct answers, might facilitate participation of more students in learning dialogues. The goal is to improve ideas, not to see who first get it right.

Table 2. Elements of reflective thinking and corresponding trigger questions

- Identify a problem:	*What did you find surprising?*
- Observations and prior knowledge:	*What do you observe/know about …?*
- Generate interpretations:	*How might you try to explain …?*
- Infer implications:	*What might be possible testable implications?*
- Identify further information:	*What more observations or facts did you find?*
- Evaluate consistency:	*How does this fit with…do you think?*

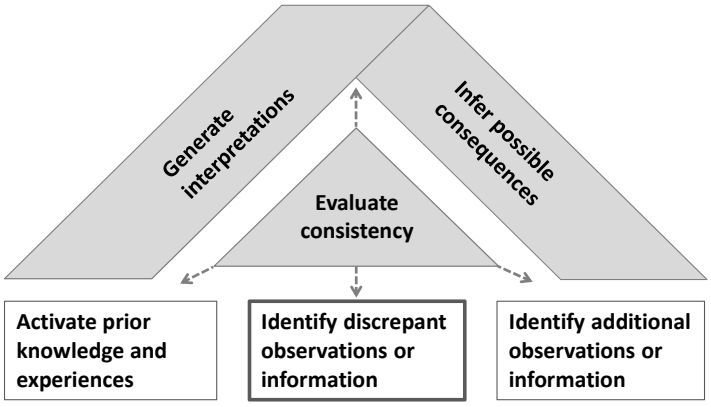

Figure 1. Six suggested basic types of learning dialogues, one for each main element in a complete act of thought, based on authentic questions aiming at eliciting ideas from students for collective analysis in groups and whole class situations.

In figure 1 three elements are shaded to indicate a focus on interpretative ideas in these dialogues, in contrast to a focus on observations and information in the three non-shaded elements. As reflective thought, according to Dewey, can be triggered by identification of discrepant observations or information, this element is marked by a bold frame in figure 1.

The four arrows indicate that evaluation of consistency involves the generated interpretative idea and the identified observations and information. One might identify a clockwise circular path through the different types of dialogues, starting with the felt problem. In practice, the sequencing of the dialogues might be mixed. Also even a short dialogue about a sub-issue in an inquiry might include all six basic types. Thus, the elaboration of the hypothesised principles in figure 1, with six types of dialogues, should be used with flexibility and taking advantage of students' emerging interests and questions. Also, it may not always be relevant to use dialogue to stimulate all six phases separately. For instance, surprising observations or relevant prior knowledge will in some cases be evident, making it natural to move on and scaffold the development of interpretative ideas. Consequently, the purpose of the two principles and the elaborations in figure 1 and table 2 is not to prescribe a certain sequencing of dialogues throughout a lesson or a project. The purpose is to offer theoretical principles which can guide teachers and researchers when designing dialogue activities intended to scaffold students learning in IBST. Further empirical research on dialogues in inquiry classrooms is needed to clarify the usefulness of the hypothesised principles and to improve them further.

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