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Understanding children's science identity through classroom interactions

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ABSTRACT

Research shows that various stereotypes about science and science learning, such as science being filled with hard and dry content, laboratory experiments, and male-dominated work environments, have resulted in feelings of distance from science in students' minds. This study explores children's experiences of science learning and science identity. It asks how children conceive of doing science like scientists and how they develop views of science beyond the stereotypes. This study employs positioning theory to examine how children and their teacher position themselves in science learning contexts and develop science identity through classroom interactions. Fifteen students in grades 4–6 science classrooms in Western Canada participated in this study. Classroom activities and interactions were videotaped, transcribed, and analysed to examine how the teacher and students position each other as scientists in the classroom. A descriptive explanatory case analysis showed how the teacher's positioning acted to develop students' science identity with responsibilities of knowledge seeking, perseverance, and excitement about science.

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Introduction

In an ideal classroom setting, students who have a strong, positive science identity perceive science as questioning, knowledge seeking, and problem-solving. They approach their science learning with scientific attitudes, such as curiosity, enthusiasm, open-mindedness, perseverance, and communication. This type of science identity encourages students to develop new knowledge by negotiating their local knowledge with scientific ways of knowing, and to shift their position from one of passive learner to active agent, upon which they may then share their own learning, thoughts, and knowledge with the learning community (Barton & Tan, 2010). Students with this type of science identity perceive and do science with wonder and willingness, and position themselves as people who are performing these actions like scientists (Trujillo & Tanner, 2014). Developing this positive, engaged science identity has, however, been challenging in science classrooms.

In an interview with *Psychology Today*, Carl Sagan (1996) once said that every child starts out as a natural-born scientist but their wonder and enthusiasm for science

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disappear through social and educational systems. Researchers explain that students develop stereotypes of science and scientists as boring, masculine, filled with lab experiments, hard and brainy, and 'geeky' (Archer et al., 2010). These stereotypical understandings of science and scientists are found in various research projects, such as children's images of scientists through 'Draw a Scientist Activity' (Özel, 2012; Zhai, Jocz, & Tan, 2014), multimodal narratives on scientists (Tucker-Raymond, Varelas, Pappas, Korzh, & Wentland, 2007), and portraits of scientists in children's books (Rawson & McCool, 2014). Students often depict scientists as men wearing glasses and lab coats in laboratory settings with sometimes explosive experiments. Their images of science and scientists are localised as laboratory work and hard conceptual knowledge, rather than within the broader view of science inquiry as involving curiosity, questioning, evidence-based thinking, and communication (Tucker-Raymond et al., 2007; Zhai et al., 2014).

With these more narrow, negative, and often exclusionary perceptions, many children do not want to engage in the undesirable discourse of science in their future and accordingly they self-identify as 'not a science person' (Archer et al., 2010; Lindahl, 2007; Tai, Qi Liu, Maltese, & Fan, 2006); indeed, they choose to associate themselves with neither science nor scientists (Archer et al., 2010). Alternatively, researchers have shown that science identity that is closely associated with competence, enthusiasm, the pursuit of interests, and respect for science affects students' learning, perseverance, and commitment to the possibility of pursuing science careers (Chemers et al., 2010; Estrada, Woodcock, Hernandez, & Schultz, 2011). Given key scientific challenges such as global warming and the need for alternative energy, to name only two, students' lack of interest in science and the decreasing number of students who consider science for future study or as a career is of real concern (Bordt, de Broucker, Read, Harris, & Zhang, 2001; Kennepohl, 2009). Research shows that students' experiences in science before age 11 seemed to determine positive attitudes and connection to science-related careers (Tai et al., 2006) and that after age 14, it is difficult to reorient students' interest in science if that interest has not already been cultivated (Lindahl, 2007). This indicates that students' experiences of science in elementary and junior high schools are critical to cultivating positive attitudes toward science and science-related careers (e.g. Shin et al., 2015). In order to positively develop scientific interests and attitudes, science educators are encouraged to practice inquiry-based activities which emphasise the role of students in learning as becoming owners of their knowledge (e.g. Gibson & Chase, 2002; Hofstein & Lunetta, 2004). Through the provision of various inquiry questions and activities, teachers are tasked to encourage students to think critically, creatively, and to act like scientists in their classrooms. In light of the ongoing, narrow stereotypes of science and scientists, the recommendations made to teachers about the ideal ways to teach science, and the real need to nurture future generations of scientists, this paper introduces a case study of a teacher's teaching and students' experiences of science learning in one elementary classroom. It particularly questions and observes: (1) how teachers may position themselves and their students in science learning to develop students' positive science identity, and (2) what kind of classroom discourse may help children experience, learn, and do science like scientists.

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Positioning/being positioned in science identity

Students develop various kinds of academic identities throughout their school years, such as being a good reader, writer, storyteller, scientist, mathematician, painter, and so on, which empower and transform their learning and actions in classroom settings (Bernard, 2015: Hall, Johnson, Juzwik, Wortham, & Mosley, 2010; Kim & Viesca, 2016). Their 'learning is an embodied activity that involves the ongoing re-creation of practices, roles, and identities' through classroom interactions (Barton & Tan, 2010, p. 189). Science learning, in particular, ideally goes beyond developing the cognitive dimensions of science knowledge. It should also be about learning who we are and how we act in science communities. In other words, it should be about the cultivation of a rich and multi-faceted science identity (Brown, 2004; Brown, Reveles, & Kelly, 2005; Tucker-Raymond et al., 2007). In this regard, how students are engaged and positioned in discursive interactions within science learning communities is critical to developing positive understandings of science and science identity (Brown, 2004; Brown et al., 2005). When students develop their science identity as filled with the qualities of wonder, research, and problem-solving rather than as boring, male-dominated, rote laboratory work, they are less likely to position themselves as passive spectators in science classrooms.

In positioning theory, positions are defined as clusters of beliefs about how rights and duties are distributed during an interaction (Harré, Moghaddam, Cairnie, Rothbart, & Sabat, 2009). In certain positions, there are also particular ways of living in the moment. When we adopt a specific position, we learn certain language and actions to speak and act in and from that position. For example, as teacher, learner, mentor, peer, and friend, we learn the language, action, and responsibilities of these positions. Positioning is therefore how we adapt to the ways of being, thinking, and living in a moment as someone in a specific, shared community. Thus, in every person's positioning, there is a mutually interactive relationship among 'position, speech-act, and storyline' (Harré & Van Langenhove, 1999, p. 30). Positioning affects each person's speech and action, and creates a storyline about that person's being and living in the position. Storylines are the ongoing repertoires that are already culturally embedded in social communities and can also be created through a person's speech act and positioning. The following

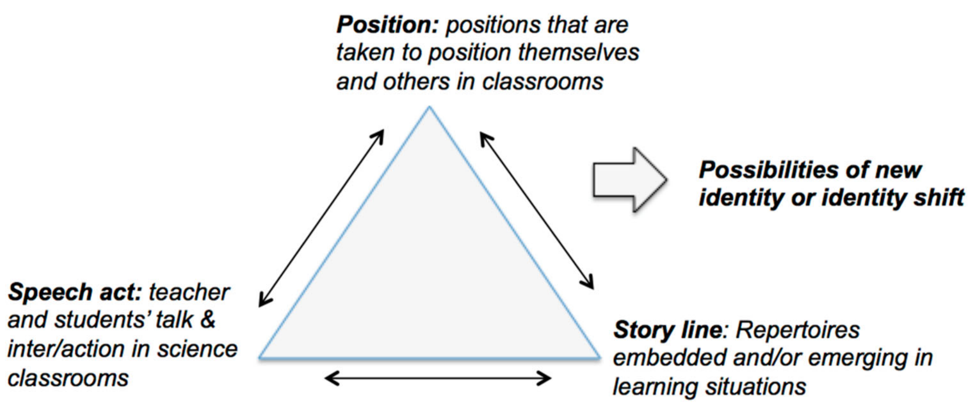

Figure 1. Positioning triangle (modified from Harré et al., 2009).

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diagram (Figure 1) shows how speech act, position, and storyline interact in a classroom setting. Students and their teacher are engaged in classroom talk and interactions (speech act), which influence and are influenced by the positions that they take (position). In the interaction between speech act and positioning act, certain storylines of learning take place.

For instance, if teachers position themselves as the facilitator in a problem-solving community, their choice of language and action would be more accommodating for students to take up the challenge of becoming problem solvers. Also, if they choose a speech act that suggests questions and proposes possibilities rather than simply explaining the right answers, the speech act will position the teacher as facilitator and students as problem solvers. A simple example of a speech act is when teachers provide students with 'why' questions and get them involved in explaining their thoughts and answers (speech act). Rather than positioning themselves as authoritative figures who hold all the right answers, teachers invite and guide students to design and process problem-solving with their classroom peers. Students engage in the speech act of questioning, discussing, and reasoning with evidence, which positions them as problem solvers with a clear responsibility to think and find answers rather than as the passive receivers of knowledge. They are empowered to conduct research like *scientists* and, in turn, teachers are positioned as facilitators and guides for students' personal and collaborative research (position). Through the social, dialogical interactions in that collaborative position, students learn the language and action of science as problem-solving (speech act). Thus, the relationship between position and speech act is mutually influential. Ultimately, this less traditional positioning for both students and teachers constructs a new idea within science classroom learning (storyline). When teachers explicitly and continuously acknowledge science as problem-solving and position students as scientists, the storyline of science emerges as one in which students have agency as problem solvers. Embedded and pre-existing storylines can also influence a person's speech act and position. When students live with the storyline of science as understanding scientific concepts, they will position themselves as the learner of science concepts and expect to learn the 'right' concepts from teachers or textbooks. Thus, storylines also interact mutually and affect both speech acts and positioning. In the mutual interrelationships amongst position, speech act, and storylines, new storylines, new positions, and new identities emerge over time.

In the triad of shifted speech act, position, and storyline within science classrooms, children can begin to develop a new learner and science identity. They become knowledge seekers and problem solvers. Instead of listening to, and receiving, knowledge and answers from a teacher, they become people who are looking for answers through their own research and through collaborative processes of research with their peers. The construction of identity changes with the dynamics of multiple identifications and negotiations in positioning acts in the community (Wenger, 1998). It is a process of *becoming* who we are in and through sociocultural contexts (Correa, Martínez-Arbelaizb, & Gutierrez, 2014). Given that identity is a *process*, students' science identity is also negotiated and constructed in and through the dynamic relationships and interactions in classrooms.

Harré and Van Langenhove (1999) stated that symbolic exchanges in conversations, such as certain language and behaviours, affect positioning acts, negotiation and the new creation of positions, and further identity development. For example, the effect of 'why' questions helps to illustrate that through and within certain conversations and interactions with science, students become positioned in certain relationships, responsibilities, and duties of doing science like scientists. During the exchange of language and acts, positioning occurs and is negotiated to take on new meaning, new action, new position, and new identity development. An example taken specifically from the classroom observations that will be discussed in more detail in later sections of this paper, serves to deepen the understanding of these processes. In one recorded classroom moment, when students asked for answers, the teacher responded, 'I'm not telling you that. That's not my job. My job is to make you figure it out' (speech act 5, turn 04, classroom data). In light of the idea of speech acts, positioning, storylines, and shifts in identity, this example invites questions: Rather than giving students the answers, how does this teacher's speech act challenge the position of learners? How would this create a new storyline of science learning? How do shifts in storyline affect students' science identity? This study works with classroom experiences to examine how particular dialogical exchanges challenge and change students' understandings and positions as learners, and how such exchanges can affect the adoption of broad, multi-faceted science identities in science classrooms.

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Research method and design

By examining the discursive interchanges that are continually taking place within classroom contexts, researchers can understand the development of students' identity (Brown, 2004). To understand how students' science identities emerge and are recognised in classroom situations, this study looks closely into classroom conversations to examine speech acts and storylines of science learning and how teachers and students position themselves and others in science classrooms.

Descriptive explanatory case study

This study uses a descriptive explanatory case study, the role of which is to examine certain phenomenon by observing, describing, and explaining classroom scenes (Yin, 1994). More specifically, it examines a set of data from classroom practice that needs to be understood in the scheme of overall curriculum and real-life classroom situations; accordingly, this case study, as with all case studies, is situational and embedded in a certain context (Baxter & Jack, 2008). Detailed, descriptive accounts of cases help researchers understand how real-life environments and situations are experienced by participants.

Drawing on the tradition of case studies, this study focused on collecting and analysing detailed data sets of children's classroom speech acts and storylines throughout science curriculum development. Through emphasis on the observation of individual and collective speech acts and storylines, the goal was to understand more deeply how children's science identity is experienced, negotiated, and developed in a classroom setting. Qualitative data were collected from observation and video recordings of regular science classes in an elementary school. There were no deliberate experimental interventions with regard to teaching science identity. Two processes defined the study context: (a) the teacher attempted to teach science with an inquiry approach; and (b) the researcher was present in the classroom with video cameras and interacted with the children to help with materials. The video data of classroom conversations and interactions between the teacher and students were later analysed to understand the different positioning acts that took place, and then interpreted in relation to the overall curriculum in order to understand the storylines of particular conversations. The details of the curriculum, data collection, and analysis are as follows.

The study context: participants and curriculum

The study was conducted for four months in a combined grades 4–6 classroom in an elementary school in Western Canada during the second term of the school year. There were 15 students in the class; five 4th graders, eight 5th graders, and two 6th graders; six girls and nine boys. Students were engaged in whole-class discussion, group discussions, hands-on group activities, and science note-writing to explain their thoughts and/or experiment results. There was a teacher assistant present in classrooms. The classroom seating arrangement varied sometimes students sat at desks in rows, sometimes in groups, and sometimes on the carpet for whole-group discussions.

During the study, the context of the science curriculum was twofold; one was to implement the provincial science curriculum, and the other was to expand inquiry-based learning through preparation and participation in science fairs. First, the units of Light and Sound and Weather were taught as part of the provincial science curriculum. Throughout the units, the teacher strove to practice inquiry-based learning by providing questions and problem-solving contexts. Due to her own interests, educational beliefs, and teaching practice, she was dedicated to developing students' inquiry skills and interests in science. No textbooks were used but the teacher brought many science trade books into the classroom for students to explore in order to further their knowledge on certain topics. The teacher also used various video resources including science activity blogs, YouTube, Bill Nye science videos, among others. Students were given activity sheets with a big question, such as 'how does sound travel?' and were asked to write down their predictions, observations, and explanations about certain phenomena. These writing tasks were combined with hands-on activities and both small-group and whole-group discussions. Second, to expand the students' inquiry-based learning and to develop their inquiry skills, the teacher also organised a science fair and guided students to develop science fair projects as part of the science curriculum. When the teacher addressed inquiry skills in the lessons of Light and Sound and Weather, she also mentioned how those skills could be used in their science fair project. The teacher asked students to come up with their own research questions and guided them through the process of designing and conducting their own scientific research. In class, she asked students to share how their research questions and methods were decided and could be answered, how the investigation process was developing, and what they had found thus far. Students presented their topics, plans, experiments, and any difficulties encountered during their research with the other students. Students' projects varied in terms of topics and research methods. Some students came up with a hypothesis investigation about types of mould while others decided upon observation or information-based research in connection with Space and the Moon. The teacher explained the importance of variables and how to control variables for hypothesis-based research and also provided resources for information-based research, which was emphasised in other science lessons. In this regard,

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the provincial science curriculum and the science fair project were integrated to develop students' inquiry process skills. All students participated in the school science fair in groups of two or three. Only a few groups of students participated in the regional science fair.

Data collection and analysis

The qualitative data collected as part of this study included classroom videos, observation notes, and activity artefacts. Whole-class activities were observed and video taped and students' interactions during the school science fair were also video taped. To record classroom activities, two cameras were set up in the classroom. One camera recorded the whole classroom interactions while the other camera was set up near a group of four children. The specific group was chosen based on the level of the children's active participation (i.e. the group was very active in their verbal communication and interactions).

For data analysis, a two-space model of the whole-class discussion was adapted (Eshach, 2010). In this model, Eshach explains that the whole-class discussion could be analysed within the individual as well as the collective space. Individual students are processing their personal positioning which is also shared and processed in the collective space with peer and teacher interactions. Thus, speech acts and positioning need to be further analysed relative to the collective community interactions to understand the storyline of identity development over time. The following diagram (Figure 2) shows how individual cases are interrelated.

In each case, the interplay of the participants' position, speech acts, and storyline was examined since individual cases are always embedded in sociocultural contexts. Besides the individual-collective levels of case development, Mercer (2008) noted the temporality of the case within a whole data set. He emphasised the importance of examining the temporal relationship between classroom dialogue and curriculum processes in order to understand how learning and teaching take place in relation to lessons and activities. That is, a scene of classroom dialogue (speech act) can show the current phase of children's thinking and positioning in relation to sociocultural contexts such as curriculum and classroom culture. Temporality of positioning in each case is examined individually to understand science identity within the particular interactions and also collectively to identify the overall storyline of science identity development in students' understandings. To do so, it was critical to go back and forth in the classroom data between individual and collective spaces of positioning, interactions, and storylines in order to understand

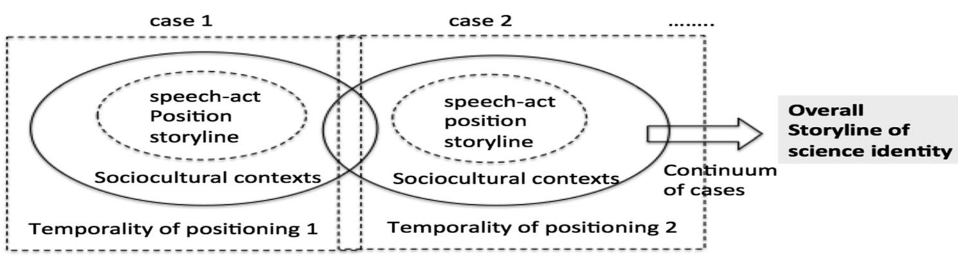

Figure 2. The framework of data analysis based on positioning theory.

students' learning and identity development. The teacher's efforts to position the students as scientists were evident throughout the study. Students also exhibited their understandings of doing science during class discussions and group activities. Among the dialogical interactions where the teacher and students explicitly mentioned science and scientists, four episodes were chosen to explain how science identity was experienced and acknowledged between the teacher and students in this study. These episodes were selected because they explicitly exhibit: (1) how the teacher distinctively acknowledged students as scientists and their work as the work of scientists, and (2) how the teacher and students together discussed the notion of science identity temporally and collectively over time. The moments of positioning were analysed in relation to the whole process of identity development through analysing speech acts and storylines in the science classroom.

Findings

By exploring classroom interactions, this study examined how the students and teacher positioned themselves and others in the context of science learning and science identity. The triad of positioning, speech act, and storyline of science learning will be explained relative to individual episodes and in relation to science identity development as it occurred during the study. Each of the four highlighted episodes exhibits stories of students' and the teacher's positioning through collective dialogue.

Positioning students as active learners

The teacher in this study was keen on using inquiry-based teaching to enhance students' inquiring minds and scientific attitudes. She organised various science activities to include questions, experiments, demonstrations, and group discussions in ways that would enhance students' thinking and skills when doing science. She often started the lesson with a big question supported by a demo to create feelings of wonder about why things happen and to help students learn how they can test to know. The following episode demonstrates one such classroom event in which the teacher led students to wonder 'why and how.'

Episode #1

The teacher introduced a number of different boomwhackers – all the same length but with various diameters and different types (wrinkled and not wrinkled) – to bring students' attention to the concepts of wavelength and pitch. She started the class discussion by asking about the different pitches the hollow plastic percussion tubes would make; 'I've got a couple of boomwhackers. Help me out, guys. If I bang this tube, will it have a higher or a lower pitch than this tube?' Then the students and teacher took turns discussing how different tubes and actions would generate different pitches. The students suggested ways to create different pitches such as blowing, twirling, whistling, and banging the boomwhacker on the floor and also demonstrated these methods in front of the class. When one student twirled the tube to create a different pitch, upon hearing the sound the

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students started to reason why there were differences in pitch. Then the following conversation took place.

Speech act 1–1

01	Kelly:	Oh, by going different speed of rotation …
02	Teacher:	What's the difference between this compared to that?
03	Olive:	The faster you go, the higher the sound is
04	Kelly:	It doesn't work as well as that one
05	Max:	A little bit
06	Kelly:	It makes a little volume. That one makes more
07	Teacher:	Does that change pitch?
08	Travis:	Because, I think it vibrates off in a different wavelength and then it (mumble), and also that one's bendy
09	Teacher:	Ok, I'll tell you what. What I'm gonna do is I'll give each group one tube like this and one tube like this … (Safely) wing it around and see what different kinds of sounds you can get, out of this one and, I don't know, maybe this one won't, maybe this one will only make one pitch, this one seems to make more than one pitch, ok … yeah?

In this speech act, students expressed ideas about speed of rotation (turn 01, speech act 1–1), the relationship between speed and pitch (turn 03), shape and volume (turn 06), pitch and wavelength (turn 08), and the shape of the boomwhacker (turn 08) to explain why there were different sounds. The teacher only raised questions to help students' thinking and reasoning (turn 01, 07). Rather than explaining what's happening during the twirling action, she wanted students to explore their ideas while experimenting with the boomwhackers (turn 09). When she was about to distribute the boomwhackers, students continued their discussion about why and how different sounds could be made.

Speech act 1–1 contd.

10	Kelly:	It seems to go better out of that one.
11	Olive:	Maybe when you twirl it in different places.
12	Aaron:	Maybe when the sound waves travel through it 'cuz there's bumps in it, maybe they kinda get split apart.
13	Teacher:	Ahh, ok.
14	Kelly:	And then they echo off.
15	Olive:	I think it like, bounces more.
16	Kelly:	The echo on the …
17	Teacher:	So you think the extra little folds in here kinda make it louder? Ok.
18	Travis:	Umm, the, when you're swinging it around, um, the vibration or the waves um, are getting hit off the side 'cuz you're turning it around, so that's what makes the difference and then when you go slower, they're not hitting as much, as much of the sides, that's why it creates different pitches.
19	Teacher:	Ok, when the pitch is higher, what's happening with the sound waves?
20	Travis:	They're going faster. And faster.
		… (speech turns omitted)
24	Ann:	Um, maybe it would make a different sound if you, um, the 2 crinkly ones, they can, I think they can attach, what if you attach them and …
25	Teacher:	You made a super, super long one? We would have to experiment with that wouldn't we? See? You guys are thinking of things that I didn't even consider.

Throughout this speech act, students shared their reasoning about why there were different sounds based on the shapes of the boomwhackers (turn 10, 12, 18), sound wave travel and vibration (turn 12, 18), bounce off and echo (turn 14, 15, 18), and the length of tube (turn 24). They collaboratively came up with the idea that wrinkles (bumps) on the tube would affect the sound waves and speed and create different pitches, then later the length of tube would also make differences in sound (turn 24). The teacher positioned students in the centre of the problem-solving and she only added questions to confirm students' ideas (turn 17, 19). Later, students were encouraged to test their ideas in groups. The teacher acknowledged that students were good thinkers (turn 25).

Students picked up their boomwhackers and started their experiments in groups. They were very active to test, observe, and share their interpretations during the experiment. The teacher circulated amongst the student groups and provided questions and comments to scaffold students' experiments. Students came up with an idea about how the air moves in the tube to make sounds. They tried to seal one end of the tube with a plastic bag and made predictions about what would happen. An example of teacher–student interactions during the group work is as follows.

Speech act 1–2

01	Aaron:	Watch. This way goes in better.
02	Teacher:	Does it? Which way do you think the air is going through the tube?
03	Aaron:	Probably goes in there because when you go like that …
04	Teacher:	I wonder if there's a way we could test that. What do you think? Yeah? Ok, turn around, tell David what you think.
05	David (TA):	Where do you think the air's going?
06	Aaron:	I think it's going in, and it's … since this side's kind of like a cup, it goes in and makes it louder, but, um, if you do it this way it doesn't really work because it's just a tube and the air isn't going in as much, or if the air isn't going in here then it could go up here and kind of project the sound louder, through here. So either way it would work but I don't know which way the air's coming through.
07	David:	Cool! So that's what we get to experiment with. Awesome.

During their group work, the teacher repeatedly asked students to explain why and how. When students expressed ideas, she asked them how they know and how to test them (turn 25 in speech act 1–1 and turn 04 in speech act 1–2). The teacher encouraged the students to test their ideas and students attempted various ways to test and make different sounds. When students were back on the carpet, they shared their findings with the whole class and the teacher continued to further invite students' thinking and explanations. She encouraged them to share their observations and explain their thinking by asking questions, sharing her ideas, and repeating what students said throughout the classroom conversation in order for students to understand the science concepts of pitch and how boomwhackers make different pitches. Throughout the activities and conversations, she positioned the students as active learners and knowledge builders in the centre of problem-solving, rather than solely as listeners or passive knowledge receivers.

In this episode, the storyline of science learning is that the teacher positioned students as active inquirers and problem solvers who could think and come up with test designs and explanations on their own. The storyline is also of how student thinking can include ideas beyond those considered or offered by the teacher. The teacher acknowledged the possibilities in their ideas and encouraged them to test them. Through this process, students in

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this storyline are creating new ideas in a process of problem-solving and the teacher's role was to facilitate their wonder, thinking, exploring, and explaining.

Positioning Scientists and Students in Research

The teacher participant in this study often used the term 'scientists' to identify the students. Whenever students were engaged in questioning and problem-solving, she positioned them as scientists by sharing what's expected in being and doing like scientists. Along with the provincial science curriculum, the students were also working on science fair projects during the study in order to develop their science inquiry skills. The science fair schedules were introduced at the beginning of the term and students were encouraged to choose topics and plan their research. The teacher discussed with students how their projects could be developed and conducted. During the discussion about project planning, she provided examples of science fair projects and explained the importance of variables in science experiments. For instance, she mentioned, 'In this instance, that variable … that variable isn't a problem, but that is a really good point. In experiments, you want to vary just one thing' while they were discussing the ways of testing hypotheses. Students shared their ongoing projects with the teacher often so that she was well aware of the evolution of their projects. The following episode is from a classroom conversation when the teacher asked how students' experiments were progressing:

Episode #2

Students had worked individually or in pairs on science projects for a few weeks. When the teacher asked them to share their projects with the class, students explained how much progress they had made and how anxious they felt about not getting the clear results as they had expected. The teacher and students talked about how they controlled variables in their experiments and the students expressed worry about the mistakes they had made in the process. They explained they were not getting the right results due to their mistakes. For example, Edith shared the difficulties of her research. She wanted to study 'mould on white and brown bread' but none of breads in her experiment grew much mould. When she shared the problem, the other students and the teacher together suggested different plans to test different bread brands from the grocery store as well as those with and without preservatives. The teacher shared what she knew about scientists' research and encouraged the students not to be afraid of making mistakes or of not having clear answers at the end of their project because that's how scientists work, too (turn 01, 03, Speech act 2).

Speech act 2

1	Teacher:	Often at the end, if you read a scientific article, you get to the end where scientists say well, we did this, but we don't know why, so we will do another experiment and try this, what we need to do more research. Right, David, when you read a lot of science articles?
2	David (TA):	Yap. Exactly.
3	Teacher:	That's what scientists do all the time. Every single study I read was like that (scientists explain what they could test further at the end of their research papers).
4	Edith:	Speaking of mould, in my experiment, we tried it in jars, it didn't work, and guess what? White sugar didn't but brown sugar started to change into mould.

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5	Teacher:	Really? Wa, that could be another experiment why brown sugar got mouldy, and white sugar didn't. Interesting.
6	Travis:	Like myth busters say, any results are results and failure is always an option.
7	Teacher:	Exactly, that's a nice way to put it in … .
8	Jay:	We tried different chewing gums … (mumble, inaudible)
		(Students share their project. Turns omitted.)
14	Teacher:	Absolutely. You know, sometimes scientists do an experiment and they … it fails so they try something and it didn't work out but then they go, oh! It didn't turn out the way I expected but wow, I can use it for this. I can give you an example. Some guys were trying to make some kind of glue but they found the glue … it just peeled right off and others found it's very handy, you can stick it somewhere and you can peel it off when you are done with it … It was an accident, they didn't plan it, but you're right, it was something unexpected and somebody went in (pointing her head) and think outside the box and made something creative I didn't expect.
15	Kelly:	Um, and also if your experiment doesn't work, don't just quit, like, maybe you did something,
16	Travis:	(over Kelly's talk) Try again with something else.
17	Kelly:	Yah!
18	Teacher:	Ah! Good for you guys. I am glad nobody was so discouraged, like ugh, I don't want to do it. I am glad you tried again and tried something new and you learned from what didn't work. That's awesome, that's really good science.

In this episode, the teacher attempted to encourage students to understand that making mistakes is part of doing science and scientists *do* make mistakes. When Edith shared her unexpected results on sugar types (turn 04), the teacher suggested another possibility of research (turn 05). Students explained how they could accept mistakes in science (turn 06) and what they could learn from making mistakes (turn 15, 16). The teacher reinforced their ideas by explaining that scientists also make mistakes and encounter uncertain and unexpected results in their findings so they often repeat their experiments or try different ways and variables to solve problems (turn 01, 03, 07, 14, 18) and she told the real-life story of the invention of the sticky note that resulted from making mistakes (turn 14). Students said they should not just quit their projects but continue to work on them with different ideas (turn 15, 16). After this episode, students continued their projects, still sometimes making mistakes and retrying, and in a few weeks, presented their projects with expected, unexpected, or incomplete results in school science fair.

Throughout the class conversations about the science fair projects, the teacher focused on motivating the students to be excited about doing their projects like scientists. She had regularly overseen the progress of students' group projects by encouraging them to design a test for their research question and to continue their research with enthusiasm, curiosity, and perseverance. They further discussed the importance of control variables to provide evidence in science. Throughout her guidance on their science fair projects, she continued to encourage students by saying, 'You are good scientists as long as you research and learn from it regardless of the results.' When the teacher encouraged students to participate in the regional science fair, some students expressed their fear about performing. The teacher further acknowledged them for being good scientists and doing good science by going

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through the challenges of science inquiry. At this point, the students were getting ready for their final reports:

> Teacher: They (the judges) know you guys are in the youngest category, Grade 4, 5, 6, so they understand, they don't expect you to know super, super, but you guys are pretty good scientists, you can do pretty good science.

In this episode of science as a process of trials and errors and perseverance, the teacher acknowledged students' work as being similar to scientists' work and expressed how the students were also good scientists as they continued their work by overcoming difficulties. By positioning students as scientists who make, and learn from, mistakes and repeat their experiments for better understanding, she encouraged them to learn how to do science like scientists. Here, the storylines of science are shifting from getting the 'right' results in experiments to learning from their mistakes and persevering in their efforts to better understand their work. Throughout the study, the teacher emphasised the process of thinking about why something happened more than what's right at the end of students' science experiments. She kept reminding the students that science is an ongoing process of questioning, thinking, and testing to find answers.

Teacher positioned as scientist

In this study, the teacher attempted to model 'what it looks like to do science' together with her students. She started with statements like 'let's do science' or 'let's think like scientists' and shared some questions and wonders and asked for evidence. When a new topic and question emerged in class, the teacher asked students for help to find answers together. When questions emerged during class discussion, she recognised the question in front of the students by identifying and repeating the question and asked students to suggest ideas to solve the problem together. In front of the whole class, she often expressed her own curiosity, raised relevant questions, and suggested possible ways to find answers in order to orient the whole class to becoming problem solvers. This kind of teacher modelling (questions-wondering about possibilities-testing-explaining) was repeated several times in class. During these classroom interactions, she positioned herself as a problem solver together with the students ('let's think about it together,' 'I didn't know that. What about this?' etc.) and students also viewed her as a scientist. Students acknowledged that the teacher was doing science or being a scientist. The following episode illustrates one of the moments that students acknowledged her actions as a scientist.

Episode #3

The class started a new unit about Light. In the episode below, the students and teacher had a discussion about how light travels. The teacher began with a question about how light travels, and the students and teacher then reviewed the concepts of photons, light reflection, and how light travels in straight lines by using models of photons and human eyes. After this, the teacher brought out a laser light, projected it onto the wall and asked, 'What's going on with the photons from my laser? Why can't I see the photons between here and the wall?' The teacher and students made a comparison between how sound and light travel in the air and came to the idea that light does not need air to travel. Students expressed many ideas based on their experiences, guesses,

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and observations from previous lessons such as gas particles, light from stars in space travel, and vibration. The conversation between the teacher and students lasted about eight minutes on one particular topic: what air does and does not do in laser light travel.

During the conversation, the teacher questioned and gathered ideas from the students to reach desirable answers. After about eight minutes of brainstorming, she asked them repeatedly, 'What does air not do?' (turn 01, 04, 06 in speech act 3), and 'What is the wall doing to the light right now' (turn 04)? The conversation continued with several turns between the teacher and students and showed both their collective excitement and patience to arrive at scientific explanations. When the brainstorming was about to end, Edith spoke out loud with excitement that the teacher was turning into a scientist (turn 09).

Speech act 3

01	Teacher:	Ok. So what does air not do, guys? Look. Here's the light source, and that's where I'm seeing it … I'm not actually seeing it until it hits a wall.
02	Edith:	It doesn't … it …
03	Travis:	'Cuz air doesn't affect it.
04	Teacher:	What does air not do? What is the wall doing to the light right now?
05	Edith:	It's reflecting it.
06	Teacher:	um … What does air not do?
07	Olive:	It doesn't reflect it!
08	Teacher:	Ok, now. (She was moving toward her desk.)
09	Edith:	(Looking at the teacher) You're turning into a scientist!
10	Teacher:	(Proudly) I know! Really.
11	Travis:	Yeah!
12	Cory:	It's a disease. (A few students repeat '"disease."')
13	Travis:	It's a good disease! Science is awesome.

After students answered, 'Air does not reflect it[light],' the teacher said, 'Ok, now' (turn 08) and moved toward her desk. Edith had actively participated in the class discussion to explore how light travels in the air and now she was excited to move onto the next step. She then exclaimed her realisation that the teacher was turning into a scientist (turn 09) as the teacher was herself going through a process of testing and questioning further ideas. The teacher patiently and persistently asked questions to find the answers and now she was ready to test them. The teacher was getting some materials from her desk and questioned further. This action was recognised by Edith as science and a clear way to *be* a scientist. Other students also repeated it with excitement and made a joke that being a scientist was a good disease (turn 11, 12, 13). After the conversation (speech act 3) ended, the teacher brought out a cloth full of chalk dust and shook it around the laser light. Students then observed a red sparkling line highlighted by the dust. They concluded that air did not block or bend light, learned that particles in the air reflected the light, and that those particles also showed that light travels in a straight line.

How light travels was a challenging concept to teach and to learn. The whole conversation between the teacher and students took about 15 minutes of questions and answers until students came up with some scientific explanations. This process was long and required much thinking and patience to reach answers. The teacher's persistent action to find answers through questioning and testing ideas was recognised as the work of a scientist by the students. Indeed, the students positioned the teacher as a scientist and the teacher also accepted the specific position. She modelled a scientist as someone who

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asks questions and seeks answers through testing with patience, determination, and excitement.

Positioning students with ownership of problem-solving

This section shows the tension between the teacher and students in terms of the duties and responsibilities of the teacher and students as scientists, teacher, and learner. Expecting students to take a position of scientist, the teacher asked her students to think and solve problems by themselves by taking ownership of their learning. Yet, this positioning act was overwhelming for students when they eagerly wanted to get answers from the teacher and also challenging for the teacher to make pedagogical decisions about guidance in inquiry-based teaching. The following episode demonstrates this tension between the teacher and students.

Episode #4

Questions emerged during class activities and discussions that were sometimes not easy to answer even for the teacher, such as how do we know what is happening in the air when there is a sound or why orange reflects only orange colour. When students asked such questions, the teacher asked a subset of relevant questions that could lead students to find the answer to their original question. Yet, sometimes the process of finding answers seemed challenging and the students asked the teacher to provide them with answers. They expressed their frustration at not having an answer when conversational turns between the teacher and students were taking what they perceived to be a long time. The following conversation illustrates one such moment. The class topic was on white light and the class was discussing how mixed colours became a new colour. After a long turn taking about mixed colours, the teacher projected blue, red, and yellow lights to create white light on the interactive whiteboard and asked students to explain what they observed and what was happening. Olive became frustrated with the puzzling notion and said, ‘You are supposed to tell us. You are the scientist,’ and insisted twice that she wanted answers from the teacher. However, the teacher answered, ‘No! My job is to help you figure it out.’ Then, rather than providing direct answers, she provided scaffolding (guiding) questions, comments, affirmation, and resources to help the students gather information and reason to find answers.

Another example of students’ positioning of teachers as the knowledge expert is as follows. During the class discussion, a student asked, ‘How does an object get its colour in the first place?’ Another student added, ‘Yeah, why does this object always reflect green? Why?’ Students became very curious about this and the teacher also acknowledged it was interesting and worthwhile as a research topic. While sharing their ideas, students talked about dyes from natural sources and synthetic chemical colours. Edith then jumped in and talked about getting colours from wild berries (turn 01 in speech act 4). Following this, the teacher asked again how grapes get purple. Still not having clear answers, Travis asked for the teacher’s theory (turn 03) but the teacher again insisted that the students needed to think for themselves (turn 04).

Speech act 4

01	Edith:	Oh, if you want to make purple crayons, you could also get some wild berries and crush them.

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02	Teacher:	Yeah, then why are some grapes still purple?
03	Travis:	I have a question. What is your theory?
04	Teacher:	Haha, I'm not telling you that. It's not my job. My job is to make you figure it out. Yes?
05	Travis:	What? (Laughs)
06	Olive:	If something has all this one thing. Everything has one thing. What was you said … ?
07	Teacher:	Atoms?
08	Olive:	Maybe different kinds of atoms are different colours?
09	Teacher:	You think different atoms might have different qualities?
10	Travis:	Possible. It's completely possible, actually! Different kinds of atoms have different kinds of properties. If you crush up blue rocks, you crush the atoms, then, yeah?
11	Jacob:	Maybe there are natural materials with natural chemicals which reflect that colour and they will reflect. If they want to make blue dye, then they choose a chemical that reflects blue light. Does it make sense?
12	Teacher:	So he has an interesting theory. So if they wanna red dye, they choose chemicals that reflect red light.

When students encountered a longer conversation resulting from a very challenging question, they asked the teacher to give them the answers. In the dialogue above, Travis asked what the teacher thought about why objects get their colours. The teacher asked them to think (turn 04) and Olive came up with a question about atoms (turn 08), which developed into ideas about the properties of atoms (turn 10–11). Travis and Jacob then considered the idea that objects have natural chemicals of colours as intrinsic property and this makes objects have their own colours. Students got excited about their capacity to theorise through collaboration. The teacher mentioned the smell of copper as another property of copper and repeated students' ideas to summarise the conversation (turn 13, below). Olive proudly recognised her contribution to finding the theory in the class conversation (turn 14). The teacher acknowledged her work as a scientist's work (turn 15) and Olive accepted it (turn 16).

Speech act 4 cont'd.

13	Teacher:	Copper has a certain smell to it. Yeah? So if things have properties, right? And one of the properties is colour. I think Travis has kind of hit it on the head, right? So you're going to mix different chemicals that have the properties of the colour that you like, so … when the painters were making a paint, they would crush up different types of rock as well that had colours?
14	Olive:	Yeah. And I helped by coming up with anything I can.
15	Teacher:	That's good. See? You're a scientist.
16	Olive:	(Smiling) Yeah.

In this storyline of Olive's positioning act and Travis' request for the teacher's theory, the teacher was being positioned as a scientist and knowledge expert who was expected to provide answers. Yet, the teacher, by saying, 'That is not my job' (turn 04), explicitly positioned students as problem solvers who had the duties and responsibilities to find answers. Tension emerged from time to time between the teacher's and students' positioning, particularly when the problem-solving became challenging. Under this tension, the teacher confidently redirected the question back to the students and facilitated a class conversation with ideas and guiding questions. When she suggested an idea, she said, 'This is a thought.

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This is to make you think and apply,' or when she demonstrated something, she said, 'It's not to show you that. It's to make you think.' She reserved her own answers until students found key ideas to questions through their own thinking and conversations. She emphasised the importance of thinking and working through the problem together and helped them realise this collective act as part of science. By doing so, she positioned students as scientists in the centre of collaborative problem-solving and positioned herself as the facilitator whose responsibilities lie in guiding and motivating students' work pedagogically. This positioning act was also reflected in students' discussions during group activities. For example, when they were making a mirror device, students ran into a problem with light reflection angles. When Edith eventually figured it out and said, 'We made it!' Kelly, who working beside her, replied, 'Like scientists! It was so hard but we did it.'

Compared to the stereotypes of science and scientists defined earlier and those repeatedly found in other studies, science in this classroom was a process of thinking and problem-solving with patience and perseverance and working together. Their recognition of thinking and working together as 'science' is a deviation from the stereotypical storyline of scientists that is encountered in many school science classrooms.

Discussion

Developing students' science skills and positive attitudes toward science is critical for scientific literacy and for the future of our societies. Yet, research shows that many students hold naïve views of science and as a result distance themselves from science (Archer et al., 2010; Tai et al., 2006). In science classrooms, it is challenging to develop students' science identity imbued with the qualities of curiosity, wonder, perseverance, scepticism, and open-mindedness. This study explored how science could be perceived and discussed differently from the naïve and more stereotypical views of science in the classroom. It examined particularly how a teacher and students positioned themselves and others in science learning contexts and developed science identity through these positioning acts. Based on the findings, this section will discuss two collective and new storylines of positioning with/in science identity in science classrooms: (a) how the teacher's positioning acts were deliberate and distinctive to develop students' capacity to think like scientists within the complexity and requirements of the mandated curriculum; and, (b) how potential conflicts and negotiation of science identity need to be taken into consideration in inquiry-based science classrooms.

The teacher's acts of positioning

In this study, the teacher's facilitation was deliberate and effective to develop students' science identity. Her positioning acts explicitly put students into the role of scientists and she expected them to take up the role of becoming problem solvers. The teacher and students positioned each other, and were variously positioned, as teacher, learner, researcher, and problem solver throughout the classroom interactions. They did not always hold the same positioning at the same times, nor did the students, in particular, take immediately to the ways in which the teacher was trying to position them. As the teacher attempted to help students solve problems with confidence, willingness, and enjoyment as part of developing their science identity, students were sometimes frustrated and concerned about not getting the ‘right’ answers. This challenged the teacher to reflect on how to respond to and remind the students about doing science and seeking knowledge with willingness, perseverance, and patience. The teacher’s efforts to position and reposition students toward their science identity were evident through her facilitation during classroom discussions. The teacher deliberately referred to the students as scientists and asked them to act like scientists who raise questions and seek answers through research. During the science fair projects, she explained what scientists do and what kind of challenges they encounter in their own research. Through her emphasis on mistakes/errors, uncertainty, and accidental findings in scientists’ work, she explained that the difficulties the students had encountered during their science projects were also shared by many scientists. During class problem-solving discussions, she told students that they, as scientists, needed to think and figure things out with patience and collaboration. She acknowledged the importance of thinking during their classroom discussions by saying, ‘Listen and think carefully,’ ‘I am here to help you think,’ and so on, when the students encountered and solved challenging tasks. She often overtly positioned students as scientists in classroom talks by saying things like, ‘You are scientists,’ and ‘You are doing good science.’ When Olive proudly expressed her contribution to the class problem-solving efforts, the teacher acknowledged her collaborative efforts to find answers as the work of a scientist. Further, the teacher positioned herself as a scientist by modelling curiosity about phenomena, raising questions, proposing and testing different ideas, and by being excited and baffled about new and unexpected outcomes in front of her students. She demonstrated perseverance in her consistent pursuit of questions over many turns of class conversation. Based on the conversation, she attempted to test the ideas being discussed. This led students to acknowledge that she was acting like a scientist. Throughout the teacher’s positioning of herself as both a facilitator and a scientist, students joined the classroom discussion with curiosity, excitement, frustration, and patience. They acknowledged their efforts at problem-solving through classroom interactions as *doing science* and thus storylines about being scientists in classrooms began to emerge. These new storylines defined scientists as collaborative problem solvers and knowledge seekers and tied those qualities with feelings of excitement, frustration, and perseverance.

Yet, there were also conflicting moments of positioning. When the students turned to the teacher and asked for answers by positioning the teacher as scientist and knowledge holder, the teacher often redirected the question to the students by saying, ‘You figure it out’ and ‘It is not my job to tell you.’ As she deliberately encouraged students to take ownership of problem-solving as part of doing science, she was concerned that students might be leaning on her to get the right answers. Yet, she was also anxious for her students to develop the science content knowledge that met the curriculum. In this conflict, it was evident that the teacher’s positioning act was also intricately practiced between the requirements of the mandated curriculum and her own beliefs in science identity through students’ own inquiry practice. In this complex situation, the teacher chose not to directly give out answers, but to guide students’ problem-solving by providing various pedagogical strategies, such as relevant questions, demonstrations, examples of everyday phenomena, affirmation of ideas and injection of further analogies and examples to help students reach scientific explanations. For instance, when students encountered difficulties in understanding the science concepts of colours, the teacher led the students’ discussion into the properties of chemicals by adding more questions, relevant science

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concepts, and examples of colours in everyday life to encourage students' thinking and reasoning. She also suggested Travis's idea as a key concept to lead the students to think further along that particular idea. In this process, she asked the students to find answers by positioning them as scientists; yet, she actively and deliberately guided the students to do so with scaffolding strategies.

Rethinking science identity in inquiry-based classrooms

Teacher positioning acts profoundly influence how student identities are co-constructed through teacher–student interactions over time (Brown, 2004). When teachers position students in certain positions, they also encourage students to understand certain duties and responsibilities of the positions and take actions accordingly. Thus, the position acts can affirm students' agency as certain types of learner to engage in purposeful actions and transform learning actions with certain responsibilities and duties (Hall et al., 2010). When a teacher positions students as passive learners and knowledge receivers, the resulting instructional goals, choice of activities, and classroom interactions with students are less motivational, less engaging, and thus negatively influence students' learning (Kim & Viesca, 2016). Throughout this study, the teacher attempted to promote science identity by positioning students as scientists, active inquirers, and problem solvers. Yet, the teacher found these positioning acts to be sometimes a challenging process as she recognised and consistently negotiated the students' science identity along with her beliefs and practices relative to teaching science as inquiry within the mandated curriculum. Positioning students in the centre of problem-solving, she expected students to experience the nature of inquiry and develop their science identity. When students asked her for answers, she put the responsibilities of finding answers back to them in order to emphasise science identity. Yet, as inquiry facilitator and curriculum practitioner, she also responsibly guided the students throughout the problem-solving process by inserting questions, examples, and comments. The space between her initial response to the students (do-it-yourself) and follow-up actions (facilitation) raises some pedagogical questions. Why did she say 'figure it out by yourselves' out loud, yet actively guide them through their inquiry? As she reflected later, it was a challenging moment of decision-making and action taking when she was asked by students to give the answers. She experienced a momentary hesitation and concerns about giving answers, which would lose the nature of inquiry and attaining students' science learning through problem-solving.

The pedagogical conflict and confusion of instructional guidance often emerges in the discussion about inquiry-based learning (e.g. Dean & Kuhn, 2007; Klahr & Nigam, 2004). The inquiry approach encourages students to 'inquire' into phenomena and find answers through research and problem-solving by themselves, and in this process students' science identity is expected to be experienced and developed. Yet, inquiry-based teaching has often been confused with discovery learning whereby students by themselves discover and build knowledge as if scientists discover theories through their scientific investigations and without drawing on history and previous theories, research, and investigations. Students in discovery learning classrooms are expected to act like scientists by investigating and understanding science with minimal guidance from teachers. Teachers may assume that inquiry-based teaching as students' discovery learning with minimal guidance promotes

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science identity among students. Researchers state that teachers often confuse authentic inquiry teaching with discovery learning and do not provide students with enough instruction for learning science through problem-solving (Kirschner, Sweller, & Clark, 2006). Yet, a discovery approach with minimal guidance has been discussed as an ineffective way of science teaching and learning as students' cognitive development requires specific instructions to develop long-term knowledge for future problem-solving (e.g. Kirschner et al., 2006). Hmelo-Silver, Duncan, and Chinn (2007) explained that the inquiry approach is different from discovery learning and it necessitates appropriate scaffolding and facilitation strategies for students' learning. Tactful inquiry instructions are necessary to help students experience and learn the culture, practices, and conceptualisation of science. This requires us to rethink the relationship between science identity and a teacher's guidance in inquiry-based classrooms. Given that an inquiry approach needs to be practiced differently from discovery learning, what does 'students as scientists' look like in inquiry-based classrooms? What kind of positioning act do teachers practice and what storyline of science identity do we want to bring forth?

Researchers note that appropriate scaffolding is not easy for teachers to conceptualise and practice in classrooms (Hmelo-Silver et al., 2007). It is challenging to decide what, when, and how to position students as active learners, inquirers, and problem solvers in order for them to feel and act like scientists. This study shared some examples of a teacher's positioning acts and facilitation that embedded the conflicting moment of science identity, curriculum, and guidance in inquiry-based classrooms. The teacher positioned her students in the centre of problem-solving in order to develop their science identity, yet her desire and beliefs in facilitation were also evident through the inquiry process. While explicitly emphasising scientists' own work to the students, she implicitly but purposefully guided students' problem-solving. Whereas the teacher's positioning act verbalised and acknowledged the science identity as associated with questioning, thinking, and investigating with perseverance, enjoyment, and collaboration, the teacher's facilitation acts made this possible to be experienced and move forward. In the process of positioning and facilitation acts, science was not all about discovery work through hands-on experiments but a complex process of inquisition, collaboration, communication, and emotional engagement. As many educators would agree, while inquiry and problem-solving can help students develop science identity, we may need to closely examine how we 'position and facilitate' students to experience, learn, and do science in order for them to develop science identity going beyond the mainstream stereotypical views of science.

Closing remarks and limitations of the study

This study suggested *one* possible way of understanding and developing students' science identity in classroom interactions. The teacher's positioning acts were shown to be critical to develop a new story of science and science learning beyond the dominant stereotypes of what it means to be a scientist in classrooms. As the study focused on teacher–student positioning acts about scientists and scientists' work as a collective, it cannot advise on any potential conflicts of individual experiences and identities of students, which would require further investigation. Also, this study only examined students' experiences of different aspects of science identity through classroom conversations and did not examine the development of students' science identity before and after the study. Therefore, the study is limited in explaining what part and how much of students' science identity were specifically changed or developed via the teacher's positioning acts through classroom interactions. With these limitations, this study can only suggest possible directions for further investigation.

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