

Engaging elementary students in learning science: an analysis of classroom dialogue

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Abstract Research over a long period of time has continued to demonstrate problems in the teaching of science in school. In addition, declining levels of participation and interest in science and related fields have been reported from many particularly western countries. Among the strategies suggested is the recruitment of professional scientists and technologists either at the graduate level or advanced career level to change career and teach. In this study, we analysed how one beginning middle primary teacher engaged with students to support their science learning by establishing rich classroom discussions. We followed his evolving teaching expertise over three years focussing on his communicative practices informed by socio-cultural theory. His practices exemplified a non-interactive dialogical communicative approach where ideas were readily discussed but were concentrated on the class acquiring acceptable scientific understandings. His focus on the language of science was a significant aspect of his practice and one that emerged from his professional background. The study affirms the theoretical frameworks proposed by Mortimer and Scott (Meaning making in secondary science classrooms, 2003) highlighting how dialogue contributes to heightened student interest in science.

Keywords Beginning teachers · Elementary education · Communicative practices · Language in science

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Introduction

In-service and pre-service teacher education programs strongly emphasise constructivist approaches, inquiry learning and active student engagement with hand-on activities in science. The influence of Vygotskian socio-cultural perspectives on learning promoted the value to learning of fostering dialectical relationships between the learner, language and context (Bruner and Watson 1983; Vygotsky 1962). Many curricula emphasise contextualised learning whereby the learner in a communal activity engages with real life problems (e.g., Bennett et al. 2007). Central to the interaction among learners in a classroom community is language and how language is used. The nature of social interactions between learners and their environment underpins a dialectical-social constructivism (Bruning et al. 2011; O'Donnell 2012). In constructivist-oriented classrooms, teachers support students to participate in activities where knowledge is situated and acquired by engaging in the discourses and social practices of communities (Mason 2007). Although constructivist approaches premised on active student engagement have been critiqued by advocates of direct instruction (e.g., Klahr 2009; Sweller et al. 2007), policies universally endorse implementation of strategies that by constructivist learning theories.

However, while many teachers endorse the general principles of constructivism (Levitt 2002; Snider and Roehl 2007), diverse conceptions of what constitutes constructivist approaches exist (Levitt 2002). Furthermore, studies have shown that implementing these strategies consistent with constructivism, particularly in elementary schools, can be problematic (Ramos 1999). Indeed, Levitt (2002) argued that “Mastering strategies consistent with the philosophy of science education reform is extremely complex” (p. 20) to which she added in terms of building expertise will “take years” (p. 20). To this body of literature we might add that implementing constructivist pedagogies may constitute yet another challenge to beginning teachers. This is an area seemingly devoid of research as asserted by Britton et al. (2012) in a recent review of beginning science teachers.

Among the strategies of effective science teaching practices include rich multilateral discussions among students. The assumption based on social-constructivist frameworks is that when students share and debate multiple perspectives, new sets of correspondences or contradictions to individual understandings can emerge. Students also become enculturated into the language and practices of the domain (Gee 2004). The study of classroom discourse has a long history and many studies of classroom discussions have been undertaken over the last five decades (Barnes and Todd 1995; Bellack 1963; Cazden 2001; Lemke 1990; Mercer and Littleton 2007; Sinclair and Coulthard 1975). For example, Bellack et al. (1963) suggested that teacher dialogue was manifested through “pedagogical moves” which included *structuring* moves that set the context by focussing on a topic, *soliciting* that involved questions to encourage engagement, *responding* that included students’ answers to questions and *reacting* where the teacher’s actions depended on the response given by the students. This and other work characterised the pattern of traditional classroom talk variously as initiating, responding, follow-up moves (I-R-F) (Sinclair and Coulthard 1975) or initiation-response-evaluation (I-R-E) (Mehan 1979). These bilateral exchanges between teacher and an individual student have been argued to represent ways that teachers maintain power in the classroom, transmit canonical knowledge and limit deep thinking by students (e.g., Kovalainen and Kumpulainen 2005; Lemke 1990). This approach contrasts with multilateral discussions where peer-to-peer discussions are encouraged.

Despite evidence of the importance of social context and dialogical interactions as significant contributors to learning, many classroom studies continue to show that teachers

adopt I-R-F/I-R-E bilateral transactions as their “default pattern” of discourse (Cazden 2001, p. 53). For example, even in early years classes in the context of science teaching Lee and Kinzie (2012) reported that teachers used “substantially more closed-ended than open-ended questions” (p. 871). Similar observations have been reported in elementary mathematics classrooms in Finland where transactions were primarily bilateral, that is, between teacher and individual student although more multilateral approaches were evident in philosophy classes (Kovalainen and Kumpulainen 2005). In a New England study of three upper secondary teachers’ patterns of talk during a series of lessons on a socio-scientific topic, the extent of multilateral discussion depended on whether the teachers were focussed on getting students to identify and provide evidence in support of an argument or to encourage conversations about their understanding of a socio-scientific topic (McNeill and Pimentel 2009). The teacher who was interested in students’ ideas adopted patterns of questioning that encouraged multilateral discussions. However, in contrast, the lack of a student voice was evident in a study of elementary grade where over 68 % of talk comprised teacher utterances (Reinsvold and Cochran 2012). When the teacher attempted to implement discussion through initiating a sequence of open-ended questions, there was silence and lack of student engagement. These studies show that engaging students in peer-to-peer discussions is difficult and the exception. Contributing factors to the difficulty appear to be the purpose that the teacher has in mind when initiating a discussion. However, teacher experience is also another contributing factor. In a case study of four teachers only the most experienced teacher appeared to encourage students to engage in extensive discussions and raise questions that challenged teacher explanations (Savasci and Berlin 2012). Thus, the literature presents a pessimistic view of the capacity of less experienced teachers to capitalise on pre-service education programs and prevailing policy imperatives to implement instructional approaches that actively engage students in productive dialogue that fosters learning.

This study examined the developing pedagogical strategies through the communicative approaches adopted by a career-change beginning teacher, Pat, who has substantial subject matter knowledge in science, technology, engineering and mathematics (STEM). The communicative approaches, we define as including the classroom discourses as well as the non-verbal activities and media resources brought to bear on the teaching of a topic, in this situation, an integrated science, social science unit. Our goal is not to evaluate the quality of teaching exhibited by the participating teacher but to document his teaching style.

The study sought to answer the following question: *What communicative approaches, practices and strategies characterise the teaching approaches adopted by a beginning teacher highly qualified in a knowledge domain of STEM?*

Theoretical framework

We examine Pat’s instructional practices at two levels. Our goal was to reveal the richness and purpose and the structure of classroom discussions. At a broad level we draw on the analytical frameworks of McGregor (2011) which provided a general description of the pedagogical approaches adopted by the teacher. At a micro level we examine the classroom discussions by drawing on the framework of Mortimer and Scott (2003). This framework examines communicative approaches that provide a perspective on how the teacher works with students to develop ideas in the classroom.

McGregor (2011) hypothesised that beginning teachers in STEM:

Initially employ pedagogic strategies that support more behaviourist learning (rote learning, repeatedly practicing for good performance, copying notes etc.). They may then extend their repertoire from didactic approaches, over time, to more constructivist and then more socially interactive ways of their pupils learning together. (p. 2)

In behaviourist approaches to teaching, strategies adopted by teachers are generally whole-class, focussed with knowledge transmitted where students are generally passive recipients of information and talk is dominated by teachers. Behaviorism in schools placed the responsibility for student learning directly on teachers and promoted the development of structured teaching practices (Jones and Brader-Araje 2002). Mortimer and Scott (2003) refer to this lecturing approach as non-interactive teaching. In mathematics education, Wood (1994) has described this approach as “funneling” and is characterised by the teacher selecting the teaching strategies and decision making to achieve a predetermined solution. In contrast, theories of learning expounded by Vygotsky (1978) and Bruner (1986) highlight the importance of social learning whereby learners develop understanding of a domain through interactive, social situations scaffolded by more knowledgeable others. Central to Vygotsky’s (1978) view of learning and dialectical-constructivism is that cognitive development stems from social interactions within the zone of proximal development (ZPD) as students co-construct knowledge. The ZPD represents the difference between what a student can achieve independently and what the student can achieve with guidance from a skilled mediator through language. Thus, the teacher assumes the role of social mediator to support students to acquire scientifically or mathematical meaning from their senses in context of the classroom. McGregor (2011) emphasises the role of the teacher as being a mediator creating a seamless connection between individual, social, historical and cultural processes by promoting collaborative learning through novice (students) and expert (teacher) working together. Knowledge is therefore situated within a real-life community experienced by the students. These latter approaches are seen to epitomise a dialectical-social constructivist approach to teaching (Mortimer and Scott 2003).

Mortimer and Scott (2003) characterised the nature of interactions between teacher and students along each of two dimensions: dialogic-authoritative and interactive-non-interactive expressed as four categories (Fig. 1). Teacher behaviours in the dialogic-authoritative dimension range from situations where the teacher accommodates and recognises multiple perspectives or “voices” and ideas are explored to where only one point of view—presumably the assumed correct answer—is accepted. According to Mortimer and Scott, what distinguishes dialogic from authoritative is the “fact that more than one point of view is represented, and ideas are explored and developed, rather than it being produced by a group of people or by a solitary individual” (p. 34). Dialogical discourses involve the acceptance of multiple points of view but the character of the interaction/communication changes as a teaching sequence progresses. For example, Mortimer et al. (2011) suggest that,

At the start of a lesson sequence, the science teacher might elicit students’ everyday views about a particular phenomenon. Later on, the teacher might encourage students to discuss how to apply a newly learned scientific idea to a novel context. In both cases, we can see the students agreeing or disagreeing on others, but working together to understand any points of difference as they develop their explanation. (p. 239)

In contrast in an authoritative discourse, the teacher although fostering multiple contributions during a lesson, only recognises and explores those ideas that contribute to an acceptable point of view with no consideration or elaboration sought on alternative views.

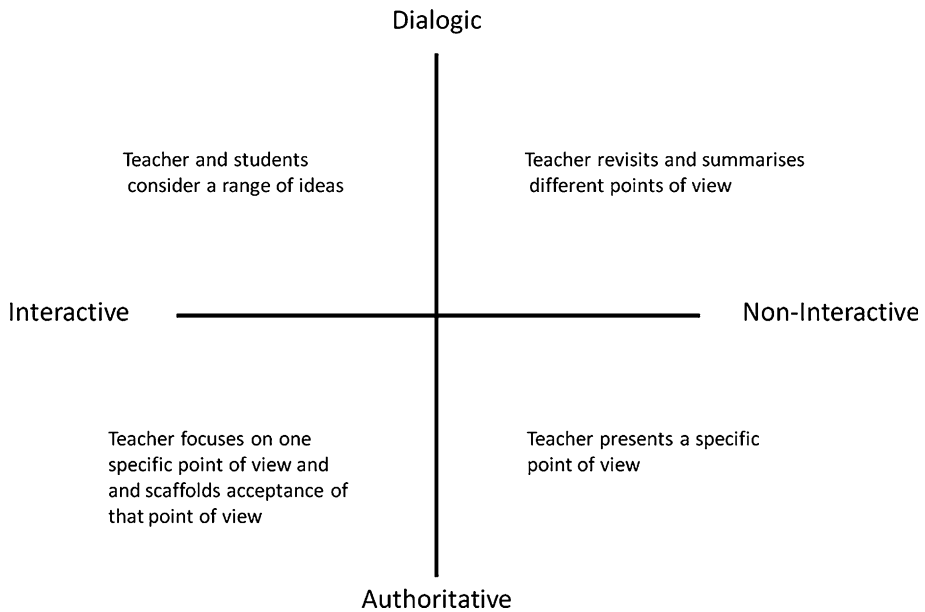


Fig. 1 Categories representing interactivity between teacher and students (Mortimer et al. 2011)

Positioning on the second dimension—interactivenon-interactive communication—is determined by the extent that interactions involve participation or exclusion of other people. Interactive discourse is characterised by opportunities for different speakers to contribute to the discussion.

Methods

This single embedded explanatory case study (Yin 2009) reported here was undertaken as part of a larger longitudinal study of career-change beginning teachers each with a background career in some aspect of STEM (Diezmann and Watters 2014; Watters and Diezmann 2013, 2015).

Participants

This paper reports the instructional practices of Pat, a career change teacher whose background was in applied human movement studies and in educational technology. Pat commenced his teaching career with a Year 5 (~9 year-olds) class in a metropolitan primary school before transferring voluntarily in his third year to a small remote country school, where he taught a Year 4 class. Pat's initial qualifications were in Applied Science in Human Movement Studies. Subsequently, he worked as an instructional designer in a university but also had prior experiences in the US working in holiday camps for children. At age 30, he decided to pursue a latent interest in teaching. His motivation was to seek a sense of career satisfaction. He saw the career change as a natural progression fulfilling a long held interest for which he felt well prepared “having the experience in the tertiary sector from a teaching and learning perspective and having that behind me certainly was a good stepping stone.” Pat

completed his teaching qualification, a one-year, middle years Graduate Diploma, which accredited him to teach from Years 4–9 across all subjects. Initially, he was appointed to a suburban government primary school teaching a Year 5 class (age 9 years).

Context

Pat's first class was in a medium size government school of nearly 900 students in a relatively affluent outer suburb of the state capital. Teachers in the school system where this study was implemented would rarely use text books and are encouraged to adopt different approaches suitable to the context of the school, for example, geographic location or ability. In Pat's words, he described the class as a "Year 5 class, 25 students, generally balanced in terms of gender—girls to boys, fairly evenly balanced. I would say that they generally are of a, you know, at least a sound C average—C to B average—sort of class... I have one child, who's ASD (Autism Spectrum Disorder), so I don't try and tie him to the general class work day to day—he's got his own sort of program." A "C" standard class in this jurisdiction is considered of average ability capable of meeting prescribed curriculum standards. English was the first language background of over 95 % of the children.

Teaching topic

In the schooling system, where this study was conducted, teachers have the autonomy to develop their own approaches, themes and topics as long as they address general standards mandated by the state education authority. The broad theme in which the first year set of lessons were embedded was on sustainability. Sustainability is an essential learning outcome at Year 5 level. This theme integrated literacy, numeracy, social studies and science. One topic that was chosen for the Year 5 class was invasive species. An invasive species is a foreign organism introduced either deliberately or by accident to a native environment where it becomes a dominant species at the expense of native species. This topic was a contribution to a theme that was co-planned by the four teachers in the school who taught that year level. Pat, because of his science background gave greater emphasis to science. His colleagues emphasised other subject matter such as literacy or social studies. In this topic Pat was trying to show how foreign organisms, be they invaders from outer space, introduced plants, or fungi can be destructive and threaten natural ecosystems. For convenience he used the analogy of bread being destroyed by fungi.

In his second year of teaching Pat chose and designed a unit on flight, a physics theme, and when he was relocated to the rural school he implemented a unit on the properties of materials, a chemistry theme.

Data collection

There were four data collection events over the three years of the study, (1) an initial 10–15 min telephone interview to obtain demographic and relevant personal data undertaken after two months teaching in the first year of the study, (2) at six months in this year the participant was interviewed using a semi-structured interview protocol adapted from the literature (Luft and Roehrig 2007; Richardson and Simmons 1994), and (3) a follow-up day-long session conducted approximately three weeks after the participant had completed videotaping six of his lessons. In years two and three of the study, (4) a sequence of five lessons were video recorded in the third term of the year by Pat followed by a one day

debriefing. Prior to debriefing, video recordings of his classroom teaching practices were reviewed and a preliminary analysis conducted to identify interesting events and practices to discuss at the debriefing sessions.

The debriefing sessions with Pat adopted an open-ended semi-structured format in which questions were guided by an interview protocol. Questions and prompts were used flexibly, being omitted, adapted or elaborated according to the prominence given to issues as they unfolded. Issues were often returned to at different periods of the interviews which lasted between 4–5 h which included refreshment breaks. A stimulated recall procedure was used in which video recordings of lessons were reviewed and salient events, interactions or teaching practices discussed. The events being recalled were selected by both researchers and Pat. Questions of a probing nature were posed to Pat at critical points in the videos such as “why was that happening”, “what were you trying to do?” “Did that work?” and so on. Questioning was used to promote a two-way dialogue in order to explore key themes addressing the teaching experience. Although stimulate recall has been criticised as a tool to probe cognitive processes as there is potential for participants to generate new insights not influential in their initial behaviours (Lyle 2003). However, we were interested in how Pat reflected on his interactions with students and stimulated video recall has been demonstrated to be an effective strategy to explore interactions between teacher and students (Rowe 2009).

Data analysis

As soon as possible after the sessions, field notes were prepared by one of the researchers and a research assistant. The debriefing sessions were audio recorded and transcripts of critical segments prepared. Data analysis proceeded through the following two cycles (Saldaña 2009). This approach acknowledges two units of analysis consistent with an embedded case study (Yin 2009).

The first unit of analysis comprised descriptive coding in which the interesting events representative of Pat’s teaching practices over the three years were segmented and categorised by both the lead researcher and research assistant in terms of McGregor’s (2011) framework. McGregor’s model was useful to assess the general characteristics that depicted Pat’s teaching. For example, episodes of teaching where the teacher gave instructions and dispensed or repeating information without discussion were considered representative of behaviourist teaching. Episodes dominated by the teacher providing challenging questions but expecting individuals to think about phenomena and provide individualised answers were indicative of constructivist approaches. When the teacher used open ended questions and encouraged students to discuss or share ideas with peers was described as socio-constructivist and finally when instances of encouragement for collective responsibility for learning and involvement of expert mentors the episodes were categorised as socio-cultural. There were no clear boundaries within these characteristics and often in the one lesson the teacher would shift from one mode to another.

A second unit of analysis involved both researchers examining transcriptions of lessons and coding using a priori codes drawn from the theoretical framework of Mortimer et al. (2011). To enhance coding reliability both coders familiarised themselves with the frameworks, and where there were discrepancies the differences were and codes revised to ensure that they were in line with the research questions and consistent across coders. Mortimer et al.’s framework provided a deeper level of analysis by aligning the discourse patterns and instructional approaches as discussed previously. Thus, behaviourist approaches of McGregor’s model would include communication practices that were non-

interactivelauthoritarian with the teacher presenting one point of view. Sociocultural approaches would incorporate communication practices where the teacher and students negotiated meaning with the support of experts or through access to sophisticated authoritative resources.

Results

The topic we report on here covered a term of about 10 weeks in Pat's first year of teaching. Through this topic, which integrated social science and science concepts, Pat wanted to raise students' understanding of introduced species, and in particular, that introduced species can be invasive and can be microscopic as part of an integrated topic on sustainability. Putting it into Pat's words his intentions as revealed in a post-teaching debriefing:

It is a bread mould experiment. So because the focus of the unit is on introduced species, in our initial research looking at introduced species the students were always concerned about, they could tell me what an introduced species was- they did the feral rabbit and the this and the that. And I was wanting to draw out through discussion that sometimes there are things you can observe, for example introduced species that you can see doing damage, either animals or plants. But in this experiment I wanted the focus to shift to something you don't see; an introduced species or an invasive species that you can't see or touch unless you obviously use microscopes. (Interview 2009)

The sequence of lessons that formed the focus of this analysis commenced with students reviewing their knowledge of invasive species, and then setting up an activity to observe the formation of mould on bread as a model of an invasive organism. The students' desks were arranged to form tables facing each other so that they could talk. The room was extensively decorated with science symbols and posters. The teacher used both a data projector connected to a laptop computer and the whiteboard for representing ideas. Given Pat's background in educational technology as an instructional designer, his use of multimedia and ICT tools was extensive. An overview of the five lessons that were recorded and his pedagogical approach is presented in Table 1.

Table 1 Pedagogical approaches adopted by Pat

Lesson	Approach
Lesson 1: As part of a broader cross-curriculum theme on sustainability, Pat implemented a biology lesson on invasive species and got students to set up an experiment to see bread mould develop as a model for invasive species. (50 min)	Constructivist/social constructivist
Lesson 2: (A week later) Students reported on the experiment, first in terms of a general morphological description of mould colonies, and then what could be seen at a microscopic level. (30 min)	Constructivist/social constructivist
Lesson 3: Students continued to examine mould under a microscope, drawing images and sharing observations (120 min)	Constructivist/social constructivist
Lesson 4: Exploration of food chains and a review of the position of various organisms including mould in the food chain (30 min)	Social constructivist
Lesson 5: Pat read a story of story of rosy dock (Jenny Baker) about invasive plants and made connections with real life phenomena. (40 min)	Constructivist

Fostering student interest and integrating disciplinary language and concepts featured strongly in his teaching approach. In the interview after the end of his first term of teaching, he described his interest in Science in a way that reflected his pedagogical approaches:

I'm always sort of inquisitive about science and always thinking about the way that things work and it's, I mean my background is in anatomy and physiology and you know those kinds of sciences. However all science interests me even though I don't proclaim to know lots about other strands of science but I think just having an inquisitive mind, be able to talk about science and use language that you know particularly in the science classes I've run here at school that kids can connect with and not be too jargon laden and really trying to spark their interests in sharing my desire to find out how things work so not forcing anybody, not forcing it upon people to necessarily be interested in science if it's not their passion but just sort of showing them that you know it can be fun and it can really help us to understand the world (Interview Year 1)

The emphasis in his teaching approach was to foster curiosity through language that connects with students. He elaborated further by saying:

So I try not to make it too obvious that we're always talking about science but just bringing in those sorts of ideas to students because, I mean, it's amazing what they notice in the world around them that relates to science as well as I kind of pick up on what they offer as well.

Now we categorise the approach adopted across five lessons that were part of a theme on sustainability adopted for the third term of the Pat's first year of teaching (Table 1). These five lessons focussed on the concept of invasive introduced species and disruption of the natural environment. The highlight of the set of lessons was the examination of the mould growth on bread as a model for invasive species. This was a topic that Pat had no significant knowledge of other than from his undergraduate courses.

The first lesson in the five lesson sequence was predominantly teacher-directed lasting 30 min. Students were seated at desks in small groups facing each other. Pat guided the students through a number of *steps* to achieve a desired outcome: that of setting up a slice of bread in a sealed bag with some moist paper towelling. About half the lesson time was taken up with the teacher posing generally open-ended questions, for example "Olive would you mind sharing some of the thoughts that you have ..." or "how did the mould get there?" Although these questions were targeted at students in an apparent I-R-F/I-R-E bilateral mode, it was common for several children to respond which Pat encouraged. Unexpected answers were acknowledged, often commented on, and recorded on the board. However, Pat frequently guided students to produce the "required" response by continuing to pose guiding questions. There was limited opportunity for any independent investigation and the task was tightly scaffolded. There was strong emphasis on developing vocabulary and the ideas were often linked to earlier lessons.

The second lesson was similar to the first lesson in that the teacher directed the processes. Nevertheless it was interactive. Students were led through a number of *lesson steps* to achieve Pat's desired outcome, namely to be able to describe and explain the growth of mould. For example, students were directed to examine the growth of mould on their samples of bread, and then they were required to reflect on their predictions, share these with peers and confirm whether their predications were "right". They were asked to complete their practical reports. As it was the last lesson of the day and the discussion consumed much of the lesson, there was little time left for the goal of setting up the slides

for the microscopes. Sociocultural approaches emphasise the interdependence of social and individual processes in the construction of knowledge. Hypothetically, the construction of knowledge in this class was orchestrated strongly by the teacher. Indeed the pedagogy was designed to get individuals to contribute ideas to the class in relation to the issue of invasive species. Students picked up on group cues and often seem to be guided in their responses by reactions to others' answers. This was particularly the case when a student gave a response that wasn't seen to be the required one by the teacher. If a child gave a correct answer, the sequencing of questions ceased. However, students on occasions continued to proffer answers, which the teacher acknowledged and responded to even if off target.

Lesson three was nearly 2 h long and was primarily focussed on students using the microscopes to investigate the bread mould. The first goal in this lesson was to prepare a slide and examine with a magnifying glass and then using a more sophisticated microscope. The task was modelled first and then students attempted the task themselves. Two microscopes were set up at the front of the class and students were provided with glass slides and coverslips and magnifying glasses. The introduction was non-interactive/authoritative in that Pat detailed without discussion the procedures for setting up the microscope and mounting material on the slides. He constantly monitored student activity and reminded them to record findings, discuss them, and share them with class. When interesting observations were made by students he would draw attention of the class to the observation and encourage the student to share with the class. A lot of one-on-one support was evident with the teacher exploring the task collaboratively with the students. However he was still perceived to be the expert. Students were engaged and the energy level of the class was high. Students shared what they were looking at and recording findings in their workbook. Consistent with effective science practical work (Hofstein and Lunetta 2004), Pat was successful in providing those learning opportunities that helped students develop concepts about fungi, enabled them to construct scientific assertions, and to justify those assertions through discussion in a classroom community.

Lesson four was an attempt to link the learning about invasive organisms with food chains. The students had previously encountered food chains and Pat's approach was to connect their emerging knowledge of invasive organism with previous learning. The lesson was again characterised by an introductory non-interactive/dialogical discussion. Pat probed student understanding of food chains, capitalising on responses and elaborating ideas by linking them with formal scientific terminology or ideas. However, Pat also adopted a non-interactive authoritative approach by getting students to read from a series of slide presentations. Responding to a technological interactive presentation, students were required to provide scientifically acceptable answers to questions. Many question adopted a close format requiring students to verbally complete sentences. Students responded enthusiastically and generally without problem. However, Pat frequently encouraged students to discuss questions with other students thus, adopting a more interactive dialogical approach. He accepted a variety of responses without initial evaluation. Students were forthcoming with responses that contradicted other students' answers. To resolve the issues, Pat provided a rationalised explanation arguing for the scientifically acceptable answer. Many of the ideas that emerged in the discussion were recorded on a white board which students were required to copy into their books. Each student was required to research an individual organism and locate it in a food chain.

Most of the fifth lesson featured Pat reading a children's story book, *The Story of Rosie Dock* (Baker 1995), about an elderly woman who moved to live in the Central Australian Desert. The intention was for students to think about introduced species and how the

woman's planting of an exotic plant, *Rosie Dock*, impacted the natural environment through the loss of biodiversity. Although Pat planned to take control and set the questioning agenda, the students were keen to ask questions. He compromised and allowed several questions before returning to his focus question: what was the message of the story. The discussion approach was consistent with a non-interactiveldialogic approach. Students provided multiple responses which Pat responded to either by agreeing or complimenting students. The lesson concluded with Pat distributing a worksheet comprising a list of statements to assess student understanding of natural habitat sustainability. He closed the lesson and topic by reviewing students' responses. Most students had grasped the complex ideas around the impact of introduced species of plants and animals on the natural habitat.

We now turn our attention to a finer grained analysis of the communication practices adopted in the lessons. Four key communicative episodes were identified in the first lesson. First, a short engaging audio recording that depicted a scenario of aliens invading from outer space was played to the class. The audio was presented in a dramatised style with speakers playing the role of aliens from a foreign planet about to invade earth. Pat was hoping to align the idea of an invading alien with invasive plants and animals that had colonised Australia.

The teacher then explored through a four-minute series of questions, discussion and documentation of ideas what students already knew about invasive species. Some 10 children responded directly to the teacher with background discussion among students evident. As students responded he wrote comments on a white board. He begins the questioning sequence by asking what they had learnt so far.

- Teacher: Today, to begin with, I just wanted to see where we're up to in terms of what we've learned so far about invasive species or introduced species. ... We've spent some time in the library doing a little bit of research, but just to get our minds thinking about invasive species again, what is that you already know? Josie. [pointing to Josie]
- Josie: They're not good.
- Teacher: Okay, so you're saying they're not good. What do you mean they're not good? What isn't good?
- Josie: Like they're [indistinct] environment and stuff.
- Teacher: So, affecting...
- Josie: Our environment.
- Teacher: Our natural environment. Can you give me an example, Josie?
- Josie: The native—the feral camel is hurting [indistinct]. The feral camels are hurting some of our native trees
- Teacher: So you're saying camels, for example, camels are hurting some of our native trees and what's the impact of the trees being damaged? What's the next problem that that results in?.

At this point several students respond talking over Josie.

- Student: That means we die.
- Josie: [Indistinct] that means that we don't have any more native trees.
- Teacher: Okay, so native trees—native species are being impacted upon. Good one.

In this exchange, Pat demonstrates a non-interactiveldialogical approach involving a series of five questions to Josie. He first extracts her recollections of what *invasive species* means drawing out her words “not good” and “our natural environment” judiciously

rephrasing some of her comments and cueing the response. Repeating the contributions and adding them to the board was a strategy to share Josie's words with the rest of the class. Building on Josie's knowledge, he selects Rachel to contribute her understanding of invasive species. While this exchange is proceeding other students are anxious to contribute and share their understandings. Pat now moves onto the seeking input from the next student. The style of questioning continued with the teacher working through his pre-oriented script questioning students on the meaning of words and selectively reinforcing the correct ones while glossing over less acceptable responses.

The final episode in this lesson involved students setting up an investigation and drawing on a *predict-observe-explain* (POE) strategy to write predictions in their worksheets. The process was strongly framed with students being re-introduced to terms such as method, materials and results depicted on a worksheet. The teacher also discussed at length through direct questioning what factors might students need to take into account in interpreting their findings. This sequence of communicative transactions represents a non-interactiveldialogical approach. Pat dominated the talk but attempted to incorporate the views of students.

In the following lesson, students set up their investigation by placing slices of bread in plastic bags, sealing them with a wet paper towel and leaving for a week. After a week, the students examined the outcomes of their experiment. There was considerable excitement with a sequence of comments such as,

- Male student: My bread's turning green.
 Pat: Wow, that's cool. Look at that. That is cool.
 Female student: Mine's orange on one side.
 Pat: Yeah, interesting.
 Female student: Mine's still white.
 Pat: Yeah, Interesting.
 Male student: Mine's turning orange turning orange.
 Pat: Yeah. Wow, different colours. Once you've got your bag, can you bring it back to your desk? Bring it back to your desks.

(Excited students discuss and show each other their mouldy bread samples.)

- Female student: There's no smell.
 Pat: There's no smell? There is no smell. Okay, have a seat please. Now, what I'd like you to do. Have a turn back to the initial data sheet which had the materials and the method. At the bottom of that sheet—you'll remember that I asked you...please to make a prediction about what you think would have happened. Now, I'd like you to have a look at your prediction that you've written down, and I want you to have a look at your bag. I want you to have a quick chat to the person next to you. Tell them what your prediction was and seeing if your prediction was right. Do that now. I'll give you 30 s.

(After students discussed their findings, Pat invited a number to report their findings referring back to the POE strategy he introduced in the first lesson).

During the short sharing time, Pat asked one boy for his prediction,

- Male student: I predicted that it would go orange.
 Pat: It would go orange?
 Male student: Orangey-reddy.

- Pat: Okay. It has gone orangey-reddy. You didn't write it down. You've just drawn it. It would have been better if you had written it down because then you can actually look at what you've written and compare, but that's good.
- Pat then invited students to share publically their findings.
- Pat Okay, Liz, in a big voice, tell us (a) your prediction and (b) what have you observed? Big voice...
- Liz: My prediction—I thought it was going to grow a lot of mould in the time in the time [unclear]
- Pat: Ah, so you predicted it was going to grow a lot of mould. I'm glad you used that word mould. You already knew what mould was, or you'd heard of the word? Yes, okay. Who's got—yeah keep going.
- Female Student: Surprisingly [unclear] has a big mould in it but my bread had nothing
- Pat: So your piece of wet paper has the mould and your bread has nothing? That's interesting. Rachel, what have you got on yours?
- Female Student: Mine's got the same thing as Liz, except on mine some of the time my paper towel was touching it, touching the bread, so it got...
- Pat: What was the effect of that?
- Female Student: Oh, just the part that was touching the paper towel—it went all mouldy as well
- Pat: Okay, cool. Good stuff. Let's hear from Josie. Josie?

Pat wanted students to become proficient with the use of microscopes and thus implemented a lesson on examining slides of spores. However, his framing of the lesson was very strong and students are acutely aware of the way the scientific activity should be done,

So I just need you to listen in quickly just to these series of steps about how we're going to do it. I'm gonna hand out a slide. An example of what a slide is, a slide is a piece of glass that is used by scientists to investigate specimens (holds up slide). So as an example, here's an example of Coprimus mushroom set (uses hand gestures throughout indicating the slide he is holding up). So basically it's a mushroom that's been sliced or part of a mushroom that's been sliced very thinly. It's been mounted on a slide. There's a dye that's been put on a slide so that the rings in the mushroom there and the features or the microscopic features can be more easily seen. So they've actually stained it. They call that staining. We won't be staining today. What we'll be doing, we'll be scraping some of our mould spore onto a slide, putting a little covering slip on it. We're gonna seal it with a drop of water and then we're going to come up to the microscopes and have a look. So the first thing I'm going to do, I'm gonna hand out the slides and a cover slip.

We pick up on Pat's practice a few lessons later when students had completed the experiment, which involved examining the mouldy bread with microscopes and identifying fungal spores. He challenged the students to explain how the mould invaded the bread. After a series of questions in his non-interactiveldialogical style, he realised that students were not presenting the sort of response he desired. He switched to an explanation about spores being in the air. This transaction represents what Mortimer and Scott (2003) describe as a *turning point*. The teacher, seemingly somewhat frustrated with the responses, adopts an authoritative discourse and presents his scientific explanation of how

the spores got into the bread. The extent to which students accepted this explanation and reconciled the scientific explanation with their existing beliefs is not clear as the lesson came to an end. Following the lessons, in his reflection of the outcomes, he argued that “It piqued their interest about what was going to happen. And I think it did link in with our unit, sort of, focus, which is around introduced species”. In discussing his approach to teaching, in the second year of the study, Pat reflected,

I wasn’t new to teaching, like I have taught before in a tertiary context. But the context of teaching in primary is very different and I guess what’s changed for me is it’s just trusting in my ability to adapt and to look at what these students need at any point—where I need to take them. So it’s a lot of reflective thought on where are they at, what am I doing, what can I do to help them and then what’s the teaching going to be—it’s like a cycle of almost diagnostic on the run with them. (Interview Yr 2)

In Pat’s first year of teaching, the investigations of bread mould represented a highly interactive albeit scaffolded inquiry. The use of microscopes and the preparation of slides required considerable modelling and support. We revisited Pat for a further two years and observed his developing practices. His pattern of teaching changed little over that period of time. In his second year of teaching, he set students the challenge of designing and testing paper airplanes. He was keen to get students into open-ended explorations around the topic of flight. He set the goal in this sequence of lessons to design a paper plane that could fly the fastest thus integrating science and mathematics. In his third year of teaching, having relocated to a remote school, he continued to implement project-based inquiry lessons on the properties of materials and their uses challenging students to identify the optimal insulation material for clothing. The instructional approaches continued to be aligned with dialectical-social constructivist approaches through rich classroom discourses that were modulated to suit the circumstances, at times authoritative and at times dialogical.

He continued to emphasise the importance of encouraging independence in students as revealed during the interview conducted in the second year:

I think—I really want to kind of enable the kids to think independently and give them—help them to develop a tool box of skills and thinking processes to to ... help them with their day-to-day schoolwork. You know, less of the content-driven sort of stuff to some extent. I mean we’ve got things we’ve got to cover, essential learnings and so forth—but I want kids to have more self-resilience and belief in themselves and trust their judgement.

Discussion

In this paper we have presented a snapshot of the instructional strategies adopted by a beginning teacher. We were interested in the *communicative approaches, practices and strategies that characterised his teaching approaches as a beginning teacher highly qualified in the knowledge domains of STEM*. We were also interested in the extent that a beginning teacher with a strong subject matter knowledge background could implement pedagogical practices that are emphasised in preservice courses. In discussing the findings we address three issues: the significance of a single case investigation, the challenge faced by a beginning teacher, and the epistemological messages implicit in Pat’s style of teaching.

First, as a single, embedded case study design, our exploration of Pat’s practices has provided a rich and in-depth analysis of a complex phenomenon in context. Yin (2009)

rationalises case studies of this type as critical cases in that it enables the researchers in “testing a well-formulated theory” (p. 47) and also represents a unique case in that Pat as a career-change teacher brings strong subject matter knowledge but limited pedagogical experience to the situation. Internationally, policy makers are striving to encourage professionals like Pat to change careers and become teachers (e.g., Holdren et al. 2010). Thus the practices of Pat are explainable by the macro theoretical frameworks of constructivism as articulated by McGregor (2011) and the detailed theories of discourse transactions among class members are proposed by Mortimer et al. (2011). Of particular note is the flexibility in his strategies as he assessed the context and adjusted his repertoire of strategies accordingly. He showed confidence, innovation and a capacity to bring to life in the classroom topics that were clearly intrinsically engaging to the students.

Second, Pat’s fundamental social constructivist approach and his non-interactiveldialogical approaches were central to his style of teaching. However, his forays into a more interactiveldialogical approach were evident. The literature has extensively documented the approaches and challenges faced by beginning teachers. The limited research on the pedagogical practices of beginning teachers suggest that although teachers with stronger subject matter knowledge tended to be more constructivist in their approach, Davis, Petish and Smithey (2006) conclude in their review of studies on beginning science teachers that they still are “less reform oriented science than many science educators would hope” (p. 627). In part, employing a behavioural approach has been attributed to primary teachers’ limited content knowledge and lack of confidence in their teaching of science (Evans et al. 2014) and maths (Goulding et al. 2002). Our own research has identified the tension between conceptual or subject matter knowledge and pedagogical knowledge among this cohort of experienced professional scientists, engineers and technologists who have transitioned from a STEM career to teaching (Diezmann and Watters 2014). Pat’s subject matter knowledge while strong and atypical of teachers in elementary school was not dominant in his philosophy of what was important for student learning at this level of schooling. Pat showed a strong capacity to or in Shulman’s (1986) terms, pedagogical content knowledge to integrate his pedagogical knowledge and his subject matter knowledge to engage students. Through his communicative practices he adapted complex material to suit students’ abilities, and prior experiences.

Third, Pat’s approach to teaching raises issues concerning the nature of scientific knowledge. Some might see a possible limitation of this study is that there are no standardised assessment strategies in these Grade levels so to what extent students acquired deep, reproducible and sustained understanding of the content is unknown. However, Mortimer et al. (2011) arguing from a Popperian third world perspective, see knowledge initially as a social construct framed by the context in which a phenomenon is encountered before being encoded into episodic memory. They propose that individuals through the language, culture and norms of practice of the classroom acquire *conceptual profiles*. Hence, each new experience gives rise to a potentially new zone which represents the way of thinking and talking about that experience:

Conceptual profiles are built for a given concept and are constituted by several zones, each representing a particular mode of thinking about that concept, related to a particular way of speaking. Each individual has his or her own individual conceptual profile, as shown by the different weighting each zone exhibits in that particular profile. (p. 235)

Hence learning is understood as the process of expanding a conceptual profile through awareness of “the multiplicity of modes of thinking that constitutes a profile as well as the

contexts in which they can be applied” (p. 236). In other words, sociocultural approaches emphasise the interdependence of social and individual processes in the construction of knowledge.

Hypothetically, the construction of knowledge in this class was orchestrated strongly by the teacher. Indeed, the pedagogy employed by Pat was designed to get individuals to contribute ideas to the class in relation to the issue of invasive species (First year), and the attributes of aircraft (Second year) or properties of plastics (Third year). However students picked up on group cues and often seem to be guided in their responses by reactions to others’ answers. This was particularly the case when a student gave a response that wasn’t seen to be the required one by the teacher. If a child gave a correct answer the sequencing of questions often ceased. However, students, on occasion, continued to proffer answers which the teacher acknowledged and responded to even if off target.

What is noteworthy is that although Pat was well qualified in science, the topics he chose to teach were outside his area of specialisation which was human movement studies. The biology unit in Year 1 drew on some specialised knowledge of environmental science and mycology. In Year 2, the unit required some understanding of physics and in Year 3 he required access to basic chemistry. Nevertheless, he was confident and comfortable in his knowledge of these topics as they represented real-world applications of science. In contrast to other participants in the larger study (e.g., Diezmann and Watters 2014), Pat’s focus was on implementing pedagogical strategies that engaged learners. It was even apparent in the bread mould activity, where he was learning alongside the students. As a beginning teacher one could argue that these experiences contributed new zones to his conceptual profile framing the teaching of science. It was also noteworthy that the approach he adopted illustrated a set of epistemological beliefs about the nature of science as being a process of negotiation of meaning. Meaning making was actioned as “a matter of bridging gaps by constituting similarities and differences between the new and unknown and matching these to what it already known” (Lundqvist et al. 2009, p. 864). The potential exists for students to acquire a view of school science that is more engaging than the traditional concept dominated perspective.

These findings contrast to those of McGregor (2011) who saw beginning science teachers more often adopt behaviourist or constructivist approaches. Pat’s adoption of social constructivist approaches may have been influenced by the context of primary classrooms in contrast to secondary science classrooms. However, it should be remembered that Pat was trained to teacher across the primary and junior secondary school. His use of more social constructivist strategies might also have been influenced by his experience in teaching literacy whereas McGregor found beginning teachers of English used whole class discussions about novels. Pat’s use of the story book in lesson 5 clearly indicated his emerging use of this approach.

Conclusions and significance

The pedagogies a beginning teacher adopts are a mixture of what they have experienced, encountered, seen modelled, trialled, and perhaps, read about. However, optimally, beginning teachers, such as Pat, will adopt a communication style that they find effective for their students. As a career-change teacher, Pat demonstrated sophistication in his pedagogy in two ways. First he adopted a communication style of (1) *sharing* and (2) *selecting and shaping* with these roles played by students and the teacher respectively. Students were encouraged to *share* their knowledge, the teacher then *selected* key content

from the students' communication and *shaped* it in a way that illustrated the content for the whole class. His non-interactiveldialogical approach engaged the students and provided a path to expand their conceptual profiles of science. Second, he supported higher order thinking in students by using the analogy of feral rabbits to support students' understanding of mould spores as an invasive species. In terms of quality teaching, this career change teacher was able to simultaneously involve the students in dialogue and scaffold the development of their conceptual knowledge. In Chubb's (2012)'s terms, even so early in his career, Pat could be regarded as an inspiring teacher "Inspiring teachers will generally be those confident that they know their subject well, and can transmit that confidence, and their passion, into the classroom" (p. 7).

The disjuncture between university and school experiences of pre-service teachers is well recognised (Zeichner 2010). This study raises implications for pre-service teacher education in two ways that may reduce this disjuncture. First, Pat's approaches challenged what is known about the epistemologies of beginning teachers. Many pre-service teachers, especially those who have advanced subject matter knowledge, assume knowledge is a stable entity to be learnt and reproduced in standardised form (e.g., Lederman 2007). Representing scientific ideas through language has been suggested as a major barrier to acquisition of knowledge (Wellington and Osborne 2001), which might be difficult for other beginning teachers. Understanding and valuing the role of language and social discourses that epitomise the community of learners in the context of science presents a new way of understanding what counts as knowledge in the classroom. That the students were not always expressing ideas that were acceptable according to the canons of science was, we believe, less important than students were engaging in, and experiencing phenomena that contributed to a richer conceptual profile. In time, with further experiences and refinement their understandings will acquire a richer alignment with acceptable scientific knowledge. Teacher education programs need to focus on strategies to engage students in rich dialogue and de-emphasise the transmission of canonical knowledge.

Second, most elementary pre-service teachers who lack confidence in their own knowledge of science find the challenge of teaching science overwhelming. Again their views of the nature of science are dominated by traditionalist views of a stable set of concepts. It is the concern about transmitting that knowledge that leads to low self-efficacy in science teaching. However, elementary teachers adopt in general highly sociocultural practices in teaching language and literacy. Scope exists for the integration of science and language teaching in so far as emphasising the pedagogies of the language class as appropriate for the science class.

In conclusion, we comment on the trustworthiness of this study. In contrast to quantitative, positivistic research, researchers are integral to the research context interpreting events through the lens of their experiences and theoretical frameworks. Thus reflexivity is vital in any naturalistic study in which the researchers and participants develop a bidirectional relationship (Liamputtong and Ezzy 2005). The researcher effects the participants' behaviours and vice versa and so interpretations may be viewed as biased or naïve. Both the authors of this paper bring with them decades of research and teaching experiences in science and mathematics classrooms. Each brings his and her own perspective and through negotiation, discussion and involvement of the participants including Pat's classroom reach agreement on what is happening and why it is happening. In the spirit of naturalistic studies another researcher may draw different interpretations based on alternative theories and personal beliefs. The trustworthiness of our conclusions are based on co-analysis of data and negotiation of meaning, on longevity in contact with the participant (over three years), maintaining an audit trail, sharing our initial interpretations as form of

member checking and communicating our findings and assumptions with peers (Creswell 2012).

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