UNIVERSITY OF CAMBRIDGE
Faculty of Education

ISSN 2043-8338

Journal of Trainee Teacher Education Research

To what extent is dialogic teaching effective in identifying and addressing year 8 students' alternative conceptions about electricity and magnetism?

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https://doi.org/10.17863/CAM.12963

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Abstract

A significant challenge in teaching science is helping students move from their prior understanding of the world to a more scientific worldview. This case study investigates whether dialogic teaching, an approach that focuses on verbal exchange in the classroom (Alexander, 2020), is effective in identifying and addressing elements of students' prior understanding – alternative conceptions - that conflict with scientific knowledge. Using data gathered from surveys and observations of a year 8 class I found that, for most students, dialogic teaching was effective in supporting the processes of identifying and addressing their alternative conceptions. I also found that some aspects of dialogic teaching were less visible and thus were harder to implement and observe. These findings suggest that dialogic teaching is a powerful tool for both diagnosing alternative conceptions and helping students move beyond them so long as it is implemented with care.

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Introduction

Educational research suggests that students are not blank slates, but that they come to our lessons with all their prior experiences and the intuitions which are built upon them. Driver et al. (1994) argue that a significant challenge to teachers, especially science teachers, is in helping students move from understanding the world through the lens of their prior experience to understanding the world scientifically. This project investigates whether dialogic teaching - a particular way of helping children learn via dialogue (Alexander, 2020) – is effective in helping children make this transition.

To begin, I will review what dialogic teaching is and what the current literature says about its effectiveness. I will then review some of the common ways that students understand electricity and magnetism prior to their formal education, referring to these ways of understanding as 'alternative conceptions'. I focus on electricity and magnetism in particular due to the practical constraints of the project. Focusing on a narrower domain of knowledge also allows for more depth in the evidence gathered and its analysis. To finish this literature review, I will define the research questions of this project. In the next section I will explain my choice of methodology and the research methods I used. Following this, I will present my findings before analysing and discussing them. Finally, I will conclude by answering the research questions defined in the literature review and suggesting some implications for my teaching practice.

Literature Review

What is dialogic teaching?

Robin Alexander, one of the eminent researchers in the area of dialogic teaching, defines dialogue as "the oral exchange and deliberative handling of information, ideas and opinions" (Alexander, 2020,

p.128). Elsewhere, Alexander defines teaching to be "the act of using method x to help students learn y" (Alexander, 2001, p.323). Dialogic teaching is therefore the use of dialogue to help students learn, or in his own words, "a pedagogy… that harnesses the power of dialogue, thus defined" (Alexander, 2020, p.128). This definition characterises dialogic teaching as the combination of the two more basic elements, dialogue and teaching. More specifically, Alexander claims that dialogic teaching is teaching that *uses* dialogue. Alexander thus claims that dialogue has a utility or a value that can enhance teaching when the two are combined.

At this point, any teaching involving dialogue would come under the definition of dialogic teaching. Such a broad definition may be advantageous in encompassing the full range of approaches to dialogic teaching, avoiding an overly prescriptive approach. However, Alexander (2020) qualifies this definition with some further conditions, making it narrower and more precise.

Dialogic teaching is further characterised by a purpose and a stance. The purpose of dialogic teaching is not only to support students' learning and understanding – as all pedagogies claim to – but also to support students' critical thinking, reasoning, and discussion skills (Alexander, 2020, p.128). This additional focus on thinking, reasoning and discussion distinguishes dialogic teaching from pedagogies that support other areas of a student's development, thus refining Alexander's definition.

The stance of dialogic teaching refers to a set of views that are necessary to adopt when implementing dialogic teaching (Alexander, 2020, p.38). These views are about human relationships, culture, knowledge, education, and society. Alexander (2020) specifies four views that constitute a dialogic stance. I summarise them below in the form of four propositions:

1. Teaching and learning unite the cognitive and social.
2. Education involves the progress towards self-direction and the acceptance of accountability.
3. Understanding is the product of interacting with different points of view, ways of arguing and ways of thinking.
4. Education involves developing an awareness of our relation to other people, places, and times.

The stance formed by these propositions does not specify what dialogic teaching is per se, but provides the "rationale" (Alexander, 2020, p.127) or the general view that motivates dialogic teaching. By including the dialogic stance as part of his characterisation of dialogic teaching,

Alexander implies that the motivation and rationale for dialogic teaching is essential to its nature. In other words, to fully understand dialogic teaching, one must understand the ideas and views that justify it as well as the procedures that constitute it.

To summarise, Alexander's characterisation of dialogic teaching contains three elements: firstly the combination of dialogue and teaching; secondly the purpose of supporting discussion, thinking and reasoning as well as learning; thirdly the adoption of a dialogic stance.

One could criticise Alexander's definition for being too abstract as opposed to being directly derived from tangible classroom evidence. Alexander starts from general definitions of dialogue and teaching, reasoning a priori to a definition of dialogic teaching. He then adds a host of what he admits could be "philosophical" or even "ideological" assumptions in the form of his dialogic stance (Alexander, 2020, p.129). However, this criticism is not entirely fair as many of Alexander's assumptions are derived from the extensive literature on dialogic teaching. This notably includes a large, randomised control trial led by Alexander and Hardman (Alexander et al., 2017) which operationalised and tested the effect of dialogic teaching on a large scale. It can therefore be said that Alexander's characterisation of dialogic teaching is indubitably informed by concrete evidence even if it is motivated by more general ideas and values.

Having discussed the strengths and limitations of Alexander's definition of dialogic teaching, I will use it for the remainder of this essay. As this essay is focused on the effectiveness of dialogic teaching in the classroom, I will move on from what the literature says about the definition of dialogic teaching to what the literature says about its effectiveness in the classroom.

How effective is dialogic teaching?

One of the most extensive pieces of research on the effectiveness of dialogic teaching is a 2017 research project led by Alexander and Hardman (Alexander et al., 2017). The purpose of this project was to evaluate the effect of a dialogic teaching intervention on the learning, attainment and engagement of students. The project consisted of two methodologies: a randomised control trial and a qualitative analysis of the same data. The project focused on year 5 students and their teachers in primary schools across 4 English cities including London, with data taken from a population of approximately 5000 students and 208 teachers.

There were two main findings from the project. Firstly, classroom talk changed significantly with the implementation of the dialogic teaching intervention. For example, the data showed longer, deeper and more extended exchanges between students and teachers; a more supportive and reciprocal culture of talking; and higher rates of student participation in classroom talk, to name but a few of the changes (Alexander, 2018, p.21). Assuming engagement correlates to a student's willingness to participate in classroom talk, these changes in classroom talk are certainly evidence of increased student engagement. It is more difficult to relate the changes in classroom talk to an increase in student learning, as evidence of learning is more directly related to the epistemic content of the talk – the knowledge contained within it – rather than the quality and quantity of the talk itself. However, if one assumes that the quality of talk – especially student talk – is an indicator of a student's understanding, then the changes in classroom talk observed by Alexander et al. (2017) also qualify as evidence of an increase in student learning.

Evidence of the changes in classroom talk was gathered via interviews with teachers and video recordings of classroom dialogue. By using two methods of data collection, Alexander et al. (2017) ensured their data has both the *depth* of the teacher's insight into the engagement and learning of their class, and the *rigour* of being backed up by actual utterances made during lessons. The teacher's perspective on the engagement and learning of their own class is invaluable data, however it is limited by its subjectivity, which makes it difficult to compare findings across multiple contexts. Alexander et al.'s (2017) analysis of video recordings using a standardised coding procedure mitigates this limitation by adding a way of assessing engagement and learning that is more objective and generalisable albeit less deep.

The second main finding of Alexander et al. (2017) comes from the independent randomised control trial performed on the data gathered by Alexander et al. (2017). Specifically, the trial used data from the attainment of students on standardised tests at the end of the dialogic intervention. Statistical analysis on this data concluded that students who were in the intervention group were "two months ahead of their control group peers in standardised tests in English, Mathematics and Science" (Alexander, 2018, p.27).

Whilst randomised control trials are traditionally considered to be more objective and rigorous than other research methodologies, Ginsburg and Smith (2016) argue that such trials have serious limitations in the context of educational research. This stems from the inherent complexity of

curriculum interventions such as the dialogic intervention of Alexander et al. (2017). Among the limitations discussed by Ginsburg and Smith (2016), they argue that the majority of interventions are not given enough time to be implemented properly, and that it may take "up to three years to implement a substantially different curricular change" (Ginsburg & Smith, 2016, p.2). The 20 week long intervention done by Alexander et al. (2017) falls far short of this mark. Therefore, while the qualitative part of Alexander's (2018) methodology may provide useful evidence on the implementation of an intervention over a short period of time, the randomised control trial may not be reliable in the same context.

In his own discussion of the randomised control trial, Alexander identifies further limitations (Alexander, 2018, pp.27-28). Notably, in evaluating the effectiveness of the dialogic intervention, the trial only considered the effect on students' performance in standardised tests. This is a crucial limitation as it means the trial could not measure the impact of the intervention on other important aspects of students' education. Alexander makes the point that measuring student engagement and use of spoken language would have been more appropriate to the aims of the dialogic intervention (Alexander, 2018, pp.27-28). Therefore, the methodology of the randomised control trial does not capture the full effects of dialogic teaching, instead focusing on attainment in exams alone. That being said, by combining the methodology of the randomised control trial with qualitative research, Alexander (2018) compensates for the trial's limitations, adding an alternative stream of evidence to support his conclusions.

In summary, Alexander et al.'s (2017) research study found that the implementation of dialogic teaching had a significant positive effect on the engagement, learning and attainment of students. This was observed through the increased depth and length of discussion between students and teachers and a more reciprocal culture of classroom talk. Both interviews with teachers and video analysis of lessons supported these claims. The randomised control trial showed that the implementation of dialogic teaching had a statistically significant positive impact on students' attainment. Whilst the trial was limited to evidence from students' scores on standardised tests, the interviews and video analysis compensate for this by providing deeper insight into the effects of dialogic teaching.

Having discussed evidence for the effectiveness of dialogic teaching in supporting learning, it remains to dig deeper in to exactly what parts of students' learning are affected. Alexander (2018) focuses on the effects on classroom talk and attainment. Whilst these are certainly important aspects of students'

learning, he does not investigate the effect on students' conceptual understanding of curricular content. Perhaps this is due to the project focusing on primary education, where supporting conceptual understanding is only one part of a more holistic approach to education. The positive effect of dialogic teaching on other aspects of students' learning shown by Alexander (2018) suggests that dialogic teaching would also have a positive effect on students' conceptual understanding. One key aspect of developing students' conceptual understanding, particularly in science education, is the identification and addressing of misconceptions or alternative conceptions (Driver et al., 1994). It is therefore to this topic that we now turn.

What alternative conceptions do students have about electricity and magnetism?

Understanding electricity and magnetism presents a conceptual challenge to students and adults alike. Part of the challenge is that students approach learning the subject with pre-conceived intuitions about how electricity and magnetism work (Driver et al., 1994). This tacit knowledge is built up from years of experience interacting with electricity and magnetism in a non-scientific, everyday context. To make sense of their experiences, students construct a conception of the natural world, these conceptions are commonly referred to as misconceptions, however many researchers prefer the less pejorative term 'alternative conceptions' (Taber, 2014) which is the term I will use in this report. Due to the strength of students' alternative conceptions, it is crucial to address the gap between them and the ideas presented in lessons, such that they form new, more informed scientific conceptions about electricity and magnetism.

Driver et al. (1994) present a comprehensive overview of students' alternative conceptions in science, using evidence gathered from secondary schools in Leeds. Whilst their research is now thirty years old, it is reasonable to assume that children today have similar experiences and intuitions about electricity and magnetism. The entire topic of electricity and magnetism is too broad for the scope of my research, so I will only consider students' alternative conceptions about electric circuits and electromagnets. These particular subtopics were chosen based on the constraints of timetabling and the practicalities of data-collection.

Driver et al. (1994) claim that students often hold a "source-consumer view" of electric circuits, where a set amount of electric current originates from a cell and is consumed by each component as it flows round the circuit (Driver et al., 1994, p.257). This intuition can lead students to make incorrect predications about the effects of adding components to a circuit in series or parallel (University of

York Science Education Group, 2024a). For example, a student that holds a source-consumer view of circuits may think that the last bulb in a series circuit of three bulbs will be dimmer, as the current was 'used up' by the previous two. Conceiving of cells as containing a set amount of current leads to further misunderstandings, where students may think that adding a parallel branch to a circuit will decrease the current through another branch.

With regards to electromagnets, Driver et al. (1994) note that students have difficulty viewing a magnetic field as the effect of an electric current. Instead, students may infer that the magnetic field is produced by the wire itself, or by static charge. In a study of 272 16-18 year-old physics students in England and Turkey, Sağlam and Millar (2006) found that 24% of students said that static electric charges would move in the direction of magnetic field lines. This suggests that students may conflate electric and magnetic fields. Sağlam and Millar (2006) also argue that these misunderstandings are developed whilst learning about electromagnetism, as it is unlikely that students would have prior experience of electromagnets.

Aims and research questions

Having discussed the nature and effectiveness of dialogic teaching, as well as some of the common alternative conceptions that students have about electric circuits and magnetism, we have now arrived at the topic of this research project: namely the use of dialogic teaching in identifying and addressing these alternative conceptions.

Driver et al. (1994) write that one of the significant challenges for students is to move from their alternative conceptions of the natural world, to a more scientific view. To help students do this, it is necessary to first *identify* what their alternative conception is and then to *address* it by providing the necessary experiences and information for them to extend, refine or radically change their view (Driver et al., 1994, p.2). In this sense, the identification and addressing of students' alternative conceptions represents an important objective for teachers and students.

The aim of this research project is to investigate whether dialogic teaching is effective in supporting the process of identifying and addressing students' alternative conceptions. This aim can be expressed in the two research questions (RQs) as presented at the beginning of the next page.

RQ1: To what extent is dialogic teaching effective in identifying students' alternative conceptions about electricity?

RQ2: To what extent is dialogic teaching effective in addressing students' alternative conceptions about electricity?

There is good reason to believe that dialogic teaching will have a positive impact due to its effectiveness in supporting other parts of students' learning such as engagement, speaking skills and attainment (Alexander, 2018). However, it remains to discuss whether the evidence gathered through this project supports this conclusion. Before presenting and discussing the findings of this project, I will now explain the methodology of the project and the methods used to gather evidence.

Methodology and methods

Methodology: case study

Due to the small scale of this project, any conclusions drawn from it are dependent on its context. Specifically, the project was limited to evidence gathered from a single class of 32 year 8 students at a secondary school in Cambridgeshire. Thus, the evidence gathered in this project reflects particular factors such as the attainment group, school policy and the individuals within the class as well as general factors that would be present in all classes independent of their context. This limitation necessitates the use of a research methodology that focuses on trying to understand the particular rather than the general.

The most suitable methodology for such a project is a case study, as the aim of a case study is to understand phenomena in their particular context (Bell, 2018). Bell argues that what case studies may lack in generalisability, they compensate for in depth. By studying phenomena on a small scale, more time can be spent delving into the details of the evidence gathered. Some researchers criticise the methodology of case studies for their lack of generalisability, arguing that their findings are only useful within their narrow context (Bell, 2018). However, others have argued that the findings of case studies can be generalised to other contexts so long as the contexts are similar to that of the case study (Denscombe, 2014). Whilst case studies are single examples of a particular phenomenon, there may be common themes that are shared with other examples and are thus generalisable.

Research methods

To obtain useful evidence in this case study, I selected a variety of research methods. Targeted observation sheets were used during some of the lessons in which I implemented dialogic teaching. These observation sheets were structured based on Alexander's (2020) dialogic framework to look for evidence of dialogic teaching. These observation sheets gave a subjective, but detailed account of the effectiveness of dialogic teaching from the perspective of an observer of the lesson.

After several lessons that included elements of dialogic teaching, I organised a survey to gather the views of the whole class on the effectiveness of dialogic teaching. The survey contained a mixture of multiple choice and free-text responses to gain both quantitative and qualitative data. Due to the survey taking place after several dialogic teaching sessions, the students' responses were likely influenced by, and can be taken to reflect, my particular implementation of dialogic teaching rather than dialogic teaching in general. It should also be noted that the strategies I used – such as extended questioning and peer to peer discussions – are only a small fraction of the possible strategies described in the literature on dialogic teaching (Alexander, 2020). Therefore, my results only reflect the successes and failures of a partial implementation of dialogic teaching. This limitation applies both to the survey and to the project as a whole. In order to investigate the effectiveness of dialogic teaching comprehensively, it would be necessary to have more time to fully implement a wider range of dialogic teaching strategies across multiple classes and teachers such as in Alexander et al. (2017).

Another limitation of the survey was that the questions had to be pitched at the level of understanding of a year 8 student. Therefore, I could not ask questions about dialogic teaching and misconceptions directly, but instead had to use proxies for both these concepts. Instead of dialogic teaching, I asked about student's views on classroom talk; and instead of misconceptions, I asked about students' understanding or confusion about a topic. Using less precise language gave room for students to interpret questions differently, increasing the unreliability of the survey's results. However, it also enabled students to access the questions on the survey, allowing for all students to express their views.

In addition to this survey, I assessed what students' alternative conceptions were using three questionnaires made by the University of York Science Education Group (2024a, 2024b). Whilst this strand of evidence does not refer specifically to dialogic teaching, it gives insight into the alternative conceptions which were the target of my dialogic teaching to identify and address.

Each of these data collection methods was used to make inferences about both the effectiveness of dialogic teaching in identifying and addressing misconceptions. They therefore apply to both research questions defined above. The mapping of methods to research questions is summarised in Table 1.

Research Question	Data collection methods		
RQ1.To what extent is dialogic teaching effective in identifying students' alternative conceptions about electricity?	Survey	Observation notes	University of York Science Education Group questionnaires
RQ2.To what extent is dialogic teaching effective in addressing students' alternative conceptions about electricity?	Survey	Observation notes	University of York Science Education Group questionnaires

Table 1: The methods used to answer each Research Question

Research ethics

It should be noted that care was taken to ensure that the research methods used in this project followed the ethical guidelines published by the British Educational Research Association (BERA) (2024). In particular, all data was anonymised to protect the privacy of the students involved. This was communicated to participants to encourage them to give honest responses, allaying any fears of repercussions. Due to the complex nature of the research, fully informed consent could not be obtained directly from the students. Therefore, consent was negotiated "within relationships of mutual trust" as specified by paragraph 10 of BERA's ethical guidelines (2024). The class teacher and my mentor were also consulted as part of this negotiation, ensuring that my research methods followed school policy regarding the handling of student data. To reduce the impact of my research on students' learning, I minimised the time spent on data collection during lessons. For example, the average time taken to complete the survey was 3 minutes 41 seconds. Moreover, the questionnaires formed part of the lesson activities, therefore providing students with a learning benefit as well as providing useful data.

Findings

The findings of this project can be divided into three main sections delineated by their methods of collection: survey, observation documents and questionnaires. In this section I will present the evidence gathered via each of these methods.

Survey

A whole class survey was conducted to gather students' views on dialogic teaching and its effectiveness. The survey consisted of seven Likert scale questions where students had to select the extent to which they agreed or disagreed with seven different statements. These questions were designed to assess students' attitudes about dialogic teaching along several dimensions that I identified from Alexander's work (2020). The first dimension I explored is students' attitudes to different types of talk. For example, general talking versus asking or being asked a question. Another dimension explored by these questions is who is doing the talking: student-student or student-teacher. Importantly, the final dimension in these questions is students' perception of the effect of the different types of talk on their learning and their engagement. These questions and a graphical summary of the students' response are given in Figure 1.

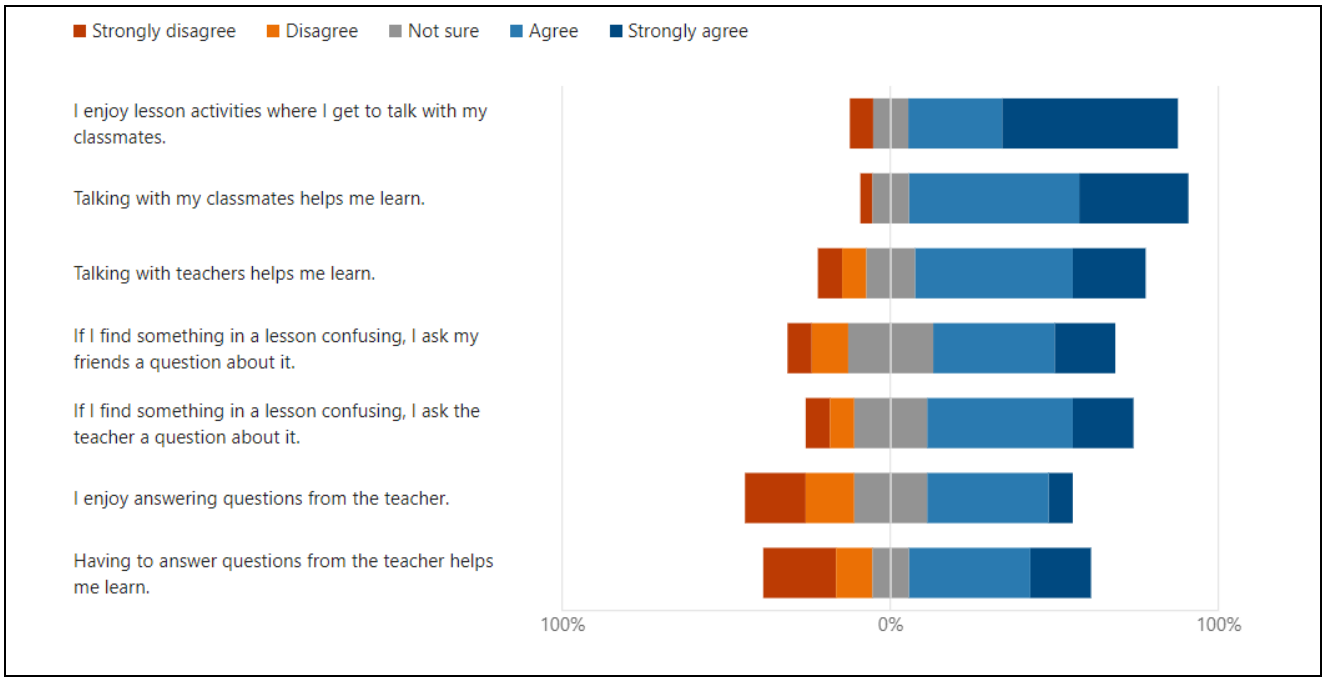

Figure 1: The proportion of responses given to each statement in the survey

The survey also included two multiple choice questions to which students could either answer yes or no and then could explain their response in free text. These questions were: (1) 'do you find that talking to your classmates and teachers helps you learn?' and (2) 'would you like to do more activities that involve talking in your lessons?'. The free text responses were analysed using a method of inductive coding whereby responses were categorised into common themes found across the responses (Bell, 2018). The themes represent the different justifications students gave for their

answers to questions (1) and (2). Table 2 explains each theme and gives an example response. Table 3 lists these themes and the proportion of responses that were assigned to each of them for each question.

Thematic code	Explanation	Example response
Reasoning	Classroom talk helps students think for themselves and solve problems independently.	"[classroom talk] helps me gather my thoughts and ideas in a group" (student 27)
Engagement	Classroom talk motivates students and helps them focus on learning.	"Because [classroom talk] is fun" (student 22)
Understanding	Classroom talk supports students' building knowledge.	"Because you share knowledge and it helps you learn." (student 13)
Distracting	Classroom talk demotivates students and undermines their focus.	"Talking a lot in lessons can be distracting as the discussions are often off topic" (student 4)

Table 2: An explanation and example for each thematic code

(1) Do you find that talking to your classmates and teachers helps you learn?	Reasoning	36
	Engagement	18
	Understanding	39
	No response	7
(2) Would you like to do more activities that involve talking in your lessons?	Reasoning	14
	Engagement	50
	Understanding	14
	Distracting	7
	No response	14

Table 3: The number of responses in each thematic code

For question (1), 100% of students answered 'yes'. Students' free text explanations for their answers were categorised into four themes, each being a different reason that students cited as being why classroom talk helped them learn. The first theme was that classroom talk supports 'reasoning, the second was that it supports 'engagement' and the third was that it supports 'understanding'. The final theme was for those students that didn't write a free text response.

Most students (39%) gave responses saying that classroom talk supported their understanding. This agrees with the finding of Alexander's randomised control trial (2018). Some students stated this

explicitly, for example one student wrote “it helps me to understand” (student 8). Other students referred to understanding indirectly, for example another student wrote that classroom talk helps them learn “because you share knowledge and it helps you learn” (student 13). I also assigned responses such as this one to the category of ‘understanding’ as they share a focus on the capacity of talk to support the acquisition of knowledge.

A slightly smaller proportion of students (36%) reported that classroom talk supported their reasoning. By this I mean a student’s capacity to think about what they are learning. This is best illustrated by examples such as one student who wrote that classroom talk “helps me gather my thoughts and ideas in a group” (student 27). Or another student who wrote that “having another view may help me understand the subject better” (student 14). These examples all share a focus on the use of classroom talk in assisting students think and reflect on the knowledge they are learning. This theme is similar to Alexander’s dialogic principle of deliberation, whereby classroom talk helps students “discuss and seek to resolve different points of view… working towards reasoned positions and outcomes” (2020, p.131).

The minority of students (18%) said that classroom talk helped them learn by supporting their engagement. Another focus in Alexander’s research (2018). These responses focused on the fact that classroom talk was enjoyable and stimulating. For example one student wrote that classroom talk helped them learn “because it is fun” (student 22). Although there were fewer responses in this category, they were generally easier to define as they exclusively mentioned enjoyment as opposed to the cognitive themes of understanding and reasoning.

For question (2), “would you like to do more activities that involve talking in your lessons?” 93% of students answered ‘yes’. Students’ explanations for their answers were categorised into the same themes as question 1. The majority of students (50%) said that they would like more classroom talk as it supported their engagement, with many writing that talking is ‘fun’ and ‘stimulating’. An equal proportion of students (14%) justified wanting more classroom talk as it supported their reasoning and understanding. Finaly 7% of students said that they did not want more classroom talk and wrote that it was “distracting” (student 4) and often “off-topic” (student 14). This finding jars with Alexander’s view that classroom talk should be “purposeful” (2020, p.131). These students were classified into a new theme ‘distracting’ during the coding process.

Observation documents

In addition to gathering the views of students on the effectiveness of classroom talk and dialogic teaching, I also gathered evidence from the perspective of teachers. To this end, I designed a targeted document that was used by an observing teacher to identify elements of dialogic teaching in my lessons. This information gives insight into the effectiveness of dialogic teaching by allowing the effect of individual elements of dialogic teaching to be analysed.

To assist the observer in identifying relevant elements of dialogic teaching, the observation document was structured around Alexander's principles of dialogic teaching. These state that dialogic teaching is collective, supportive, reciprocal, deliberative, cumulative and purposeful (Alexander, 2020). I formulated each principle as a question that the observer could answer. For example, the principle of 'collectiveness' was formulated as the question: 'does the activity involve more than one person speaking?'. Through the observer's answers, I was able to gather information about the extent to which dialogic teaching in my lessons reflected the principles defined by Alexander (2020).

This observation document was used to analyse a particular dialogic activity where students each wrote down a question about what they had learned so far about electricity, they then moved around the classroom asking it to other students to test each other's understanding of the topic. The observer found that some dialogic principles (Alexander, 2020) were more evident in my lesson than others. For example, collectiveness was easy to observe via the quantity of talk between students. The observer also noted that the level of supportiveness and reciprocity could be identified through the engagement of the students and their willingness to participate. However, deliberativeness was more difficult to observe as it relates to the content of the classroom talk, not just its presence and character. Cumulativeness was difficult to observe for the same reason. Whilst students could be seen interacting and helping each other answer questions, it was difficult to evaluate the extent to which their dialogue built on each other's ideas without analysing their conversations. In contrast, the purpose of dialogic teaching could be identified from considering the lesson plan and the overall nature of the dialogic activities.

The findings from the observation documents thus raise the crucial point that some parts of dialogic teaching are more difficult to gather evidence for than others. This is due to dialogic teaching relating to both the content of classroom talk as well as its presence and character. The content of classroom talk could be more readily analysed in more controlled activities involving fewer speakers. The

inherent difficulty in monitoring multiple conversations is a limitation of dialogic teaching involving many speakers as the teacher inevitably has less control. The more speakers there are, the more the success of the dialogic activity depends on the students. In concordance with this finding, Alexander (2020) suggests that the success of such activities depends on the prior instruction of students on how to engage in classroom talk.

Questionnaires

While the survey and observation documents focused primarily on students' and teachers' views of dialogic teaching, the questionnaires that form my final strand of evidence were directly focused on what the students knew. More specifically, any alternative conceptions they may have had. The purpose of the questionnaires was to gather evidence about students' alternative conceptions, which is relevant when evaluating the extent to which dialogic teaching could be used to identify and address these misconceptions.

Two questionnaires were used targeting students' alternative conceptions in two different areas of electricity and magnetism: electromagnets, series and parallel circuits (2024a, 2024b). The complete results of the questionnaires are too extensive to report here, therefore I will summarise the most significant findings from each.

The questionnaire on electromagnets (University of York Science Education Group, 2024b) tested students' understanding of the connection between electric current and magnetic fields. It presented the students with four configurations of a wire, cell and iron rod and asked students to choose the configurations in which there would be a magnetic field. Whilst 73% of students correctly identified that a wire with no current through it would not have a magnetic field, only 13% of students correctly identified that a wire of any shape with a current through it would have a magnetic field. This suggests that the majority of the students in the class thought that the shape of the wire or presence of an iron core affected whether an electric current would produce a magnetic field. This alternative conception likely arose whilst students learnt about electromagnets due to the lack of student's prior experience with electromagnets (Sağlam & Millar, 2006). One possible explanation is that students conflated the factors that affect the strength of an electromagnet with the more fundamental connection between electric current and magnetic fields.

The remaining questionnaire on series and parallel circuits (University of York Science Education Group, 2024a) tested students' understanding of how adding components to a circuit in parallel or series affects the properties of the circuit. These questionnaires were completed after an activity where students answered questions about series and parallel circuits on mini-whiteboards. I then asked some students to explain their answers before revealing the correct answer. This enabled some class discussion about the common mistakes students made when thinking about series and parallel circuits. Students' answers to the survey therefore reflect their understanding shortly after the implementation of a type of dialogic teaching.

In this questionnaire, 96% of students correctly identified that adding a parallel branch to a circuit increases the current through the cell of a simple circuit. 79% of students correctly identified that the current through each parallel branch is independent and that they add up to the current through the cell. This suggests that the majority of students could recall how adding a parallel branch affects the current through a cell and most students understood the reasons behind this.

However, 21% of students did not correctly identify the reasons for parallel branches increasing the current through a cell. Of these students, 60% wrote that adding components in parallel increases resistance, suggesting that they were conflating the rules for series and parallel circuits. This misunderstanding often stems from a "source-consumer view" of electrical circuits (Driver et al., 1994, p.257), where students view electric current as a finite substance that is 'used up' by components in a circuit. Students with this alternative conception may erroneously reason that adding a component in parallel 'uses up' more current therefore reducing the current flowing through the battery.

Summary of findings

The main findings from the survey were that students thought that classroom talk helped them learn as it supported their understanding and reasoning. The majority of students attributed the learning benefit of classroom talk to these cognitive factors as opposed to the affective factor of engagement. However, the majority of students also reported that the reason they wanted to do more classroom talk was because they found it engaging, rather than because it supported their understanding and reasoning. This suggests that students view the potential of classroom talk to help them learn as distinct from the potential of classroom talk to support their engagement. This finding is contrary to Alexander's view that dialogic teaching "unites the cognitive and the social" (2020, p.129).

The observation document showed that some aspects of dialogic teaching are easier to identify than others. Especially in activities with lots of speakers, it is easier to monitor the presence and general character of the discussions than it is to monitor their content. By extension, dialogic activities with high numbers of speakers are more difficult to implement due to the teacher's lower degree of control. This is a challenge that is acknowledged in the literature of dialogic teaching (Alexander, 2020).

The questionnaires (University of York Science Education Group, 2024a, 2024b) found that more students had alternative conceptions about series and parallel circuits than they did about electromagnets. Students performed well on questions that required them to recall facts. For example, that a wire with no current through it has no magnetic field, or that adding a parallel branch to a circuit increases the current through the cell. Students did not perform as well on questions where they had to reason independently. For example, to determine if there would be a magnetic field for different configurations of wire, or to justify why adding a parallel branch increases the current through the cell. It is tempting to immediately make inferences about the effect of dialogic teaching in identifying and addressing these alternative conceptions, especially for the series and parallel circuits questionnaire which was completed directly after a dialogic activity. However, one must first consider the status of these findings, their reliability, and what factors they may depend on.

Analysis and discussion

The methodology of a case study means that the findings presented in the previous section depend on a host of factors specific to the context of this project (Bell, 2018). These factors can either be strengths or limitations when it comes to making inferences based on the evidence. It is therefore imperative to understand these factors before one can draw reliable conclusions from the findings. In this section, I will discuss the strengths and limitations of my findings and then use them to answer my two research questions (RQ).

RQ1: To what extent is dialogic teaching effective in identifying students' alternative conceptions about electricity?

The observation document shows that some parts of dialogic teaching are more difficult to implement and gather evidence for. In particular, the content of classroom talk is difficult to evidence, especially in activities involving large numbers of speakers. This raises a problem in answering this research

question, as to determine whether alternative conceptions were identified during the course of a dialogic activity, one must have access to the content of what is being said. Unlike Alexander's (2018) project which used video recordings of lessons to analyse classroom talk, the research methods used in this project did not include the recording of any classroom talk. Therefore, a different approach must be taken to answering this research question.

The survey gives us valuable insight into how students perceive classroom talk as a means of learning. A crucial part of the process of learning involves identifying alternative conceptions (Driver et al., 1994). Therefore, students' views on classroom talk and learning tell us something about their views on classroom talk and the identification of alternative conceptions. The fact the students unanimously said that classroom talk helps them learn suggests that students see it as helpful for identifying alternative conceptions. This is further implied by the majority of students saying that classroom talk helped them learn by supporting two cognitive aspects of learning, understanding and reasoning. Students' understanding of scientific concepts and their ability to reason with them relies on them having correct conceptions of scientific ideas. Therefore, if classroom talk supports students' understanding and reasoning, it is likely that it also supports them in having correct conceptions of scientific ideas. As Driver et al. (1994) argue, the means for obtaining these correct conceptions are via identifying and addressing their alternative conceptions. Thus, supporting students' understanding and reasoning involves identifying and addressing their alternative conceptions.

In the survey, a student put this succinctly by writing "[classroom talk] helps me understand the thing I was confused about better" (student 25). One can interpret the student as referring to the process of identifying and addressing alternative conceptions in several ways. As we have established, the identification and addressing of alternative conceptions is an important part supporting students' understanding. Thus, while we cannot know if this was what the student meant when they wrote that classroom talk 'helps [them] understand…', it is implied by their choice of language. Furthermore, the students' reference to "the thing I was confused about" (student 25) suggests that classroom talk was effective in helping them understand something that they previously misunderstood, in other words, an alternative conception. The findings from the survey would therefore suggest that dialogic teaching is effective in identifying and addressing students' alternative conceptions. This supports Alexander's view that dialogic teaching is deliberative, allowing students to "work towards reasoned positions and outcomes" (2020, p.131).

The main strength of the survey is that it represents the views of the entire class. Due to the consensus among students that classroom talk helps them learn, and the fact that 72% of students attributed this to it supporting their understanding and reasoning, the case above can be taken to reflect the views of most students in the class.

The reliability of the survey is limited due the process of inductive coding (Bell, 2018). The free text responses allowed students to fully express their views, however by assigning each view to a discrete category, my own interpretation of their response was imposed. Ideally, this should allow us to focus on only the relevant information in each response – in this case, the reasons students think classroom talk helps them learn. However, we should be careful to regard the coding process as an interpretation rather than a completely accurate representation of the view of the students.

The findings of the survey therefore suggest that classroom talk, and by extension dialogic teaching, is effective in identifying students' alternative conceptions. This includes their alternative conceptions about electricity as specified by Driver et al. (1994). The observation document adds the important caveat that it is difficult to find evidence as to whether an alternative conception has been identified through dialogic teaching due to the ephemeral nature of classroom talk. The effectiveness of dialogic teaching is therefore inferred from an interpretation of students' views on how classroom talk helps them learn.

RQ2: To what extent is dialogic teaching effective in addressing students' alternative conceptions about electricity?

The same conclusions from the survey can also be applied to answer this research question. If classroom talk supports students' understanding and reasoning, then it must also help 'address' students' alternative conceptions for the same reasons that it must help 'identify' them. Namely that the identification and addressing of alternative conceptions is a necessary part of supporting students' understanding (Driver et al., 1994).

The questionnaires (University of York Science Education Group, 2024a, 2024b) can also tell us something about the effectiveness of dialogic teaching in addressing students' alternative conceptions. Of particular relevance is the performance of students on the series and parallel circuits questionnaire as it came immediately after a dialogic activity in the lesson. Students performed better on the questions that required them to recall facts than the questions that asked them to explain their

answer. For example, 96% of students correctly stated that the current through a cell would increase if a bulb was added in parallel, but only 76% of students gave the correct explanation for this. This could imply that the dialogic teaching beforehand was more effective in helping students recall knowledge and less effective in consolidating their conceptual understanding. This would undermine Alexander's view that dialogic teaching promotes higher order thinking (Alexander, 2020).

Such a conclusion relies on a crucial assumption: that students' performance on the questionnaire directly reflects the effectiveness of the dialogic activity that came before it. This assumption is flawed as other factors such as the topic of the questionnaire, students' prior knowledge of the topic and a host of other uncontrollable variables also inevitably affected students' performance. Any inference that singles out one factor is therefore incredibly unreliable. In contrast to Alexander's (2018) randomised control trial, the small scale of this case study precludes any argument that seeks to establish a causal relationship between dialogic teaching and student performance.

It is far more useful to consider what alternative conceptions were identified by the questionnaire, and what the persistence of these alternative conceptions tells us about the effectiveness of dialogic teaching. The predominant alternative conception identified by the questionnaire on series and parallel circuits was the conflation of the rules for series and parallel circuits. This misunderstanding indicates that some students may have had a "source-consumer view" of circuits (Driver et al., 1994, p.257), which is a more general alternative conception of how electrical circuits work.

The persistence of this alternative conception, even after an episode of dialogic teaching that was specifically aimed at identifying and addressing alternative conceptions, demonstrates how entrenched they can be. This finding agrees with the view stressed by Driver et al. (1994) that addressing alternative conceptions presents a challenge to students as much as it does a challenge to teachers. Furthermore, the disparity between students who answered the questionnaire correctly and those who did not suggests that, whilst dialogic teaching may be effective in identifying and addressing alternative conceptions in some students, it may not be as effective for others. This is reflected in students' responses to the survey. Whilst all students said that classroom talk helped them learn, 7% of students said that they did not want more classroom talk in their lessons because it was "distracting" (student 4) and sometimes "off topic" (student 14). This contrasts with Alexander's (2020) view that classroom talk should be purposeful. The lack of purposeful classroom talk could

indicate that, for some students, dialogic teaching was less effective at identifying and addressing their alternative conceptions.

The findings of the survey and questionnaires suggest that dialogic teaching can be effective in addressing students' alternative conceptions about electricity. Through the survey, students reported that classroom talk supports their understanding and reasoning, both of which rely on the identification and addressing of alternative conceptions. The questionnaires show that despite the implementation of dialogic teaching, alternative conceptions persist amongst a minority of students. This suggests that dialogic teaching may be more effective in identifying and addressing the alternative conceptions of some students over others.

Conclusions and implications

From the previous analysis and discussion of my findings, we can conclude that dialogic teaching is effective in identifying and addressing students' alternative conceptions about electricity. This conclusion is supported by the survey, in which the majority of students said that classroom talk supported their understanding and reasoning. I made the argument that a necessary component of supporting students' understanding and reasoning is the identification and addressing of alternative conceptions. If we accept this assumption, then students' views on classroom talk and dialogic teaching support the conclusion that it is effective in identifying and addressing their alternative conceptions.

There are two important qualifications to add to this conclusion. Firstly, evidence gathered from the observation document shows that not all aspects of dialogic teaching are equally visible and easy to implement. For example, the participation of students in a discussion can be monitored by watching which students are talking. However, the content of a discussion is more difficult to monitor as it requires careful attention to be paid to the utterances of each student. This becomes increasingly difficult the more speakers there are. To implement certain types of dialogic teaching which involve lots of speakers therefore requires the teacher to relinquish some control of the students. This poses a challenge to its implementation, as the purpose of dialogic teaching may be lost without the control of the teacher. What would ideally be purposeful, deliberative, cumulative discussion could potentially descend into idle conversation without the input of the teacher.

Secondly, the questionnaires suggest that some students' alternative conceptions were not identified and addressed by dialogic teaching. Whilst one must be careful not to overstate this conclusion by making causal inferences about the reasons for students' performance, the results of the survey concur with the notion that for some students, dialogic teaching is less effective at identifying and addressing their misconceptions.

To finish, some modest implications for teaching practice can be drawn from these conclusions. Due to the case study methodology of this project, these implications should be regarded within the context of my own teaching and so should not be taken to apply universally. The main implication of this project is that dialogic teaching should be implemented as a means of identifying and addressing students' alternative conceptions about electricity and magnetism. The results of the survey suggest that students value teaching of a dialogic nature and view it as an effective way of helping them learn. However, in order to increase its effectiveness, the literature on dialogic teaching argues that one should explicitly instruct students on how to engage in discussion and classroom talk (Alexander, 2020), thus reducing the need for the teacher to have constant control. This is especially important for activities involving large numbers of speakers. One should also be mindful that dialogic teaching may not be as effective in identifying and addressing the alternative conceptions of some students - there is room here for further research into why this may be. However, for the majority of students, dialogic teaching remains effective.

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