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Using discrepant events with questioning and argumentation to target students' science misconceptions

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Abstract

Students come into the classroom with many of their preconceived ideas. To help our students learn better, teachers need to have a better appreciation of students’ conceptual understanding so that they are better able to tackle students’ misconceptions and knowledge gaps. At the same time, students also have to be engaged to learn actively to reconcile any discrepancies in their understanding of science concepts. This study examined how discrepant events, together with other scaffolding tools, could be used to promote discussions, questioning, and argumentation among students so as to drive their learning, foster critical thinking and surface their misconceptions. The teacher carried out demonstrations of these events and the students, working in small groups, put up their ideas for questioning and critical review. Through the lively discussions triggered by the discrepant events, the students evaluated their own and each others’ ideas. Data were collected through students’ written work and audio-recording. Students' questions and assertions pertaining to concepts demonstrated in the discrepant event provided insight into what and how the students were thinking. It was found that through proper scaffolding, students’ misconceptions could be elicited and dialogic discussions and argumentation could be encouraged to take place. By drawing on each others’ ideas, students’ discussions were rich as students found themselves having to defend what they believed in.

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Introduction

Science misconceptions are common among students. As teachers, we need to elicit these ideas from students so that we are able to address them during our lessons. If we were to ignore the ideas of these students, this could end up hindering their learning processes. There are many ways to draw out misconceptions from students and using discrepant event is one possible technique.

Using discrepant events in science lessons is not new and has been advocated since the 1980s. Generally, a discrepant event refers to the physical experience that provides students with novel evidence that contradicts their existing conceptions (Kang, Scharmann and Noh, 2004). Previous studies (Pheeney, 1997 and Friedl, 1986) on discrepant events have provided reasons for using discrepant events and how to set them up in a classroom context. However, their focus was on the benefits of using discrepant events to arouse students' curiosity and provoke their thinking process. Not many studies on discrepant events have emphasized the follow-up. In fact, little has been reported on how teachers can use discrepant events to bring about conceptual change in students after demonstrating them. According to Thompson's (1989) observation, many teachers often deem discrepant events as fun activities and do not use them for illustrating science concepts and principles. While discrepant events that are presented in this way might grab students' attention, such activities would do little to enhance our students' understanding of scientific concepts. Hence there is a need to know how we can use discrepant events more effectively.

The challenge for teachers lies in how best to address students' misconceptions so that students are aware of their misconceptions before proceeding further. This is where questioning and argumentation can help. Questioning is an important part of science inquiry and the ability to self-question can promote reflective thinking (Chin, 2006). At the same time, argumentation offers a platform to engage students in their thinking and reasoning (Newton, Driver, & Osborne, 1999).

Questioning and argumentation have been found to result in conceptual change and help students to internalize concepts well (Nussbaum, 2005). Because questions are generated by the students themselves, it also increases students' personal motivation in answering their own questions (NRC, 1996). Such relationships gave rise to the possibility of deploying questioning and argumentation as follow-up tools to discrepant events. Hence, if we were able to structure discrepant events well and follow up with proper students' questioning and argumentation, we could provide students with the opportunity to foster their own critical thinking process and facilitate their science misconception correction process.

While previous studies (Watts & Alsop, 1995 and Watts, Gould, & Alsop, 1997) have stated the importance of questions in learning science, the aim of this study was to explore the possibility and effectiveness of questioning and argumentation in a group setting to surface students' misconceptions of science, as well as using discrepant events and concept cartoons (Keogh & Naylor, 1993) to trigger discussions. At the same time, through this research, it is hoped that this would help teachers to identify certain pedagogical skills and structures that will (i) promote "argument" and questioning strategies amongst students, (ii) facilitate their discussions effectively and (iii) address students' misconceptions more effectively.

Methods

Classroom Setting and Participants

This study was carried out in two primary 6 (aged 11-12 years old) classes in the school. Each class has 20 students. Students from both classes were middle to high ability and were evenly matched in terms of academic performance. In their primary 6 Term 1 class test, the mean science score of class A was 71.2% while class B scored 69.8%. All sessions were conducted by the first author (who was their science teacher) and students worked in groups of four to six. There were 4 groups in each class and for most of the activities, the students were in the same groups for all demonstrations. The study was carried out over three sessions for each Primary 6 class. Each session lasted about 3 periods or 1.5 hours.

Instructional Procedure and Materials Used

During the study, discrepant events, as a trigger to elicit students' misconceptions and argumentation about the science concepts, were used to kick off all lessons for both classes. Three discrepant events were used in this study. All of these discrepant events were related to the topic of heat transfer and energy conversion. In selecting these discrepant events, extra care was taken to ensure that each of them had the potential of provoking students to give different claims and explanation about an observed phenomenon. Details of one of the discrepant events (Fire & Balloon) will be discussed in greater detail in the Results section.

At the start of each lesson during the study, students were given their worksheets before the teacher explained the demonstration set-up and posed the problem related to the discrepant event. This provided students with the necessary context of the discrepant event and allowed them to pose relevant questions about the set-up and make predictions about the outcomes before they observed what really happened. Once students had listed out their questions and predictions individually, they got into their groups to discuss what they thought might happen.

After 15 minutes, the teacher demonstrated the discrepant event and gave students sufficient time to describe individually what they had just observed. During this demonstration, students were more than welcome to list down any questions that may come to mind. After the demonstration, students had to explain the observed phenomenon on their own. They also had to also pose any questions that they had at this time and to indicate whether their observation turned out as predicted. The first part of the individual worksheet follows the sequence of the Predict-Observe-Evaluate (POE) model and aimed to engage students' in the thinking process before and after observing the discrepant event.

Once completed, students got into their groups again to discuss their ideas. If possible, students were placed into groups where half of their group members had opposing views. If that was not possible, the teacher arranged to have at least one student with opposing view in the group. This was to ensure that there would be the possibility of discussions and argumentation among the students. As a group, students shared and recorded their ideas and thoughts on their concept cartoon sheet. Students who shared the same ideas would record their ideas in the same speech bubble. Separate speech bubbles were used for different explanations. To prevent students from being swayed by different arguments, all members in a group had to present their views before any one could be challenged. After this, students could choose to challenge any of their peers' idea in their group by posing questions or counter-arguing the points they made.

To help students articulate their ideas and thoughts, various scaffolding tools were used. These tools, which included concept cartoons, worksheets and graphic organizers, served to document students' ideas for further analysis. The individual worksheet guided students through the various activities during the lesson. Concept cartoons were used to help surface common students' misconception for discussions while the argument/counter-argument sheet served to facilitate students' discussions in small groups and allowed them to record their reasons for agreeing or disagreeing with the various alternatives for the outcome of the discrepant event.

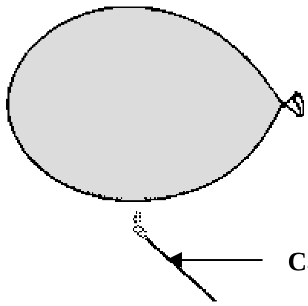
Other strategies like cooperative learning strategies and teacher questioning were deployed to enhance the quality of discussions. Group activities were carried out using cooperative learning strategies such as “Roundrobin” and “Roundtable” (Kagan, 1994). Student took turns to present their ideas orally during the Roundrobin. After each student’s sharing, the other students in the group wrote what they agreed or disagreed with the presenter’s ideas, using the Argument/Counter-argument Sheet. Once everyone had completed their presentation, students passed their sheet in a Roundtable format for further comments. This ensured that all students in the group contributed to the group’s discussions. Some of the group discussions were facilitated by teacher questioning. During these discussions, teacher joined the group discussions to prompt and provoke students’ thinking and questioning.

Results

This section presents findings from the use of one of the three discrepant events that is related to the topic of heat transfer. Pseudonyms have been used in place of the students’ names.

Fire & Balloon

This discrepant event tested students’ ideas about heat and required them to explain why a balloon filled with water could continue to be heated by a candle without bursting, while a balloon filled with air would burst.



For this activity, students' responses were collated mainly through their written responses and the audio-recording of their group discussion with the teacher. Students' ideas in this activity included:

- Air expansion is what causes the air-filled balloon to burst.
- Water will evaporate from the sealed balloon.
- Rubber is a poor conductor of heat and that is why both balloons will not burst.
- Air a good heat conductor and will make air in the balloon expand faster.

This is a tricky misconception as the reason why an air-filled balloon will burst is because the rubber of the balloon softens as it is heated. When the rubber becomes too weak to withstand the pressure of the air in the balloon, the balloon bursts. Similarly, in a water-filled balloon, water has a higher heat capacity compared to the rubber and as such, it requires more heat to raise its temperature. Water absorbs most of the heat energy of the flame and slows the increase of temperature. As such, the rubber is prevented from becoming too soft to withstand the internal air pressure and hence the balloon did not burst.

During the audio-recording, it was found that students were responsive to their peers' ideas. The excerpt below from a post-observation discussion shows that Jason from a group in Class A suggested how water, being a heat insulator, prevented the water-filled balloon from bursting. Heng proposed that the balloon did not burst because heat could travel through water. Ken suggested that the balloon would burst as it would contain air spaces which would cause the balloon to expand further. At this point, Jen asked if the heat absorbed by the water would cause it to evaporate. Heng rebutted her suggestion. There was evidence of extended thinking when the students suggested scenarios beyond the discrepant event. The students in this group did not change their ideas even after their discussions. It is likely that this group of students believed their explanations were able to explain the observed phenomenon correctly.

Jason: I think that the balloon filled with air will burst but not the one filled with water [claim 1]. This is because the air will expand but the water is an insulator of heat [reason 1].

Jen: How can? The balloon will also expand [rebuttal to reason 1].

Jason: The balloon filled with water is cooler [backing to reason 1].

Heng: The balloon filled with water will not explode [claim 2] because the heat travels through water and water won't explode [reason 2].

Ken: How can water explode?

Jason: Can.

Ken: Anyway, there is also a little bit of air space so it will burst [rebuttal to reason 2].

Jason: But the balloon is filled with water [counter rebuttal].

Ken: Yeah but it is not all.

Jason: The balloon is totally filled with water. So how can it expand further [counter rebuttal]?

Ken: Can.

Jason: But the water will absorb the heat [backing to reason 2].

Jen: So the water will evaporate?

Heng: No. It is sealed so water cannot even evaporate.

Jen: But it can condense.

Ken: What happens if it is a hot day and it can’t condense?

Heng: But even when it condenses, it doesn’t come back (in)to the water (balloon).

Ken: Fire is hot so what happen if the water boils?

Heng: Fire is so small. How can?

Jen: If it boils, the balloon will burst because the water (balloon) is already full.

The excerpt above shows the students questioning and challenging each others’ ideas in their attempt to make sense of the observed phenomenon.

Below is an example of how the teacher drew out students’ ideas and stretched their thinking through questioning during their group discussion in Class B. The questions built on students’ previous ideas and by getting students to respond to them, students’ thinking advanced step-by-step.

Zen: What does absorb heat mean?

Jay: It means that the water takes in the heat.

Aaron: So you mean that the water takes the heat away from the fire?

Shin: Not all. Some of it is taken by the balloon and that is why there is a black mark. Most of the heat is taken by the water.

Aaron: Does that mean that the water will be hot?

Shin: No the water will still be quite cool.

Teacher: What do you mean by quite cool? Is it higher or lower than room temperature? Or the same?

Shin: Same as the room temperature.

Teacher: Even after some time?

Shin: After some time, it may go above room temperature but not so much.

Nick: I think the water will cool the balloon first before it burst [claim].

Teacher: How does the water cool the balloon?

Aaron: Er… because heat travels to a cooler place [reason] so the heat will travel to the balloon. The water will bring heat to some other place.

Teacher: What place?

Aaron: Inside the balloon.

Teacher: So you mean that heat will move inside the balloon through the water?

Shin: So you mean that the water will transfer the heat?

Aaron: Yeah.

Teacher: How does heat circulate?

Aaron: Er…

Many misconceptions or contradictions in ideas made by students in the midst of their reasoning and explanation were picked up and pointed out by their peers. This helped somewhat to moderate the discussions. One such example is given in the following excerpt. Here a student in class B, Ru, believed that both balloons (air filled or water filled) will not burst but would become smaller. She was rebutted by Nic who pointed out that when air is heated, air will expand. Ru thought for a while before she decided to change her idea.

Ru: I think that both balloons (air filled or water filled) will not burst [claim] because the heat is heating above them (heat source is below the balloons) [reason] but they will become smaller.

Nic: When air is heated, air will expand and balloon will get bigger [rebuttal].

Teacher: Any response to that? (Pause; Ru pondered and was quiet) Do you want to change your idea? (Ru nodded)

However, while students can help moderate the discussions, the role of teacher continues to be crucial as there were some misconceptions that were not picked up. The teacher had to move around the groups and helped to facilitate the discussion to bring the group back on track.

After the group discussions, the teacher brought the students together in a whole-class discussion to consolidate the key group discussions. The following is an excerpt from the classroom talk in Class B.

Jay: I think that the balloon filled with air will burst but not the one filled with water [claim] because when the balloon filled with air touches the fire, [it] will expand and burst [reason]. But the balloon filled with water will not burst [claim] because the water inside is a poor conductor of heat [reason].

Teacher: Any question? So we all agree that when heated, the air in the balloon will expand and cause the balloon to burst. But the water in the water balloon is an insulator of heat? How is that related to expansion? Does that mean that a heat insulator does not expand?

Jay: Expand slowly.

Teacher: Are you saying that if I put the water balloon long enough, the water will expand and cause the balloon to burst?

Aaron: I disagree as I think the fire will burn the rubber first [rebuttal].

Jay: I think the water balloon did not burst [claim] as water absorbs most of the heat [2^{nd} reason].

In the above excerpt, we see that although Jay did not have an accurate idea about water expansion, the teacher did not correct what was said during the class discussion. Instead, the teacher took the opportunity to probe further into Jay's reasoning.

Discussion

Besides the typical approach of using discrepant events to elicit students' misconceptions, discrepant events can also be used to promote questioning, discussion and argumentation among students. Using discrepant events in such a way provides teachers with a better understanding of what conceptual understanding students have and allow teachers to better tackle students' misconceptions and knowledge gaps. Students' questions and assertions related to concepts demonstrated in the discrepant event also provide insight into what and how the students are thinking. For students, the scaffolding tools that supported the discrepant event provide a platform for them to articulate their thoughts and challenge their peers' ideas. By stimulating dialogic talk among students, it has also allowed students an opportunity to construct their own scientific knowledge.

A limitation of this study is that it involves a small group of average to high ability level students (n=40) in my school and as such cannot be generalized to all Primary 6 students in Singapore schools or even the Primary 6 students in my school. Also there are many other factors that affect the outcomes of the lessons such as the students' group dynamics and teacher's facilitation skills.

After conducting the study, we offer the following suggestions that we believe would enhance teachers' pedagogical practices.

- *How can we make use of discrepant events to promote debate and questions among students? What kind of discrepant events would be more suitable for such a purpose?*

To promote debate and questions among students, discrepant events cannot stand alone. Scaffolding tools need to be provided to students so that students' thoughts can be unpacked and their ideas can be articulated clearly for their peers to understand. At the same time, a safe classroom environment must be provided so that students are more likely to share their ideas willingly. Discrepant events for such a purpose should:

→ Have a clear and fast outcome (most physical science demonstrations should fit this bill easily) so that students are able to observed the outcomes of the effects and that discussions can continue in class;

→ Be related to concepts which the students have already learnt or at least have connections to students' daily lives so that students have the necessary vocabulary to explain the observed phenomenon;

→ Encourage different students to come up with different explanations.

- *How can questioning and debate be used to expose students' science misconceptions in my class?*

As seen in the results section, as students discussed what they thought could have caused the observed phenomenon, science misconceptions were revealed. Most of the times, these were picked up by their peers and discussed further.

Contribution to the Learning of Science

In this study, it was found that the activity sheet, argument/counter-argument sheet and concept cartoon provided a structure for students to carry out their discussion about the discrepant event. It guided students in questioning what they see, expressing their thoughts, coming up with explanations and challenging others.

Analysis of the audio recording showed that students do build on their peers' ideas and provide responses that stretch the group's original thinking. By writing their responses first before they present to their peers, it allowed them to think through what they are thinking about and gave them something to refer to during their group discussion. This helped to boost the confidence level of students, especially the quiet ones in sharing. Even when they do not have the definite answers, students are found to be more willing to come up with possible explanations to justify their claims.

Having to defend their viewpoints following their peers' questions might have deterred some students from speaking. However, it also encouraged many students to think twice before they spoke. One common observation is that most students who began their group discussions had a lengthier explanation and often these students would pause halfway through their verbal responses and tried to recollect their thoughts in their attempt to give a complete explanation of what they had observed. As such, they were deemed to be more thoughtful in their answers. Overall, the students were more confident in expressing themselves and reflective in their thoughts and the group and class discussions were much richer.

Conclusion

This study showed how discrepant events, together with the use of other scaffolding tools, can be used to support students' learning and how teachers can support students in their quest to evaluate their knowledge claims and to communicate them to others. Such critical thinking and communication skills are important as they are part of the 21st Century skills (http://www.21stcenturyskills.org) which our students should have. To enhance the use of discrepant events in teaching and learning science, teachers cannot just depend on the cognitive dissonance generated by discrepant events. Instead, teachers need to design classroom routines and structures to stretch students' thinking and provide opportunities for collaboration so that the full benefits from discrepant events can be harnessed.

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