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How to Make the Teaching of Heat Transfer More Effective

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Maskill and de Jesus (1997, 781) write, "According to the constructivist approach, all learning starts from a basis of previous experience and develops in a purposeful fashion according to the usefulness or value which the new ways of dealing with the world have for each individual learner."

The field of learning today emphasizes the exploration of students' prior ideas and expectations, because knowing students' prior knowledge can help teachers proceed in a meaningful way. However, investigating every student's prior knowledge or alternative frameworks, especially in a large class, is challenging. An alternative strategy is to draw on the literature to find common alternative frameworks on a particular topic. However, this strategy assumes that all students' ideas match the findings in the literature, which may not be the case; context influences students' alternative frameworks. The question–answer technique is another alternative for exploring students' ideas, but this strategy may not give the students adequate time to think. There is no single effective technique for exploring students' prior knowledge. However, using a combination of techniques—such as brainstorming, written response and prediction—can be effective and interesting in eliciting students' ideas about a topic. Teachers can also give students various types of practical activities, ask them to make predictions and then test their observations.

In this article, we share our insights into how to make the teaching of heat transfer more effective in light of students' alternative frameworks.

Rationale

Teaching and learning are difficult, complex tasks. To teach effectively, teachers must constantly plan and reflect. Many factors can affect the processes of teaching and learning.

When we recently taught heat transfer to a class of 13- and 14-year-olds at a school in Pakistan, we applied techniques such as brainstorming, prediction and written response to elicit the students' prior knowledge. These techniques helped make our lessons more interesting, and the students seemed to enjoy the learning process.

Writing this article has helped us to further increase our understanding about teaching heat transfer and to carry on further in-depth exploration. It has also helped us to analyze the relationship between students' alternative frameworks, practical work and new learning. Finally, it has allowed us to reflect on how alternative frameworks hinder new learning and to determine what strategies and activities we can adopt to make our lessons interesting and the students' learning purposeful.

Data-Collection Strategies

This article is mostly based on our classroom teaching. We collected data from our unit plan, the students' worksheets, questions and answers, predictions, objective tests, observations, the facilitator's feedback and the literature. We also got data from after-lesson discussions with our classmates and facilitator during the Lower Secondary Science Module at the Aga Khan University Institute for Educational Development (AKU-IED) in Karachi, Pakistan.

Analysis and Literature Review

This article aims to reveal the importance of considering students' alternative frameworks in making the teaching and learning of heat transfer more effective. Our facilitator assigned us the task of delivering three lessons (one per day) on heat transfer to a class of 13- and 14-year-old students. For this purpose, we prepared a tentative and flexible unit plan (see the appendix for our reflection on our unit plan).

Our Plan in Action

Lesson 1

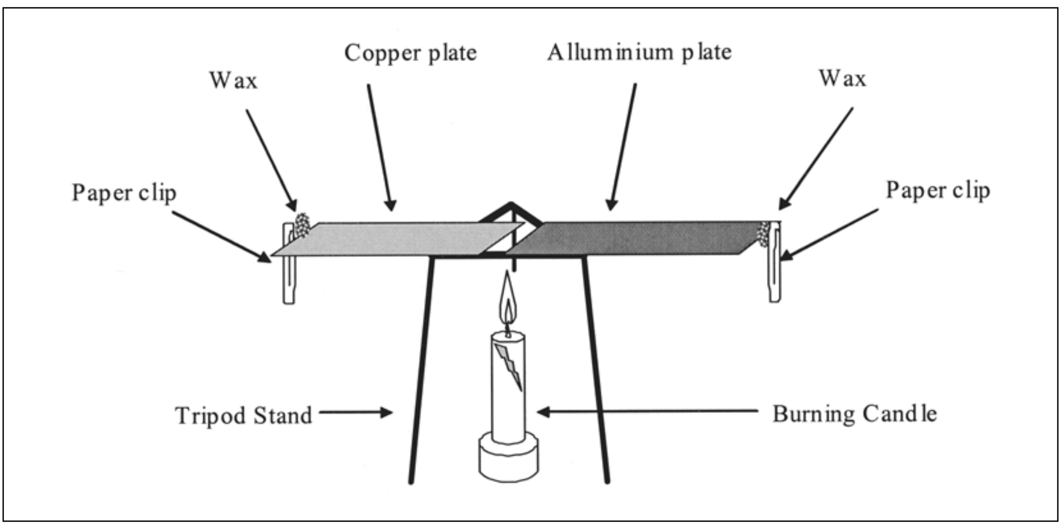
On the first day, we asked the students some exploratory questions and observed that only a few students responded, perhaps because the others did not have enough time to think or were not prepared for this approach.

We next applied the predict–observe–explain (POE) strategy. The students wrote down their predictions and participated in a class discussion. We gave the students activity sheets and metal plates (copper, iron, brass, aluminum and zinc) and asked them to predict which plate would best conduct heat and to then order the plates by conductivity. The students all ordered the plates differently. Most put iron at the top of the list. Upon testing (see Figure 1 for the set-up), when the wax on the copper plate melted first, the students were surprised and started reasoning about the observation. We recognized this as a good start for students to learn in light of their alternative frameworks.

As for copper and aluminum, there was little difference; therefore, the students repeated this activity three times by changing the angles and positions of the plates. This we interpreted as follows: when students find something that contradicts their prior knowledge, they become curious, keenly scrutinize the new findings and then ultimately reconceptualize. This strategy helped the students to rethink their predictions.

However, limited activities may not be enough, because alternative frameworks sometimes become so strong that, after continuous practice, students revert to them. Stevenson and Palmer (1994, 130) argue that, to bring about real learning, real reorganization of knowledge and understanding is needed: "This requires considerable effort and the use of sophisticated metacognitive strategies." Therefore, students should be given ample time to investigate.

Figure 1
Conductivity Experiment



During the discussion, some students asked why heat is transferred more easily through metal. The activity got the students to engage in critical thinking. At this point, we discussed the role of free electrons in heat transfer (Hoong 1997).

Lesson 2

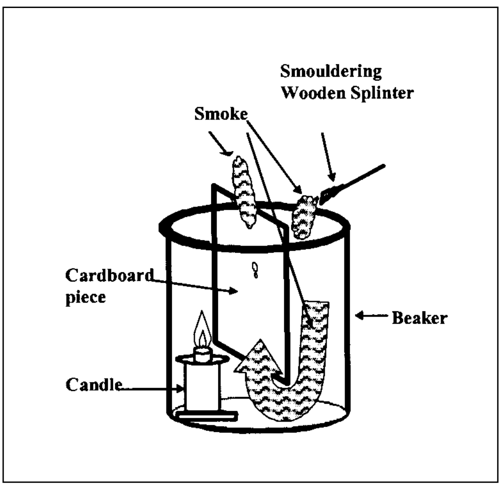
On the second day, we changed our strategy slightly but still used POE. The topic was heat convection.

We asked the students to predict the movement of smoke in a smoke cell (see Figure 2).

Many of them wrote that the smoke would move up from the smouldering splinter. When the smoke went down to the other side, where the candle was, and came out of the beaker from the candle side, the students were surprised and started reasoning. When we asked one student why the smoke moved downward and toward the candle, the student responded that the candle flame attracted the smoke. We took the candle out and brought the smouldering wooden splinter close to the candle flame. The candle flame did not attract the smoke. We asked the student why. The student became silent (perhaps thinking about it). Then we asked the student why on a hot day a cool breeze blows toward land. The student responded, "It is the nature of air." Thus, we used the student's ideas as a starting point for discussion. We discussed convection current, which caused the flow of the smoke current in the smoke box. We then discussed how hot air expands, becomes less dense and rises upward while cool air, which is more dense, sinks and takes the place of the hot air, thus setting up a convection current (Hoong 1997).

The students needed more activities and discussion to understand convection current. Otherwise, it was difficult to change their alternative frameworks because their ideas made sense to them.

Figure 2
Smoke Cell

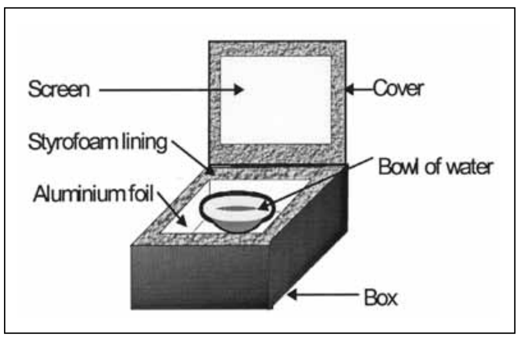


Lesson 3

On the third day, we discussed heat radiation. We gave the students some activities, the most interesting of which was the solar box (see Figure 3).

We poured equal amounts of water into two small stainless-steel bowls of the same size. The students then took the temperature of the water in each bowl using the same thermometer. The temperature in both was 20°C. The children then put one bowl of water in direct sunlight and the other in the solar box (with the box facing direct sunlight like the first bowl). After 10 minutes, the students predicted the temperature of the water in each set-up. Nearly all the students said that the water in the bowl outside the solar box would be warmer because it was getting direct sunlight. The students then checked the temperatures. They were surprised that the temperature of the water in the bowl in the solar box was 34°C whereas the temperature of the water in the other bowl was only 24°C. They became curious and started asking questions and trying to make sense of the results. A number of students

Figure 3
Solar Box



said that the aluminum foil inside the solar box increased the temperature. This was the right moment to extend student response and discuss heat transfer by radiation and the greenhouse effect (Hoong 1997). We also discussed how aluminum foil acts as a reflector of heat and how Styrofoam is a poor conductor of heat.

We then drew on students' real-life experiences: "Do you feel hotter inside the vehicle or outside on a sunny day?" Most of the students said that they felt hotter inside. We asked them why. Some explained it in terms of the greenhouse effect. When students are taught through exploration of their prior knowledge, they understand a concept better. To internalize the idea, the students needed more activities, but time constraints did not allow this.

When we gave the students the materials to make the solar box, they became engrossed in the task. One group completed the box during class time, but the others only partially finished. The students were enthusiastic and did their practical work with interest. They asked many questions. One student inquired, "Where can I buy aluminum foil?" The students were interested in making the solar box at home. Hofstein (1988) suggests that involving children actively in practical work enhances their interest and learning.

Our experiences in this science classroom reveal the important role students' prior knowledge plays in teaching and learning. McCloskey and Kargon (quoted by Stevenson and Palmer 1994, 125) refer to this view as "the intuitive impetus theory" and write, "Intuitive theories that are misconceived can have serious consequences." Thus, we believe that these theories should be addressed. Otherwise, preexisting ideas might create conflict in students' minds, and the students may not be ready to accept the new concepts.

What We Learned

It is not easy to change students' alternative frameworks in a short time. The process requires more time, work and reflection. Driver, Guesne and Tiberghien (1985, 148) believe that "when new ideas conflict with children's point of view they can be an obstacle to learning." They further remark that children internalize experiences that are partially their own, and their personal ideas influence the newly acquired information. This means that a teacher who teaches without knowing the students' prior knowledge will not understand the students, and this could create further misconceptions. White and Gunstone (1992) also argue that learners enter the classroom already holding personally constructed ideas and beliefs. They observe and think about new findings critically and try to make sense of them. Maskill and de Jesus (1997, 788) write, "Pupils are making a serious effort to understand why their previous ideas are not scientifically correct and are seeking help to learn the difficult ideas." We observed a similar situation in our classroom teaching: the students started reasoning about and reflecting on the topic when their findings did not match their predictions.

Students' prior ideas are crucial in teaching and learning, but how should the teacher explore these ideas? As already mentioned, teachers can use many techniques—including question–answer, brainstorming, written response, literature and POE—to reveal students' alternative frameworks. During question–answer, we found that most children felt threatened or did not have enough time to think deeply. Also, some children might not have understood the questions (Maskill and de Jesus 1997). Maskill and de Jesus (1997) recommend that teachers provide written questions to give students enough time to think and to express themselves. When we gave the students written questions during activities, almost every student wrote something on the worksheet, which helped us greatly in understanding their prior knowledge.

Another way to reveal students' alternative frameworks is examining research on alternative frameworks in a specific topic. However, the alternative frameworks noted in the literature may not match those of the given students, because students have different cultural and contextual backgrounds and experiences. Examples of students' alternative frameworks about heat transfer noted in the literature include the following:

- "Heat acts as a fluid. It accumulates in one spot until that spot is filled" (Stepans 1994, 77).
- "Metal is colder than plastic because cold passes through it more quickly than plastic" (Stepans 1994, 77).
- "When they [students] wear lots of clothes they heat up" (Newell and Ross 1996, 35).

We found different alternative frameworks during our classroom teaching, even though the topic was the same. Also, different teaching approaches can affect students' learning in different ways. Children get their prior ideas from their parents and peers and through observing their surroundings. They also get prior ideas through trial and error in society. Lynch (1996) designates culture, language and the way the same word may have different meanings in different contexts as the main sources of alternative frameworks.

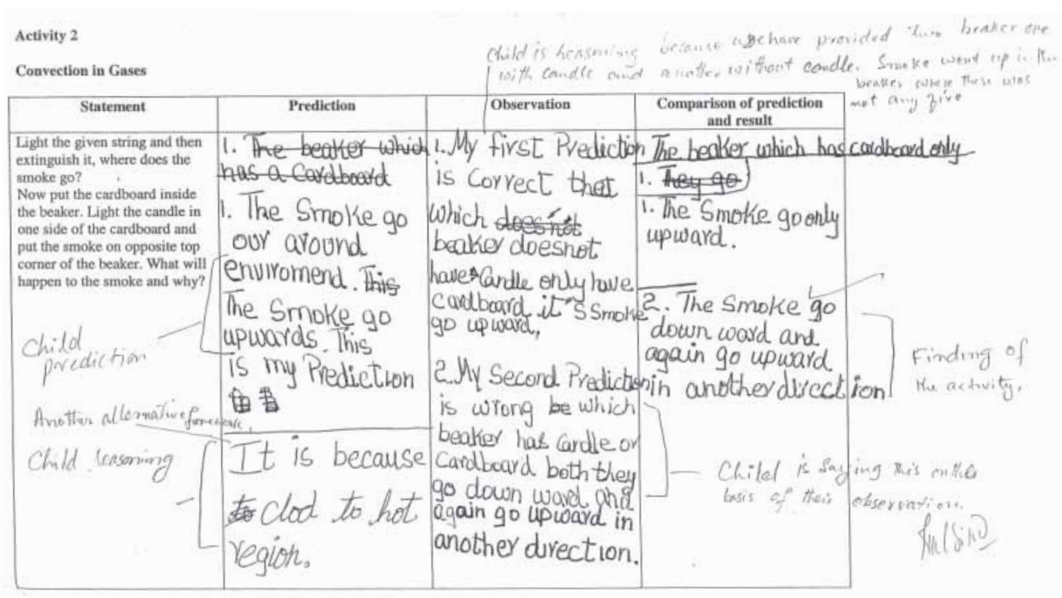
In light of the above insights, we predominantly applied the POE strategy and written response to reveal students' prior knowledge and alternative frameworks. White and Gunstone (1992, 45) write, "POE is often more direct than the usual style of question in revealing understanding."

Practical work plays an important role in teaching and learning. Leach and Scott (2000, 68) write, "Practical work is one of the hallmarks of science, and many educators argue that a science education without practical work fails to reflect the true nature of scientific activity." Thus, practical work is crucial to understanding scientific ideas. Bentley and Watts (1989) also argue that practical work is necessary for developing students' skills in science. Students internalize new concepts better through hands-on activities. During our three days of teaching, we also found that the students learned better through practical work. We assessed their learning through question–answer, observation, worksheets and a short test (see Figure 4) and found that most students could provide answers in their own words.

White (1991) also favours practical work and writes, "It is necessary to see the process of practical work particularly if the focus is on conceptual restructuring." However, engaging students in practical work without exploring their alternative frameworks is not as effective.

Providing challenging activities involving questions, prediction and problem posing can make lessons more effective. During our three days of teaching, we made our activities more interesting and enjoyable by exploring students' prior knowledge through POE and question–answer techniques. We now realize that there are a variety of techniques for making teaching and learning effective. More important, we now believe that hands-on activities that explore students' alternative frameworks play a significant role in students' learning.

Figure 4
An Example of POE


Activity 2

Convection in Gases

Statement	Prediction	Observation	Comparison of prediction and result
Light the given string and then extinguish it, where does the smoke go? Now put the cardboard inside the beaker. Light the candle in one side of the cardboard and put the smoke on opposite top corner of the beaker. What will happen to the smoke and why?	1. The Smoke go our around environment. The Smoke go upwards. This is my Prediction. It is because to clod to hot region.	1. My first Prediction is Correct that which beaker doesnot have Candle only have Cardboard it's Smoke go upward, 2. My Second Prediction is wrong be which beaker has Candle or Cardboard both they go down ward and again go upward in another direction.	The beaker which has cardboard only 1. The Smoke go only upward. 2. The Smoke go down ward and again go upward in another direction

Implications

Ausubel (quoted by Cockburn 1999, 13) writes, "The most important single factor influencing learning is what the child already knows." We can make our lessons more effective through exploring students' prior knowledge. But simple, short questions and answers are not enough because sometimes students do not take questions seriously and respond with whatever comes to mind. Therefore, teachers should further probe during the question–answer process by using *what, why* and *how* questions.

Giving students different types of activities without exploring their alternative frameworks poses difficulties for their understanding of new concepts. When children encounter a new concept, they naturally think of it in terms of what they already know. Students' prior knowledge has far-reaching effects on their learning.

Teachers should use POE and written response to explore students' alternative frameworks because this strategy will make practical work more challenging and help students to think more critically. Students become engrossed in hands-on activities when such activities are assigned to them after exploration of their alternative frameworks.

Teachers can use a variety of activities to make lessons challenging for students. For example, a teacher can put a Thermos in front of the students and ask them why its outer and inner layers are silvery and shiny, and why there is a space between the inner and outer layers.

After an activity, teachers should give students enough time to discuss the topic and should listen to their points of view carefully, because there can be strong reasoning behind them.

Conclusion

The minds of students are not like empty vessels (Lynch 1996). They contain ideas gathered from various sources. When students encounter something new, they see it in light of their previous knowledge. During our three days of teaching about heat transfer, we tried to explore students' ideas through prediction and written questions. We found that students do have ideas about abstract topics such as transfer of heat. In light of these alternative frameworks, we gave them hands-on activities and found that they became curious when something went against their predictions. They asked questions and tried to find the real cause. We now realize that we can make teaching heat transfer more interesting and enjoyable by exploring students' alternative frameworks and using hands-on activities.

Appendix
Unit-Plan Reflection

With guidance from our facilitator, we developed our unit plan in a systematic and sequential manner. We started with the conceptual framework and then developed three lesson plans and activities. The facilitator read the lesson plans and gave us feedback.

We were also given the opportunity to discuss and modify our unit plan with classmates teaching a similar topic. We shared and learned from each other and from the facilitator's feedback. This helped us to enrich our unit plan. Also, we engaged in self- and peer evaluation using criteria provided by the facilitator. Furthermore, we modified our unit plan and experiment designs after trying the experiments ourselves. This was followed by a briefing on how to proceed with the actual teaching. In the process, we clarified our own concepts and developed trust between us, our classmates and the facilitator.

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