Overview and Comparison of Basic Teaching Techniques That Promote Conceptual Change in Students

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Abstract

For meaningful learning of physics to occur it is necessary that teachers address students' alternative conceptions during teaching, and help students overcome their conceptual difficulties. In other words, teaching should induce conceptual change in students. Four basic teaching techniques (cognitive conflict, concept substitution, bridging analogies and Socratic dialogue), that are known from physics education research to promote conceptual change in students, are analyzed. A brief introduction in each technique is given, along with some examples of its application. The techniques are then compared regarding their functioning in the classroom, based on the teaching experience of the authors.

Introduction

It is well known from physics education research worldwide that students hold many alternative conceptions regarding various physics phenomena. If meaningful learning of physics is to occur, it is important to help students make the transition from their existing viewpoints towards the science view. In other words, it is necessary to induce conceptual change in students. However, that is not an easy task for the teacher. Several teaching techniques or strategies that promote conceptual change in students have been proposed by researchers in the field of physics education. All of these strategies have shown some success in inducing conceptual change, but all of them also have their limitations.

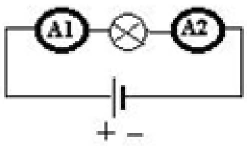
The aim of this article is to present four basic teaching strategies that can lead to conceptual change in students and point to some important differences between them and to different effects that they have on students. The authors have been using these strategies for a number of years while teaching physics education and physics education lab at University of Zagreb.

Cognitive conflict

In this approach (Posner et al., 1982) student's existing ideas about some phenomenon are made explicit and then directly challenged, in order to create a state of cognitive conflict in student. It is the oldest and most well known strategy of promoting conceptual change. It may be seen to derive from a Piagetian view of learning in which the learner's active part in reorganizing their knowledge is central (Scott, Asoko & Driver, 1991). This approach is mostly used with experiments. Before an experiment is performed, the teacher asks students to give their prediction of its outcome, based on their existing ideas. The experiment is then performed, and the outcome turns out to be different from students' predictions. The discrepancy between prediction and outcome creates cognitive conflict in students. In trying to resolve that conflict, students (guided by the teacher) should abandon their old conception and replace it with the proposed scientific conception.

That is the main idea of the cognitive conflict approach, but in practice many problems can occur with its application. First, the success of this type of approach depends strongly on the will and ability of each individual student to recognize and resolve the conflict. Some intellectually less able students may fail to even recognize the conflict, and some of those who do recognize it might not be able to resolve it. Secondly, students are generally reluctant to abandon their ideas, which is understandable. Alternative conceptions are their own ideas, formed upon their own experience. On the other hand, scientific ideas are counterintuitive, often hard to understand, and not grounded in students' experience. Therefore, only one experiment that contradicts their predictions, will often not be enough for students to reject their alternative idea and replace it with the scientific one. On the contrary, students will first try to discredit and reject the result of the experiment in question. Usually it will be necessary to challenge an alternative conception on several occasion and in different contexts to achieve conceptual change. More able students generally respond better to cognitive conflict approach than less able students, since this approach presupposes the existence of a certain structure of ideas in students, and a need for consistency among ideas. Another problem with cognitive conflict is that it can create a certain frustration in students, especially in those students who have less confidence in their knowledge. For more self - confident students cognitive conflict can be challenging and motivating, but less self - confident students can see it as a confirmation of their inability to do physics.

Example: Is electric current used up in the circuit?



Before the circuit is closed, students are asked to give their prediction of ammeter readings. Usually they will predict that one of the ammeters will indicate stronger current, the one that comes „before“ the bulb in the direction of the flow, because some current will be used up in the bulb. After the predictions are established, the circuit is connected and students can see that both ammeters reading are the same. They are surprised by this result, and they usually don't accept it immediately. Some will claim that the ammeters do show slightly different readings (that can actually be true, due to small differences in construction of ammeters). Others will say that the ammeters are not sensitive enough, or that the bulb is too weak so the difference is hard to detect. The teacher has to be prepared to answer to all these objections and perform additional experiments if necessary. Eventually students do accept that the ammeters show the same reading, but that doesn't necessarily mean that they have completely abandoned the idea of current being used up in the circuit.

Concept substitution

Concept substitution technique (Grayson, 2004) is based on the fact that the essence of some student ideas is correct, but the idea is applied to the wrong concept. If this concept is substituted with another concept, the idea may become correct. A good case for concept substitution is the idea of the electric current being used up in the circuit. The idea that something is used up in the circuit is very obvious to students, and in essence correct. Batteries become flat with use, bills come every month for something that was used up in our electric circuits at home. The problem is that students associate this idea with electric current, since they see it as the central concept with which they try to explain all phenomena related to electric circuits. If the idea that something is used up in the circuit is applied to energy in the circuit (with detailed discussion that “using up” energy means transforming it to other forms of energy, that cannot be used in the circuit any more), this idea becomes correct, and it makes the acceptance of conservation of current easier for students. Besides, this technique is much more agreeable for students, because it confirms their ideas to some extent.

Students accept concept substitution well, because unlike cognitive conflict it doesn't require radical restructuring of ideas on their part, but only a modification of their existing ideas. The limitation of this strategy is that it can not always be implemented. However, there are many important cases where it can be implemented (e.g. impetus ideas, Newton's third law etc.)

Anchoring conceptions and bridging analogies

Similar to concept substitution, this teaching strategy also starts from students' correct ideas. Many ideas in physics are counterintuitive and students therefore don't accept them easily. This strategy builds on students' existing ideas by forming analogy relations between a misunderstood target case and an „anchoring example“, which draws upon intuitive knowledge held by the student (Clement, Brown & Zeitsman, 1989; Clement, 1993). Anchoring conceptions are student ideas that are roughly correct from physics point of view, and can serve as analogies with counterintuitive target conceptions. They represent a good, unproblematic starting point for thinking about a certain phenomenon.

If the analogy between the anchoring conception and target conception does not work immediately, additional bridging analogies are introduced, that lead the student to the target conception.

Example: A book is at rest on the table. Does the table exert a force on the book?
Target: The table exerts a normal force on the book directed upward.
Anchor: If a book is supported by hand, the hand exerts a force directed upward on the book.
Bridge: If a book is placed on an elastic spring, the spring is deformed, and exerts a force on the book in the upward direction.

Students have no problem with the idea that the hand exerts a normal force on the book. This idea is rooted in their experience. However, the analogy between a book on the table, and a book on the hand may not work for all students. Problem is usually that students cannot imagine how the table produces that force. The bridging analogy with a book on a spring provides the mechanism for the normal force and usually resolves the problem.

This strategy works well for those cases where suitable analogies can be found. It brings about conceptual change by building on students' correct intuitions.

Socratic dialogue

Socratic dialogue (Hake, 1992) is a form of teacher's conversation with a student in which the teacher encourages student's thinking and, instead of providing the correct answer, leads the student slowly to his/her own conclusion, that may be different from the student's initial opinion on the problem.

Example: Newton's third law – are the forces of interaction between two object always equal in magnitude?
Teacher: The Earth attracts a falling apple with gravitational force. Is there a force of the apple on the Earth?
Student: Yes, but it is much smaller than the force of the Earth on the apple.
T: Why do you think that it is smaller?
S: Because the apple falls and the Earth is at rest.
T: Could Newton's third law be applied to this case?
S: Well, according to Newton's third law the forces would have to be equal … but I don't see how that could be true…
T: What would happen if the forces were equal?
S: I guess the apple and the Earth would get equal velocities.
T: What about the masses, do they influence the velocities?
S: The masses are very different..

T: If equal forces act on objects of different masses, will the effects of the forces on the objects be equal?

(Here the conversation stops for a while, the student uses Newton’s second law to determine the accelerations that the objects will acquire.)

S: No, the effect will be larger on the smaller object.

T: So, if forces on the apple and on the Earth were equal, what would happen?

S: The acceleration of the apple would be larger…Oh, I see, that means the forces can actually be of equal magnitude…

T: Yes, it is important to distinguish between forces and the effects that they produce. Equal forces can produce different effects.

This short example shows how students can be led to correct their own thinking. Socratic dialogue is especially useful in those settings where students work individually or in small groups. It can be very productive in improving student reasoning, but it requires considerable time and effort on the part of the teacher.

Conclusion

Every one of the four described teaching strategies has their advantages as well as limitations. This suggests that it is important to combine different strategies in teaching for conceptual change. Cognitive conflict presents a significant intellectual challenge for students, that can be motivating, but sometimes also frustrating. Concept substitution and analogies are easier for students to accept, but have the limitation of not being applicable to all alternative conceptions. Socratic dialogue is a technique which builds on student existing knowledge and which can improve student reasoning, but is rather time consuming. Through careful combination of different techniques it is usually possible to find the right approach to each physics topic and help students improve their reasoning in physics as well as achieve conceptual change.

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