

# CONCEPTUAL UNDERSTANDING OF SCIENTIFIC IDEAS THROUGH DIALOGUE AND EXPERIMENT

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*Students come into the science classroom with, often erroneous, preconceptions of scientific concepts. These preconceptions serve the student well in explaining the world in everyday life, but they inhibit the learning of scientific concepts in the science class. Posner suggested that the shortcomings of the preconceptions must be shown, thus allowing the students to rationally make the step from the preconception to the scientific concept. Vosniadou and colleagues, and Mortimer and colleagues both continue on this idea with respectively a framework theory and a conceptual profile-theory. To stimulate conceptual understanding in the science classroom about concepts such as energy, we aim to continue the work of Vosniadou and Mortimer by combining Socratic dialogue with hands-on experimentation. An approach is presented with six distinct steps: waking up, identifying, and challenging the preconception are followed by introducing, securing and using the scientific concept.*

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Students come into the science classroom with preconceptions of scientific concepts. These preconceptions might be correct but are often erroneous, hence they are often labeled as misconceptions. For instance, while riding a bicycle a constant force is required to maintain a constant speed whereas in science force is not a prerequisite for velocity (but it is for acceleration). These erroneous preconceptions serve the students in explaining the world around them and are often in line with everyday language, hence students are only seldom aware of their erroneous nature. Furthermore, these misconceptions inhibit the learning of the scientific concepts taught in the science class (Davis, 1997). The question rises how the scientific concept can successfully be taught to students.

Posner (Posner, Strike, Hewson, & Gertzog, 1982) indicates that a student must first become aware of the shortcoming of the existing concept in a certain context. Only then is the student able to accept an alternative concept that is presented. However, the alternative must be viable and must offer a broader applicability than the existing concept. Vosniadou, and Skopeliti continue on Posner's ideas in their Framework theory (Vosniadou, & Skopeliti, 2014). They state that students have naïve frameworks of science and mathematics to explain reality. These naïve frameworks are coherent within the realm of everyday experiences and are constantly re-confirmed. It is therefore very difficult for students to defer from these naïve frameworks. Students might even try to incorporate scientific ideas and concepts as seen in the science class into their naïve framework, leading to an incoherent framework and frustration (Vosniadou, 2013). Therefore, rather than replacing the preconception by the scientific concept, a science class should introduce the scientific conceptual framework as an alternative framework that can also reside in the

students' mind, as suggested by Mortimer and El-Hani in their work on conceptual profiles (Mortimer, & El-Hani, 2014).

To add the scientific concept as a viable alternative to the naïve conceptual framework of the student several conditions must be met that are in line with the conditions set by Posner. The student must (1) realize that there are multiple possible concepts concerning a similar phenomenon, (2) realize the shortcomings of these existing naïve misconceptions within a certain context, and (3) be presented with a viable alternative that allows to understand new phenomena that were thus far left unexplained. This last point defers from Posner, because the new scientific concept is no longer required to cover both the known and the new phenomena. Note that the scientific concepts of course do explain both the known and the new phenomena. However, this might initially not be perceived as such by the student.

This implies that the ambition for teachers to replace all intuitive preconceptions with scientific ones may be too ambitious. Therefore, there is need for teaching methods which (1) respect the existing preconceptions, (2) discover shortcomings, (3) offer an alternative, and (4) continue to challenge the students' frameworks to eventually expand the applicability of the scientific framework.

Here a dialogic approach seems promising (Alexander, 2006; Wenning, Holbrook, & Stankevitz, 2006). In a Socratic dialogue all input is regarded as valuable, thus allowing acknowledgement of the existing naïve framework. However, every statement can also be the object of inquisitive scrutiny. This is equally important as it allows the naïve framework to be challenged thus uncovering its shortcomings. While the Socratic dialogue is a very powerful didactical tool, experimentation can also serve the same purpose in a science class, i.e. experimentation also allows a thorough investigation of any hypothesis, statement or idea.

In this work we present a didactical approach to develop conceptual understanding of scientific ideas through dialogue and experiment. It has been developed using a design based research methodology (Van den Akker, Gravemeijer, McKenney, & Nieveen, 2006) where through several cycles the didactical approach is improved. Six distinct steps can be distinguished in the approach:

1. Waking up the existing preconceptions by means of a Socratic dialogue. This step points the existing naïve frameworks out to the students. The teacher takes on the Socratic stance. This has shown, in the finished research cycles, to be important. However, it has also shown to be very difficult, as it requires a very different role from the teacher.
2. Identifying the preconception that will be the focus of the class. This is a necessary step to introduce the approach in a class of students of 20 to 25 students, as is typical in Flanders. Focusing the attention of all students on a single preconception has shown to be effective in the first cycles of the design based research.
3. Problematizing the preconception. This is done initially by the teacher through a demonstration that serves as a discrepant event (Longfield, 2009), but it is followed by experimentation from the students. The reason for the experimentation is to allow students to convince themselves that indeed the preconception is flawed. Here too the Socratic stance of the teacher plays a key role in the guidance of the students through the experiments.
4. Introducing the core of the scientific concept. The teacher takes on the role of a translator or a guide. By doing so the scientific concept is not postulated by the authoritative figure of the teacher, and therefore it can become subject to investigation.
5. Securing the scientific concept through experimental or theoretical investigation. The new, scientific, concept thus goes through the same scrutiny as the naïve framework.

6. Using the scientific concept in situations that are outside the usual scope of the science class. This final step challenges students to confront the two frameworks, i.e. the naïve and the new constructed framework, allowing an expansion of the applicability of the scientific framework.

This approach has been well received by both teachers and students in all tests and try-outs from the completed research cycles. Material to support the presented approach has been developed for the concepts of energy, heat, buoyancy and the particle model of matter. The current cycle (January to May 2017) sets out to measure the impact of the approach on the conceptual understanding of the students with regard to the concept of energy. The impact will be measured in a pre-posttest research design. The test used is a concept-test based on the test used by Heron et al. (Heron, Michelini, & Stefanel, 2008). A convenience sampling of a combined total of 200 secondary education students of ages 12-13 will be part of the investigation in Belgium and Lesotho. Additionally, a convenience sampling of a combined total of 260 teacher training students of ages 18-21 will participate in the study in Belgium and Spain. This additional international study allows a comparison across different cultures (El-Hani, & Mortimer, 2007). Half of the involved students will be part of the experimental group and will receive instruction on energy following the layout presented above. The other half of the students will be part of the control group and will receive a classic lecture on energy where the teacher lectures the students on energy rather than engaging in a Socratic dialogue but where equal time is given to demonstration and experimentation.

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