ESERA 2021
Fostering scientific citizenship in an uncertain world
30 Aug - 3 Sep 2021
Organised by
University of Minho, Braga, Portugal

RESOURCES AND BARRIERS IN REASONING

The resources framework, developed within physics education research, emphasizes the knowledge elements we employ when we reason about the world. Those knowledge elements are, within the framework, referred to as resources, and they are context dependent: A resource that may lead to an incorrect conclusion in one context may lead to a correct conclusion in another context. The framework does, however, lack a concept to handle the types of resources that lead the reasoning astray or inhibit a, for the purpose of the learning activity, productive reasoning. This paper proposes such a construct, a so-called barrier, and presents a case in which a group of students investigates a phase transition with infrared cameras. Barriers are identified in the case and possible ways to handle barriers are discussed.

Keywords: Context-based learning, Reasoning

THE RESOURCES FRAMEWORK

The ways students reason, and the resources they employ when reasoning in physics, has been explored in several studies (Chi, Feltovich, & Glaser, 1981; Redish, 2014; Rozier & Viennot, 1990; Scherr & Hammer, 2009; Viennot, 1998). A theoretical framework emphasizing the cognitive constructs employed by students when reasoning about physics, so called resources, and which integrates ideas from sociocultural and cognitive research, has been developed within physics education research (Hammer, 2000; Hammer, Elby, Scherr, & Redish, 2004; Redish, 2004). This framework is called the resources framework and is the basis for my research. Although the resources framework promotes the view that resources are context dependent, and that there are contextualizations (or epistemological framings as it is referred to by Redish (2014)) by "which students are led astray" (Redish, 2014, p. 544) it does not include an explicit conceptualization for resources that inhibit or distract reasoning processes. The concept of misconceptions does not fulfill this purpose as misconceptions are robust across contexts and the resources framework emphasize context dependence. In other words, the resources framework in its current state does not have a tool to emphasize resources that act as barriers to students' understanding and learning. The aim of this paper is to propose, and to make a case for such a concept.

Resources and barriers

A resource could be described as a knowledge element (Redish, 2004), an umbrella term that covers multiple types of cognitive units such as prototypes and exemplars (e.g. Rosch, 1973; Smith, 2014), and phenomenological primitives (DiSessa, 1993). An important aspect of the resources framework is that a cognitive resource that is "wrong" in one context may be "correct" in another context, depending on the task. As an example, although the resource "closer is stronger" may lead to an incorrect reasoning when trying to explain why summers are warmer than winters, the same resource may lead to correct reasoning when explaining why it gets warmer when moving towards a fire (Redish, 2004). This emphasis on context dependence is in contrast with frameworks that employ the concept of misconceptions, i.e. conceptual change (Linder, 1993).

Students' choice of resources for reasoning thus matters and a designer of an activity should be aware of what the students pay attention to and thus what their associations and reasoning is based on. Aspects that were not relevant for the task at hand can form a basis for reasoning that undermine the learning process, i.e. act as barriers. The term barrier is borrowed from a study by Loverude, Kautz & Heron (2002) in which they show how students' confidence in the ideal gas law acts as a barrier to the first law of thermodynamics in solving a problem in thermodynamics, a barrier that hinders access to another, more productive resource. In a study by Chi, Feltovich & Glaser (1981) on students categorizing problems on energy conservation, they found that the students tended to categorize the problems based on literal features (an inclined block-problem, etc.) rather

than on more abstract categories (an energy conservation problem) as the disciplinary experts did. In this case, the images and their features acted as barriers for the students in accessing resources related to the concept of energy. The activity of categorizing the problems could potentially have been improved by having textual problems (suppressing structural aspects of the problem and enhancing aspects related to the energy concept).

A barrier can be either distracting (an association that leads to another which makes the line of thought wander away from the task at hand) or inhibiting (a barrier that is employed at multiple occasions during the reasoning process). In contrast, resources that progress the learning in accordance with the purpose of the activity are called productive resources.

RESOURCES IN REASONING: A CASE

A case involving a group of students reasoning about a thermal phenomenon will be presented to illustrate the concept of a barrier. A group of science teacher students were introduced to a set of activities in which they were to investigate phase transitions with the purpose to learn more about how phase transitions relate to energy transfer. Each activity was based in an everyday situation and students used infrared cameras in their investigations. One of these activities involved an experiment where a piece of paper is placed on top of a plastic glass almost filled with water[1] (leaving a space with air between the water and paper) close to room temperature. The temperature of the paper initially increases due to the condensation of water on the paper. It then decreases and reaches an equilibrium at room temperature. The students observed this through an IR camera. The paper was then moved off from the glass onto an empty glass and the students observed a decrease in temperature and were then asked to explain what was happening. A condensed path of reasoning of the group is illustrated in Figure 1. Each circle node in the path indicate a resource based on a condensed argument or statement of a student. The rectangles represent any external input affecting the students' reasoning, for example input from the instructor who at one occasion asked the students what happens when water is in a glass (indicated as the green rectangle "Glass with water"). Red indicates a possible barrier and green a possible productive resource. The arrows indicate the chronological position of each resource.

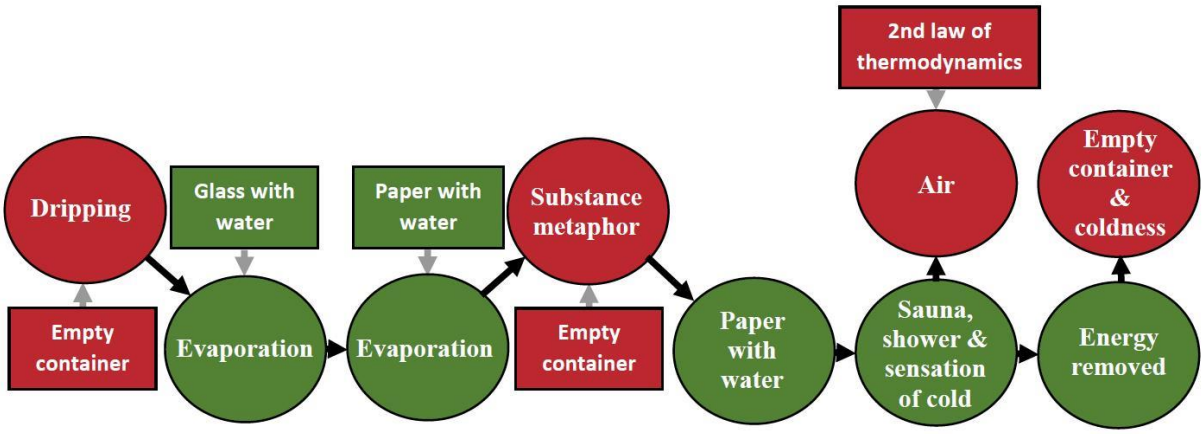

Figure 1. The reasoning path of the students as resources. Any external inputs are illustrated as rectangles.

The empty glass and the second law of thermodynamics seem to act as barriers in this reasoning path, either inhibiting or distracting any productive reasoning. The empty glass has the function of a container from its form, which allows for the reasoning of dripping of water or the movement of energy into the glass (the substance metaphor). However, specific situations related to everyday situations (walking out from the shower or leaving a glass of water for a longer period of time) or experience (sensation of cold), either mentioned by the instructor or the students, progress a productive path of reasoning. However, they return to the empty glass in the end of the reasoning path.

[1] The activity was based on an experiment suggested by Xie & Hazzard (2011).

DISCUSSION AND CONCLUSION

When proposing the resources framework, Redish (2004) argued that studies on what resources students employ in an instructional environment could tell us how to improve on those environments and perhaps even "predict what environments are likely to be more effective for more students" (Redish, 2004, p. 9). However, to improve a learning activity one does not only need to know what aspects to emphasize or enhance in the activity but also what aspects to suppress. In the presented case, the empty glass seems to have acted as an inhibiting barrier as the students returned to it at multiple occasions, and should thus have been avoided completely in the design of the experiment (as it was also irrelevant to the result of the experiment). In contrast, the students found an analogical relationship between water on the paper and water on the skin (in the situations involving a sauna and a shower) so this aspect could, if enhanced, be fruitful for the reasoning process. Another potential barrier that can be identified in the presented case is the second law of thermodynamics: When taught to the students in their previous education as "heat is only spontaneously transferred from a warmer to a colder body", it may lead to a reasoning that air leads away heat from the body (when walking out from a shower or sauna) or the paper in the experiment and that this is the primary cause for the decrease in temperature. However, the other students do not build upon this resource in this specific path of reasoning so it does not become an inhibiting barrier nor a distracting barrier as that line of reasoning ends there. As mentioned earlier on, an earlier study (Loverude et al., 2002) indicate that the ideal gas law could be another, of what in this paper is called, inhibiting barrier. In the end, an abstract barrier, such as the second law of thermodynamics or the ideal gas law, does present a bigger challenge compared to the empty glass when it comes to how to modify the learning activity to suppress the barrier: While the latter just needs an adjustment in the setup, the former potentially needs to be handled during a longer period of time, for example by teaching about the ideal gas law in a different way.

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