New Perspectives in Science Education
International Conference NEW PERSPECTIVES in SCIENCE EDUCATION
5th Edition

Students' Ideas in Novel Situations: Misconceptions or Fragmented Pieces of Knowledge?

Nikolaos Fotou[1], Ian Abrahams[2]
[1, 2] University of Lincoln, School of Education (United Kingdom)
[1]Nfotou@lincoln.ac.uk, [2]iabrahams@lincoln.ac.uk

Abstract
Since the mid-1970s a large body of research in science education has focused on identifying students' ideas and difficulties in understanding science across a wide student age range. Whilst this research has informed the design of instructional approaches and curriculum development, it has contributed little to our understanding of how students reason when presented with a novel situation and the knowledge they draw upon to understand that situation. Currently there are two main perspectives on the nature of students' knowledge: that of misconceptions and that of knowledge in pieces (p-prims). From the former perspective students' knowledge is perceived as being theory-like and stable with students' ideas being context-independent whereas the latter perspective sees students' knowledge as composed of smaller, loosely organized, elements with their activation and subsequent arrangement into 'strings' being dependent upon the context of the situation students are trying to understand.
In this cross-age study, conducted in Greece, students (n=166) aged 10 to 17 years were asked to make predictions about novel situations and then explain how they arrived at those predictions. We report here on a number of ideas identified in students' explanations by considering how they can be seen either as misconceptions or, alternatively, as situated acts of construction involving the activation and arrangement of smaller p-prims. Although our purpose was not to judge the merits of one perspective over the other, we were better able to understand and interpret the ideas identified in students' explanations in terms of p-prims already documented in the literature. Our results showed that students' ideas were not theoretically grounded but rather appeared to be composed of independent 'pieces of knowledge' strung together in response to the contextual features of the novel situation they were presented with. Further research is now needed to better understand the nature of students' knowledge and reasoning and how these could be directly linked to teaching approaches.

1. Introduction
By and large research in science education has focused on students' ideas and understanding across a wide range of ages as well as on an increasing range of science topics. The findings of this research suggest that students experience difficulties in understanding and learning science as they struggle to relate what they are taught in school science with ideas they hold and are experientially based building on their experiences obtained via observations and interactions with the world around them [1].

1.2 Students' ideas as misconceptions
A mix of terms have been used in the literature to describe these students' ideas. Many researchers have used the term *misconceptions* to refer to explanations or understandings that differ from the scientific perspective whereas others have employed alternative terms, like *preconceptions*, *alternative* and *naïve conceptions* or *alternative frameworks*. Although there are differences in the philosophical positions of these terms it has been argued that they actually mean the same thing or that these alternative terms have been used as synonyms for the term *misconception* [2] (a term we use throughout the paper for all the synonyms of this term suggested).
The common usage of all these various terms suggests that students' conceptions: a) differ from experts' concepts, b) have a strong influence in students' understanding and c) must be avoided or replaced towards scientific understanding [3]. A recent debate about the nature of students' ideas has added new connotations for the use of the term *misconception*. This ongoing debate, which began 20 years ago, pits the *coherence* perspective against the *fragmentation* one. According to the *coherence* perspective, *misconceptions* implies the hypothesis that students' knowledge is coherent or theory-like [3]. This view held that students have stable ways of thinking about topics in science because their understanding emerges from ideas that are cohesive and strongly integrated with other ideas [4].

Current research, however, has come to largely reject this view that students' ideas are *theory-like* as evidence suggest that they emerge from finer-grained, fragmented pieces of knowledge which are more loosely organized than 'theories' and their activation depends on the context of the situation the students try to understand and reason about [5].

1.3 Students' ideas from a knowledge in pieces perspective

The most prominent voice in the fragmentation perspective is diSessa and colleagues [5] [6] who challenged accounts of students holding unitary ideas in the form of misconceptions by introducing the notion of *phenomenological primitives* (hereafter p-prims for short). P-prims are the basic finer-grained elemements which can be used to explain students' reasoning and understading [7]. These fragmented pieces of knowledge are *phenomenological* in that they are minimal abstractions derived from experiences and closely tied to familiar phenomena and they are *primitive* in that they "stand without significant explanatory substructure or explanation" (p.15) [7]. Students' ideas, therefore, do not exist as coherent theories, but are constructed in the moment from the activation of p-prims which, in turn, depends on the contextuality of the situation students try to understand and explain.
The *knowledge in pieces* view challenges another aspect of the *misconception* perspective which is the relationship between students' ideas and the scientifically acceptable ones. In the latter case, there is a mere perception of students' ideas as showing an inherent inconsistency with scientists' knowledge and that there is always a need for replacement of the ideas students hold before being exposed to school science in order to understand science. However, any approach that involves such a large scale replacement of prior knowledge is fundamentally at odds with constructivism and such a direct ''flipping from the misconceived view to the correct view'' (p.10) [8] offers no account on how actually the change occurs and what happens to the prior knowledge abandoned. In contrast, the *knowledge in pieces* perspective perceives learning of science as a process of reorganizing students' ideas into scientific knowledge acknowledging, at the same time, that they might be still present in scientists' way of thinking [9].

1.4 Misconceptions or P-prims: How different are the two approaches in terms of instruction?

Researchers from these two different perspectives often suggest and implement similar teaching approaches as they both acknowledge that a student comes to school holding ideas and explanations about how things work in their everyday life and not as blank slates which can be easily fitted with scientific concept. As diSessa [10] suggests paying attention to students' naïve ideas is powerful regardless of the details on how the change from these naïve ideas to the scientific ones take place. The only difference lies in the way the *knowledge in pieces* perspective interprets constructivism as it perceives students' ideas as the resource upon which scientific knowledge can be built. Therefore, instead of challenging or replacing students' ideas towards expertise, as the *misconceptions* perspective implies, expert knowledge can be achieved through a continuous construction and reconstruction of the knowledge students bring in the classroom. Instruction should guide students through that process by giving the opportunities to reflect on that knowledge. Teachers should find contexts in which their students' ideas are and are not productive and then guide them to refine that knowledge accordingly [9].

2. The study

We have recently conducted a research in which we have attempted to identify students' reasoning behind predictions made in situations they have not considered before. We report here on the ideas identified in students' explanations by considering how they can be seen either as misconceptions or as situated acts of construction involving the activation of p-prims.

2.1 Design aspects

The research involved a cross-age study in which Greek students, ranging from 10 to 17 years of age, were asked to make predictions about six novel situations and then provide explanations about them. All of the situations were presented to the students in a pictorial form and were novel in the sense that they had not been asked previously to think and make predictions about them. A mixed method approach was used with data being collected through the administration of a paper-and-pencil survey and the conduction of group interviews (for more details about the study sample and the research methodology please see our previous work [12] [13]).

3. Results and Discussion

To a large extent, we were able, to interpret ideas in students' explanations in terms of p-prims documented in the literature. For example, in the weight and gravity novel situation (Figure 3.1) most of students (116 out of the 166) articulated a rather common idea identified in the literature according to which heavier objects fall faster. The misconceptions perspective attributes to this idea a rather stable knowledge structure which directly relates time, speed and acceleration of a falling object with

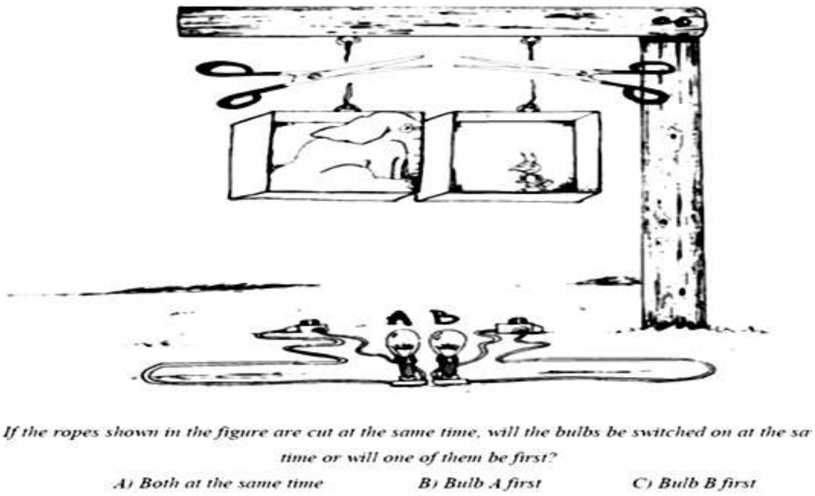

Figure 3.1 Weight and gravity novel situation

its mass constituting in this way a scientifcally incorrect idea and a misunderstanding of free fall. The idea could be also interpreted from diSessa's [9] perspective as being constructed by the students in the context of this particular novel situation. The activation of *Ohm's* and *supporting p-prims* could be used to understand this idea that heavier objects fall faster. The activation of the *supporting p-prim* (unsupported objects fall) in this case implies that since the ropes are cut and the objects are unsupported they will fall. Subsequently the *Ohm's p-prim* is activated, according to which "the stronger the agency, the greater the effect" (p.104) [3]. With the agency in this case being that of weight, *Ohm's p-prim* implies that the heavier an object is, the faster it falls. *Ohm's p-prim* involves another common primitive, that of "the more x, the more y'' (p.147) [9], and again, in this case the heavier the object the faster it moves. Both p-prims, diSessa [9] argues, are abstractions of everyday experiences which can be used to develop understanding of various situations. The supporting p-prim might be abstracted from and used to understand phenomena where objects placed on a supporting surface (table, rack) do not move and can explain related situations, whereas *Ohm's* p-*prim* might be related with experiences where the more something or someone is pushed the farthest of fastest it moves [9]. The p-prims perspective, therefore, does not attribute a knowledge structure concerning weight and speed of falling. Rather, there is a more abstract element of knowledge concerning the agent's effort and its result.

There have been cases in which there were correct elements in students incorrect responses (either the prediction was incorrect and/or the ideas used in students' reasoning). The misconceptions perspective does not analyse these correct knowledge elements in students' ideas. To illustrate, there have been two novel situations in which students expressed the very same idea of a decrease in mass of buring object. In the case of the burning a candle novel situation (Figure 3.1) this idea could be understood on the basis of the finer-grained knowledge element of something being used up in all processes (*something used up p-prim* as we name it). This is not inconsistent with the scientific account according to which carbon made materials being burnt are indeed losing weight (carbon particles in the candle react with oxygen in the air to form carbon oxides which is then given off with the reamining candle weighing less than before being lit). Thus, accordingly, students' scientifically incorrect idea of a decrease in mass in the case of iron wool being burnt (Figure 3.3) could be understood as merely reflecting on the use of *something used up p-prim* outside its range of legitimate applicability as in this case, iron made materials (particles of the iron wool are chemically combined with oxygen durng the burning process, and thus, having oxidised to form an 'ash' of iron oxide, its weight would increase).

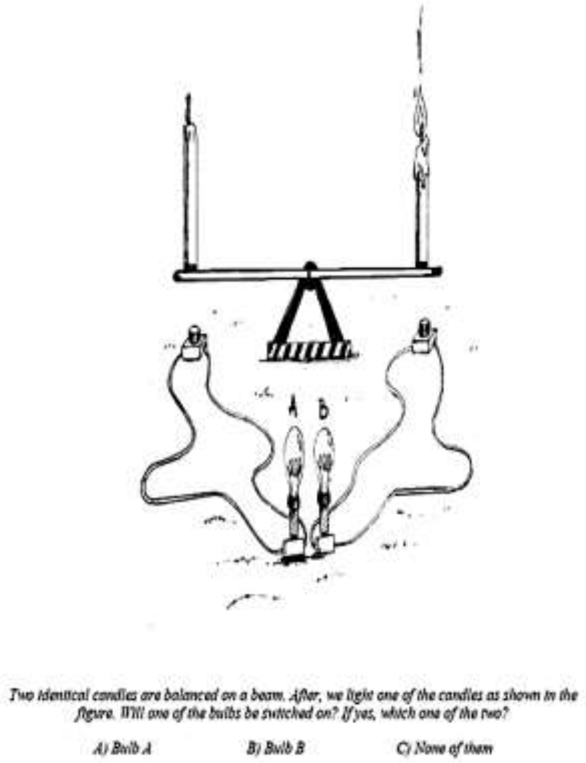

Figure 3.2. Burning candles novel situation

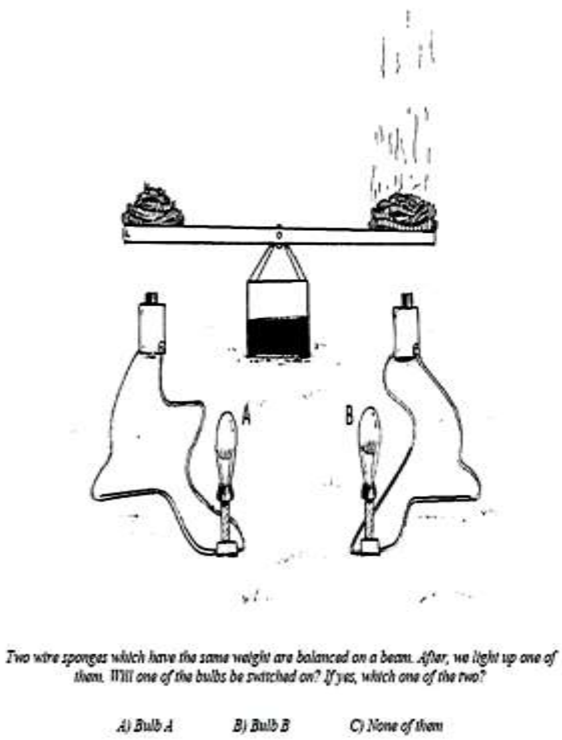

Figure 3.3 Burning wire wools novel situation

The comparison of the explanations given by the students in our research showed that, irrespective of their age, the majority of them expressed very similar, and in many cases identical, ideas. As we have shown elsewhere [12][13] the persistence of the ideas identified across the different ages was the result of a common way of reasoning based on similar analogies arisen, in turn, from similar observations students made in their everyday life. The only difference that the older students (aged 15 and 17 years) attempted to synthesize their ideas with something they learnt or heard merely by involving some scientific terminology in their explanations without, however, showing any understanding (correct or incorrect).
There were also cases in which older students who made an incorrect prediction, and were then asked further about their explanations, showed that they were aware of the scientific idea but they did not access it. Students aged 15 and 17 years who predicted that the box with the elephant falls faster showed that they were aware of Galileo's experiments when they were questioned further about their explanations. They showed a correct understanding of free fall and this way they produced a response conflict. Such responses show that these students did not lack the scientific information to reason about the situation with *p-prims* derived from their experiential knowledge coexisting with the scientific one but it was actually these that were more easily accessible.

3.1. Final thoughts

The findings of our study indicated that students had a fragmentary understanding and that their ideas were not theoretically grounded but rather, as we have shown elsewhere [12] [13], were based upon their experiential knowledge. Although the purpose was not to judge the merits of one perspective over the other, but rather, to consider which of the two perspectives provides a better means of understanding the ideas expressed in our study, we support their interpretation from a *p-prims* perspective as students were appeared to string together pieces of knowledge in response to the contextual features of the novel situations.

References

[1] Novak, I. D. (2002). Meaningful learning: The essential factor for conceptual change in limited or inappropriate prepositional hierarchies leading to improvement of learners. *Science Education*, 86 (4), 587-571.
[2] Leonard, M. J., Kalinowski, S. T., & Andrews, T. C. (2014). Misconceptions Yesterday, today, and tomorrow. *CBE Life Sciences Education*, 13 (2), 179–186.
[3] Hammer, D. (1996). Misconceptions or p-prims: How may alternative perspective of cognitive structure influence instructional perceptions and intentions? *Journal of the Learning Sciences*, 5 (2), 97–127.
[4] Taber, K. S. (2008) Exploring conceptual integration in student thinking: Evidence from a case study. *International Journal of Science Education*, 30 (14), 1915-1943.
[5] diSessa, A. A., Gillespie, N. M., & Esterly, J. B. (2004*). Coherence vs. fragmentation in the development of the concept of force*. Cognitive Science, 28 (6), 843-900
[6] Smith, J. P., diSessa, A. A., & Roschelle, J. (1993). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *Journal of the Learning Sciences*, 3 (2), 115-163.
[7] diSessa, A.A. (1983). Phenomenology and the evolution of intuition. In: D. Gentner and A.L. Sevens (Eds.), *Mental models* (pp. 15-34). Hillsdale, NJ: Lawrence Erlbaum Associates.
[8] Brown, D. E. (2010). Students' conceptions-coherent or fragmented? And what difference does it make? *Paper presented at the annual meeting of the National Association for Research in Science Teaching*, Philadelphia, PA.
[9] diSessa, A. A. (1993). Toward an epistemology of physics. *Cognition and Instruction*, 10 (2-3), 105-225.
[10] diSessa, A. A. (2006). A history of conceptual change research: Threads and fault lines. In K. Sawyer (ed), *The Cambridge handbook of the learning sciences* (pp. 265–281). New York, NY: Cambridge University Press
[11] Rowlands, S., Graham, E., Berry, J., & McWilliam, P. (2005). Misconceptions of force: Spontaneous reasoning or well-formed ideas prior to instruction. *Research in Mathematics Education*, 7, 47-65.
[12] Fotou, N., & Abrahams, I. (2015). Students' reasoning in making predictions about novel situations: the role of self-generated analogies. In: N. Papadouris, A. Hadjigeorgiou & C. Constantinou (Eds.), *Insights from research in science teaching and learning, Book of selected papers from the European Science Education Research Association (ESERA) 2013 Conference*. Dordrecht: Springer
[13] Fotou, N. (2014). Students' use of analogies in making predictions in novel situations. In: *International Conference New Perspectives in Science Education*, 2014, Florence. Italy: Libreriauniversitaria.it.