Problem Solving Processes in Science Education: Integrating the Representational Pluralism Perspective

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Abstract

Theoretical problem solving (PS) in science education is considered as a source of difficulties for many students and a consequently an important challenge for teachers. We argue the activity of PS in science can be considered as a modeling process in its essence. Recent studies highlighted a link between inhibitory control processes and students' difficulties during the PS. However, we don't know a lot about the epistemology of this link and how inhibitory control influences the modelling process of PS. Moreover, in science education, several models of PS have been proposed by researchers in science education and mathematics education. These models identify a number of difficulties encountered by students in PS. However, to our knowledge, these models do not integrate neither students' plurality of representations nor a dual process approach to reasoning. We believe that the perspective of representational pluralism can offer new opportunities to a better understanding of the PS in science education.

Keywords: *Problem solving, Modeling process, Science education, Inhibitory control, Representational pluralism, Dual process of reasoning*

Problem statement

In science education, teachers essentially use theoretical problem solving (PS) to consolidate or evaluate scientific knowledge supposedly learned, as well as to develop students' scientific reasoning [1]. Thus, we have traced in several scientific writings that theoretical PS in sciences most frequently emphasizes the application and/or the evaluation of models and of PS strategies. There is indeed a significant gap between the models and teaching strategies of PS proposed by research and the way in which they are used in science classes [2].

When properly used by the student, PS models should allow them to improve their performance during theoretical PS. However, for a large number of students in chemistry and physics, the application of PS models does not always produce success and can even demotivate some [3]. Despite training students in PS by using prescriptive models of the PS process, several authors have noted the persistence of students' difficulties in problem solving. Three observations can be made on this regard.

The first is that during PS, students are confronted with the task of selecting and adapting a set of representations and concepts that can potentially be used to solve the problem [4,5]. The second is that theoretical PS in science corresponds to a complex cognitive process in which the student must reason, often in terms of epistemic games, using various resources [7]. The third observation is that the theoretical PS models used for science teaching, in their conceptual articulation, do not consider the activity of representations when modeling the PS. However, certain authors have recognized that the difficulties of students in scientific PS are often of representational nature [5].

In light of the presented findings, we put forward the hypothesis that part of the persistence of students' difficulties during theoretical science PS could probably be attributable to a complex management of representations and concepts explicitly evoked in a problem during a PS [2]. To our knowledge, PS models used in science education do not integrate students' plurality of representations.

Research object

Sharing the point of view of some science educators and philosophers of science, we consider PS as complex reasoning activity characterized by the presence of a modeling process by which students construct and use one or more models to understand the problem and to solve it. The concept of "model" refers to representations used in an inferential manner [8]. As for the concept of "representation", the latter corresponds to a resource constructed by a student to think about a target in a context of achievement of a task [9]. It is a sort of cognitive "stand in" of the studied phenomenon, allowing students to initiate, pursue, or solve a task. For example, the ideas that a student may have about the behavior of light (reflexion, refraction) are representations that could be uses to solve an optical problem. A solution borrowed from a previous learning situation could also be invoked. During a task, mobilized representations can (or not) be available (previously constructed) or be constructed or adapted to current tasks.

What we know about theoretical PS in science education

In science education, many PS models use the same steps: 1) encode the information of the target, 2) use model X by producing inferences and 3) decode the result to target X. Among the models of PS we identified, we have not identified a single one that makes it possible to study the role of representations during an theoretical PS. However, we find in some models [1,4,10] the presence of representational plurality to varying degrees. In other words, in these models, we find instances where students must select among different concepts, conceptions, models or strategies to pursue PS. Like Domin (2000) [7], who is interested in the role of representation in PS without moving toward a PS model, we agree that representational pluralism is an important aspect of the process of modeling PS.

Still on the subject of the phenomenon of the persistence of difficulties during PS in sciences, we have selected certain ideas which come from writings on conceptual change. What emerges is that learning difficulties in science, and by extension, during theoretical scientific PS, would be a matter of management of conceptions. A conception refers to an idea having the potential to generate explanations plausible for the student [11,12]. In science learning literacy, two kind of conceptions emerge: scientific conceptions and alternative conceptions (or wrong conception). Since these conceptions could coexist [12], alternative conceptions, considered in a normative context, should be inhibited in favor of scientific ones [11]. However, the exercise of inhibitory control requires effort [12].

What we know about PS in mathematics education

In mathematics education, among the PS models of interest for our purpose, we have selected the model of Verschaffel, Greer & de Corte (2000) [13]. This model highlights the aspect of plurality in the PS modeling process compared to other models. Moreover, it shows how this process can be short-circuited and generate wrong solution. Finally, the model of Verschaffel &

al. (2000) makes it possible to consider elements of responses to explain potential difficulties of students during theoretical PS in science.

In this model, students transform their initial understanding of problems statements into a more advanced state depending on the specificities of the context. The author calls “situational model” this new state of understanding the problem. Then students use resources to reach another state of understanding the problem that allows it to be manipulated mathematically. This other state of understanding the problem named “mathematical model” becomes the starting point for the mathematical resolution of the problem [13].

Although the model of Verschaffel & al. (2000) does not elaborate on representational activity during PS, we note that it is fully compatible with the inferential approach that we find in PS. Furthermore, we note that this model suggests a certain form of representational plurality that is intrinsic to the modeling of PS even though it is not labeled as such. Thus, we see this possibility in different places in this model. Those are steps where students are called upon to make choices to continue their resolution process.

Even if the model of Verschaffel & al. (2000) does not endeavor to explain how resources are mobilized during scientific PS, it remains perfectible for use in the context of theoretical PS in science education. Additionally, coming from mathematics education research, this model does not consider some important ideas from the literature on conceptual change about science learning. However, some of these ideas (coexistence of conceptions, inhibitory control) could be considered to understand the PS processes in the scientific domain, which involves various conceptions.

What we know about PS in cognitive psychology

According to some authors [14,15,16], humans consciously or unconsciously use two reasoning processes to accomplish a reasoning task. Type 1 refers to the use of automated and intuitive thoughts [15,16], while type 2 refers to the use of working memory [16] and the mobilization of the logical/algorithmic system [14]. According to dual reasoning processes models, an important place is given to the embodiment of “mindware” [16] to motivational and situational factors [15] as well as to the heuristic process [14]. According to the mentioned previously authors, two types of correct responses could be observed in a PS type task: automated non-normative response (fast) versus normative (slow) which is consecutive to an “override” of Type 1 reasoning [16].

In light of the literature consulted on PS in science and mathematics, modeling process would possibly be a matter of managing representations of the problem involving dual reasoning processes. Like some authors [14,15,16], we believe dual reasoning processes must also be paid particular attention to understand the origins of certain difficulties during PS. Epistemologically, reflecting on the PS modeling process in science provides a compatible and complementary perspective with an important aspect of theoretical PS in science put forward in our discussion, namely, representational pluralism. To our knowledge, PS models used in science education do not integrate dual process approach to reasoning.

Further research avenue

Considering all above, future research should explore the PS modeling process for better understanding of the phenomenon of the persistence of students’ difficulties and the phenomenon of the persistence of initial conceptions during theoretical PS in science. We must remember that the modeling process is inferential and that it involves representational work. Hence, the avenue of representational pluralism should be considered because it allows us to construct explanation about these difficulties. In short, the difficulties encountered during the theoretical PS can be considered as being a matter of management of representations which probably involves dual reasoning processes and activation of inhibitory control.

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