Solving a problem with the aid of another: a teaching strategy in electromagnetism[1]

Resolviendo un problema con la ayuda de otro: una estrategia de enseñanza en electromagnetismo

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Abstract

The plausibility of a teaching strategy in physics problem solving is explored. The strategy consists of productively using cognitive resources activated in one problem to solve another problem. The design and data analysis is approached from a manifold and context-sensitive view of cognition, based on cognitive resources, as proposed by REDISH (2004) and HAMMER et al. (2005). The study consists of an exploratory qualitative phase and a descriptive quantitative phase. A total of 33 *participants were part of the study*, who were students of an introductory physics course majoring in Chemistry at the University level. Results show that: a) different problems correlate with the activation of different resources by the students, and b) the presence of one of the problems, in which students spontaneously activate resources that are useful to solve it, favors reflection and the correct solving of the other problem, in which the resources students spontaneously activate are not useful.

Key words: *physics problem solving, cognitive resources, electromagnetism, teaching strategy.*

Resumen

Se explora la viabilidad de una estrategia instruccional basada en la utilización productiva de recursos cognitivos activados durante la resolución de un problema para hallar otro. El diseño y la interpretación de los registros se realiza y se basa en recursos a partir de un enfoque múltiple y contextualizado de la cognición, propuesto por REDISH *(2004) y* HAMMER et al. *(2005). El estudio consta de una fase exploratoria cualitativa y otra descriptiva cuantitativa donde intervienen un total de 33 estudiantes universitarios de física de carreras de ciencias químicas. Los resultados muestran que: a) diferentes problemas correlacionan con la activación de distintos recursos por parte de los estudiantes, y b) uno de los problemas, en el que estos sujetos activan espontáneamente recursos que son útiles para abordarlo, favorece la reflexión y la solución sobre el otro problema, en el que los recursos que se activan espontáneamente no son útiles para abordar su solución.*

Palabras clave: *resolución de problemas en física, recursos cognitivos, electromagnetismo, estrategia de enseñanza.*

INTRODUCTION

A question that arises within the study of physics problem solving is related to the knowledge involved in this process. One approach to this question is that of the research known as *expert-novice differences*, which focuses on the characteristics of the knowledge that experts use during the task of solving problems (MALONEY, 1994). The educational suggestions derived from this line of research aim at fostering certain expert-like habits in students by having them follow specific action rules (MESTRE *et al.*, 1993, FOSTER, 2000, GANGOSO *et al.*, 2006). These instructional approaches are basically prescriptive: students' previous knowledge is taken into account in order to be disregarded, and subjects' attention is directed towards options that lead them to mimic expert behavior.

Another approach, which is complementary to the one just mentioned, has focused on the spontaneous conceptions with which novices address physical situations, and is therefore more attentive to novices' "as-is" knowledge (MCCLOSEY, 1983, WILLIAM, HOLLAN & STEVEN, 1983, SCHNOTZ & PREUB, 1997, DIAKIDOY *et al.*, 1997). These studies are very useful for the study of problem solving, since such conceptions, particularly those that disagree with scientifically accepted knowledge, could cause important interference with students' problem solving in formal learning environments. Results stemming from these two perspectives have given rise to important curricular developments that have proven useful in improving students' problem solving behavior and conceptual understanding in physics (MCDERMOTT & REDISH, 1999). However, recent work by DI SESSA & SHERIN (1998), ELBY (2001), HAMMER (2004), Redish (2004), MESTRE *et al.* (2004), HAMMER *et al.* (2005), shows suggestive analysis of students' reasoning which invite to revise certain assumptions that have been implicitly or explicitly present in previous research. HAMMER (2004), for instance, argues there is confusion between phenomenology and ontology. In other words, he questions that ontology –what sort of things do we attribute to students' minds– is not necessarily aligned to phenomenology –what sorts of occurrences do we see in students' reasoning–. This alignment, he adds, leads to the assertion that students either have or do not have (as a unit of cognitive structure) certain conceptions regarding physical phenomena. If this were the case, the context in which physical situations are presented should not affect students' reasoning and they would systematically and invariably use, for example, the conception "force causes motion", in all situations involving forces and motions. This is not what is observed.

On the contrary, an increasing number of studies report on the variability of reasoning and answers given by students to identical situations presented in different contexts, and even throughout the reasoning occurring during the solving of a single situation (MESTRE *et al.*, 2004, WARNAKULASOORIYA & BAO, 2003, MELTZER, 2005). Also, assigning the status of cognitive entities to the conceptions that students either do or do not have, poses an inconsistency with a constructivist view of learning: when student's conceptions are in disagreement with scientifically accepted knowledge, how can this student build further knowledge based on these conceptions? How is knowledge re-structured without necessarily "removing" this conception? These questions are difficult to answer in constructivist fashion.

This critical stance regarding a unitary and context-non-sensitive view of cognition -cognitive units correspond to students ideas and these ideas are insensitive to the context of the task- has generated a growing consensus among some physics education researchers that a more adequate description of students' reasoning should be made in other terms. HAMMER (2004), Redish (2004), DI SESSA & SHERIN (1998), DI SESSA (2004) & HAMMER *et al.* (2005), share a manifold and context-sensitive view of cognition -observable cognitive phenomena are the result of the activation of elementary cognitive elements, and that this activation is context-sensitive-. HAMMER & REDISH (op. cit.), to a great extent based on diSessa's accounts (op. cit), have given these elemental cognitive units the name of *cognitive resources*. These elemental units are the basis on which observable phenomena occur.

ELBY (2001), for instance, describes an instructional strategy that illustrates how useful a resources-based view of cognition can be. As a part of a class on Newton's third Law, he poses a situation in which a truck of mass *2m* rams into a parked car of mass *m*. When students are asked about the forces exerted by the masses on one another, students answer that the force the truck exerts on the car is twice as large as the one the car exerts on the truck. However, when students are asked about the changes in the speed of both vehicles, students answer that the change in speed of the car is twice that of the truck. Even though these two answers are mutually inconsistent, (in fact only one of them is in agreement with Newton's third law), were identified by Elby as corresponding both to the same intuitive notion, which he called "the car reacts more", and can be thought of as a resource with which they understand the situation. Asked about forces, students tend to map these resources onto forces, and asked about changes in speed, the same resource is mapped onto this magnitude.

This example illustrates the way in which a cognitive resources-based framework naturally accounts for the context-sensitive reasoning observed in students, overcoming the difficulties of a description in terms of unique and context-insensitive conceptions. Furthermore, it shows how students' cognitive resources, many of which came from their everyday experience or their prior instruction, far from being obstacles to learn, are essential tools for building scientifically accurate physics knowledge.

Even though there isn't yet a precise theory in terms of cognitive resources to account cognitive phenomena involved in learning physics, there are some general ideas that serve as a guide for research and that have appealing implications for instruction:

- Students have a collection of cognitive resources, which they have acquired through everyday experience and prior instruction, and their joint activation is what produces the observed behavior.
- The activation of resources is context-sensitive. Certain contexts "call for" the activation of particular resources.
- Cognitive resources are neither correct nor incorrect in themselves, but rather useful or not to approach a given physical situation.
- All the resources in a person's repertoire exist because they have been useful in some context, otherwise they would not exist as such.

The following section describes an empirical study designed on the basis of the theoretical framework just described. In this study, the feasibility of an instructional proposal is explored. The aim of this instructional approach is to make use of the cognitive resources that students activate when solving one problem and to favor the productive use of these resources when the same students solve another problem.

THE STUDY

In a previous study, some cognitive resources that students activated while solving two ray-optics and two E&M problems were identified (BUTELER & COLEONI, 2006). One of the problems in this study consisted in asking the angle between a conducting rod, through which a current was passing, and an external, constant, magnetic field, lying both on the same plane, for which the rod would be in equilibrium. This problem is the first part of problem 1, shown in figure 1 (non-boldfaced text). Many students activated a resource which was given the name *alignment*, which mapped onto the rod and the magnetic field turn out the rod is in equilibrium when it is aligned with the direction of the magnetic field. This resource, which is unproductive to address this situation, is useful, for instance, to address the interactions between magnetic and electric dipolar moments and magnetic and electric fields respectively. A resource that would be useful to address this situation, however, is *balance* (HAMMER *et al*, op. cit.), according to which, the effect of one agent is cancelled by that of another agent. Mapped onto forces, this resource can provide a correct description for the equilibrium of the rod in the presence of the magnetic field. On the basis of these findings, a situation similar to the previous one was designed, but with the potential of inducing the activation of the *balance* resource. The problem proposed corresponds to the non-boldfaced text of problem 2 in figure 1. The idea underlying this choice is that students could strongly associate the idea of equilibrium to problems with springs.

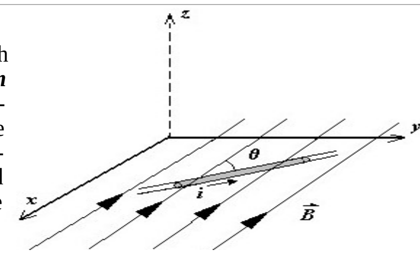
A- Qualitative analysis

The task designed for this qualitative stage corresponds to the non-boldfaced text of both problems in figure 1. Seven students from an introductory physics course volunteered to participate in this stage of the study, who had recently passed the course (in which the corresponding contents of magnetism had been covered). The aim of the interviews was to find out whether problem 2 favored the activation of *balance*, and if this activation was an aid to solve problem 1. Students were interviewed in two pairs and a group of three, in an informal environment that was not related to the regular course. Students were interviewed in groups to promote the natural communication among peers that could provide richer verbalizations. The interviewer intervened only to request clarification of ideas. An interpretive analysis of few cases is carried out in this stage, since the goal is to obtain information about subjects' thought processes (BUTELER *et al*., 2008).

Participants were asked to think aloud, discuss, and answer the questions presented. By the end of the interviews, students were asked to compare in terms of similarities/differences between both problems, and if after that they would change the answers they had given.

Problem 1

A current i passes through a conducting rod of mass ***m*** and length ***l***, horizontally located in a region where there is a uniform and also horizontal magnetic field ***B***. The rod and the field are at an angle *è*, as shown in the figure.



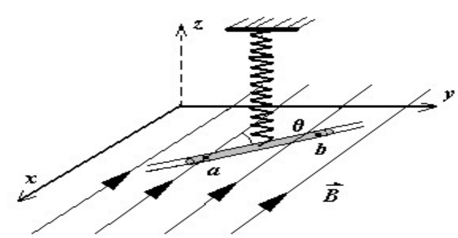
Consider that: i = 0.1 A, B = 0.3 T, l = 0.5 m, g =10 m/s^2 y m =0.00045 kg. For what value of ***θ*** will the rod be in equilibrium?

Chose one of the following options, and justify your choice:

For θ such that $\sin\theta = 0.3$
For $\theta = 0$
Other

Problem 2

A conducting rod of length ***l*** and mass ***m*** hangs from a spring, of elastic constant ***k***, as shown in the figure. A uniform and constant magnetic field ***B*** exists in the space in which the rod is placed. Both the rod and the field lie in the horizontal plane.



a) Given that ***k*** = 4,5 N/m and ***m*** = 0,00045 kg, how much was the spring stretched when the rod was hung on its end?

Choose one of the following options, and justify your choice:

$\Delta x = 0.001$ m
$\Delta x = 0$ m
Other

b) If now a current passes through the rod, what will happen to the spring, compared to the situation in part a)?

Chose one of the following options, and justify your choice:

The spring does not stretch or shrink, and the rod aligns with the field *B*.
The spring stretches less than when no current passed through the rod.
Other

Figure 1

Qualitative outcomes

The verbalizations for the three groups of students solving the task corresponding to the qualitative stage (non-boldfaced text of problems 1 and 2) are analyzed following the tradition of case study methodology from qualitative research. The idea is to analyze a small number of students' verbalizations to develop case studies: rich, detailed descriptions of student reasoning in each episode. The selected episodes are the result of a negotiation between independent interpretations carried out by three researchers (two of them are the authors of this study). The interpretations were about when and where a particular cognitive resource is activated. Figure 2 shows representative excerpts from these protocols corresponding to three different moments: solving problem 1, solving problem 2, and comparison of both problems.

	Group 1: Ana and Guillermo	**Group 2: Nadia and Mauricio**	**Group 3: Valeria, Darío and Gustavo**
Problem 1	**G**: *ok, this is gonna turn until it aligns with the field...* **A**: *yeah, I mean, this rod is gonna go up...* **G**: (reads the question)*...what is "g"?!...for zero degrees!!* **A**: *but the force...wasn't it upward?* **G**: *cause it is aligned with the field... theta is zero...* **A**:. *That way, there won't be any force...* **A y G**: *The force is... times the sine of theta...* **A**: *but... then we got it all wrong! The rod goes up! It doesn't align with the field!* **G**: *right...that's why we chose theta equal zero so that the rod is in equilibrium...* **A**: *but there is still gravity... but then... the rod... falls!* **G**: *ok, wait... let me see... oh! So then there's an opposite force pointing up, and equal to the weight...*	**N**: *well... it asks for which value of the angle the rod will be in equilibrium... well... when the angle is zero...* **M**: *'course...* **N**: *but if we put this* (the rod)*like this* (aligned with the field)*... I don't know... I'm thinking some formula that can tell me...* **Interviewer (I)**: *Something bothering you about theta being zero?* **M**: *... well, no... 'cause it won't be in equilibrium because of the force of the external field...* **N**: *that force, isn't it* ***i*** *times* ***l*** *times the field times the sine of the angle?* **M**: *yeah, times the sine of the angle...* **N**: *... well then if the angle is zero, the force is zero... so... yeah, same thing... that's the answer*	**G**: *I'd say... the rod will place itself like the field* **V** and **D**: *sure, its gonna align with the field* **G**: *until it reaches zero degrees* **V**: *it will align because there will be a torque that makes it align... and for what value of theta will it be in equilibtrium... well for zero degrees!* **G**: *right... and then there's no force any more*
Problem 2 (item a)	**A**: *oh, its the same problem, only that besides gravity there's the force of the spring... what was that like?* **G**: *yeah, gravity balances off the force of the spring... its supposed to be in equilibrium, it doesn't move...*	**N**: *now... they're two very different things, the force the spring is gonna make and the one that the field is going to exert...* **I**: *why are they different?* **N**: *I don't know! They're just different!* (laughing) **M**: *the one of the spring is upward, and the force of the field...* **N**: *wait, no!! if there's no current, then there's no field-force!!* **M**: *ahh!!... well all right, then... then I'd compute the weight and that'd be the force the rod does on the spring...* **N**: *right...*	**V**: *...its the same as before, only there's a spring there... well, I don't know if the angle is the same, but its the same problem* **G**: (reading the first question) *what was the formula?* **V**: *...the formula for the spring...*(laughs) *–k times Äx... times how much it is stretched...* **D**: *...its the force oposed to weight... I mean... the force the spring does on the rod counteracts the force...*
Problema 2 (item b)	**G**: *well... depends on the sense the current goes... if its like before, the spring goes up, it shrinks a bit* **A**: *so then Äx decreases* **G**: *and if it goes the other way it stretches further down...*	**N**: *ok .... well... the same thing we did already... but now there's going to be a force...* **M**: *right, in that direction* (aligning the rod with the field) **N**: *no! But you don't know which way the current is going!* **M**: *if its like before... its that way...* **N**: *well, then...its gonna be that way* (upward)*...no...let me see... that way* (aligning rod with field) **I**: *ok... we have the field, the rod, the current...* **M**: *and there's... the current is like it was before... and the field that it will generate* (used right-hand rule)*... an upward force...* **N**: *so the spring will be less stretched... 'cause its like the field is helping the spring to hold the rod*	**V**: *well, what we said before, there's going to be a torque and its going to be in line with the field... ehh...oh, but now...* **G**: *the spring will get twisted like this* (aligning rod with field) **D**: *the spring was already in equilibrium, and now the rod will turn 'cause there is a torque that aligns it* (with the field) **V**: *right, the spring stretches and the rod turns...*
Comparison	**G**: *its the same, I mean this drawing is the same as this one* (the graphs of both problems)*... because the force the field does in the same problem is the same one the spring does in the first question of the second one...*	**M**: *well... if the angle is the same, then you'll have the same force...* **N**: *.... the thing is that...* **M**: *.... in the first one we considered the angle to be zero so that it would be in equilibrium...* **I**: *would you change any of the answers?* **N**: *in the second problem we compared the force of the spring with the force... the weight... and then with the force of the current... which is... upward...* **I**: *and in the first problem?* **N**: *....the one done by the current... also upward!!* **M**: *yes!! upward!!* **I**: *is that what you said before?* **N**: *no*, I mean... *the first item in problem 1 would be similar to the second one of problem 2, just with the difference that in the first problem there's no spring...*	**I**: *Do you see anything that is similar between both problems?* **D**: *well... equilibrium in the first one is given by the torque that makes it align with the field, and in the other one, by the spring force that counteracts the weight* (meaning 2a) **I**: *and what about item 2b?* **G** and **V**: *there they are even more alike...* **G**: *that is, if we include the current, this one will align like in the first one, 'cause this angle here is the same...* **I**: *these two rods, of the two problems, are they the same? Do they have the same mass?* **V**, **D** and **G**: yes! **D**: *...to me, it couldn't just be there because there's the force "weight" that pulls it down...* **V**: *right! This couldn't just stay there*! **D**: *there has GOT to be a force counteracting the weight so that there's equilibrium...* **V**: *so in this problem* (1) *what happens is not what we said... the bar goes down... c'cause I don't think the field is like... pulling it up, right?* **G**: *...the field generates a force on the conductor... and well... if this turns like this* (alignment)*...* .... **I**: *How would you compute that torque that you say is acting there?* **V**: *I don't remember the formula for the torque...* **I**: *the torque on what?* **V**: *...on the rod... no! I'm mixing up with the stuff about coils!!* **G**: *oh!! the torque is for coils... its for coils, not for rods!!* **V**: *nothing to do with this!...its really not the same thing!!* **I**: *so would you answer the same as before in problem 1?* **G**, **V** and **D**: *no*

Figure 2

Problem 1

Guillermo addresses problem 1 with alignment mapped onto the rod and the external field. Alignment is apparently reinforced noting that if è = 0˚, the magnetic force is zero and therefore there is equilibrium. Only when Ana –who might even have activated balance right from the beginning– mentions gravity, Guillermo activates balance to understand the situation. The activation of alignment is unstable, and the activation of balance seems to take over not only to understand problem 1, but also for problem 2. From this point on, both problems are successfully solved.

In order to understand problem 1, Nadia and Mauricio seen to have activated alignment. As Guillermo, the activation of this resource is apparently reinforced by the formula of magnetic forces on currents in magnetic fields. Gustavo, Valeria and Darío also seem to activate alignment in problem 1, and reinforce this idea with the aid of a torque that, acting on the rod, will lead to its alignment. In the case of these two groups, the activation of alignment is apparently more stable than in the case of Ana and Guillermo, since this activation persists throughout the solving of the whole problem.

Even though there are differences in stability, and in the ways its activation is reinforced, the resource of alignment is present in all the cases reported above.

Problem 2

All the subjects activate balance to understand item "a" of this problem. The "agents" that balance each other out are mapped onto the elastic force of the spring and to the weight of the rod.

In item "b" of problem 2, Ana and Guillermo, as well as Valeria, Darío and Gustavo, respond on the basis of the same resources activated to answer item 1 and 2a, thus giving an answer that is the juxtaposition of their preceding responses. Ana and Guillermo answer in terms of balance, and Valeria, Darío and Gustavo in terms of balance and alignment. The excerpts of Nadia and Mauricio show something different. At the beginning they evidence the activation of both alignment and balance, but after the intervention of the interviewer, their responses show only the activation of balance. Although it is possible that the interviewer´s intervention could have biased students´ behavior, the chances that this is the case is low, attending to the fact that other similar interventions with these and other students did not alter their reasoning.

Comparison of both problems

Comparison of both problems produces confusion in students whenever any of their prior answers were based on the activation of alignment mapped onto the rod and the direction of the magnetic field. This is not the case of Ana and Guillermo, who understand this problem, almost from the beginning, in terms of balance. Nadia and Mauricio appear confused for a short period of time, and make an attempt to reconcile the answers given in problem 1 with that of item b of problem 2. They overcome this confusion when the activation of balance takes over and alignment is apparently no longer activated. These same students experienced a state of confusion prior to this, when solving item b of problem 2, while the resource alignment was activated. Perhaps these students had already compared both situations, while solving item b of problem 2, without explicitly verbalizing this.

The greatest state of confusion observed is that of Valeria, Darío and Gustavo as they compare both problems. When the interviewer asks if the masses of both rods are the same, they begin to doubt their answer to Problem 1 because they notice the existence of the weight and their verbalizations evidence the activation of balance. The dotted line in the far right column of figure 2 represents a fairly long portion of these students' protocol, in which they make an unsuccessful attempt to compute the torque applied on the rod through the computation of a magnetic moment which they believe could lead them to find a force. The interviewer leads their attention to what they are attempting to do, and they realize that they have calculated torque on currents circulating in closed coils, and this seems to hint them to abandon the idea of alignment and from then on they arrive at an adequate description of the problem in terms of balance.

A- Quantitative analysis

On the basis of the results obtained in the previous stage, a written task was designed which corresponds to the complete problem statements shown in figure 2 (the non-boldfaced text as in the previous stage, plus the three items added to each problem, typed in boldface). The task was carried out by 26 students of the same course as in the previous stage, corresponding to the following cohort. It was included as one of the regular tests the students had to pass within the course.

The aim of this second stage was to statistically corroborate some of the tendencies observed in the previous stage. The answers given by each of the 26 participants in the study were analyzed in order to study the relation between the context of each problem and the cognitive resources activated. According to the characteristics of the sample under consideration, non-parametric statistics tools were used.

The data collected through the written task were interpreted to identify the resources activated. Following the findings in the previous exploratory stage, the task was designed so that all of students' answers could be associated to the activation of one of these resources. This was done by considering the option picked by each student (among the three typed in boldface, figure 2) and the justification given. For instance, picking the first option in problem 1 (*è* such that *sin è = 0.3*) was assigned to the activation of balance, unless contradicted by the justification given. Picking the second option (*è = 0*°), was assigned to the activation of alignment, unless otherwise indicated in the justification. Also, the justifications give for the option "other" were also analyzed, assigning this option to the activation of either of the resources mentioned. Analogously, options and justifications for the second problem were also assigned to the activation of either balance or alignment for item a, and to balance and/or alignment for item b. The results of this assignment are shown in Table 1.

Table 1

	Problem 1	Problem 2	
Alignment	14	6	20
Balance	12	26	38
	26	32	58

Performing a Chi square (χ^2) test, a result above the critical value was obtained (χ^2 =7.87 with χ^2_c = 6.64, for s = 0.01) and thus an association was corroborated between the context of problems and resources activated: problem 1 is associated with the activation of alignment and problem 2 with the activation of balance.

DISCUSSION AND PERSPECTIVES

This study (qualitative and quantitative stages) replicates findings also obtained in previous work (Buteler & Coleoni, op. cit.), regarding the activation of alignment when addressing problem 1. This replication has appealing implications, instruction-wise, due to the regularity with which it occurs and also because, although incorrect as a whole, it reveals the existence of "pieces" of knowledge which are correct. An answer based on the activation of alignment may not implicate that a student ignores the interaction between electric currents magnetic fields. The results from the first exploratory stage indicate that some of these students correctly describe the magnetic force experienced by a conductor carrying an electric current ***i*** in the presence of a uniform magnetic field ***B*** (***F*** = *i* ***l*** ***B***). In cases such as these, the following question is in order: what is it that students don't know when they answer that the rod aligns with the direction of the magnetic field? This is a particularly interesting question, since problems such as Problem 1 can be found at the end of the chapter dealing with magnetism of most university-level textbooks. Knowing the source of students' mistakes can be a very useful tool to build evaluation criteria.

As for the benefits problem 2 can offer for the solving of problem 1, it is seen in the qualitative stage, and confirmed through the χ^2 test of the second stage, that the context of this problem is associated with the activation of balance. This evidence supports the idea that the problem is effective in achieving one of the goals of the teaching strategy proposed in this study. It is thus possible to conclude that problem 2 is efficient to induce the activation of the balance resource.

The other issue addressed in this study is whether this activation favors confusion and discussion of the situation of problem 1, and furthermore, if this process helps students accomplish the solving task successfully. The protocols from the interviews show that at some point of the solving process, the activation of alignment conflicts with the existence of the weight of the rod. In the case of Nadia and Mauricio, the conflict appears naturally even before the interviewer cues students to compare both problems. From this point on, the process takes students to a successful solution. In the case of Valeria, Darío and Gustavo, this confusion arises after the interviewer explicitly asks them to compare the problems, and persists until almost the end of the interviews, together with the activation of alignment. They arrive at a successful solution after several interventions from the researcher who questions them on their reasoning.

The results allow the conclusion that the comparison of both problems favors confusion about problem 1, regarding alignment. The value of this state of confusion lies in the fact that this is a legitimate confusion students face due to the conflict between two ideas of their own, and not one of theirs and another one stemming from an authority (as in the case of a textbook or a teacher). Solving this contradiction provides the student with a chance of making sense of the knowledge being learned.

CONCLUSIONS

In more general terms, these results suggest that those problems that are simple for students (such as the one of a rod hanging from a spring) can be used to help them figure out others that are usually less simple, such as the one of the rod in the presence of a magnetic field. A strategy such as this one provides the opportunity for students to make use, in one context, of the resources they have available, but naturally activate in others. At the same time, and also of benefit for students learning to solve physics problems, it provides them with the opportunity to solve contradictions generated by conflicting ideas of their own and which they are therefore willing to reconcile. Although the limited size of the sample only allows conclusions regarding the subjects interviewed, it is helpful to improve our understanding of the knowledge that students make use of while solving physics problems, and possible ways to take advantage of it, instruction-wise. As for the implications for future research, the results suggest the need to investigate the role in students' physics learning of situations used during instruction.

Footnotes

Partial results were presented at the 2007 Foundations and Frontiers in Physics Education Research Conference (FFPER), Bar Harbor, Maine, USA.

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