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INTRODUCTION

Students of introductory physics courses have difficulties in sucessfully aplying relevant concepts to situations that are raised in evaluations. Two general aspects can explain these difficulties, the attitude toward the subject matter and the lack of basics skills, both having to do with students background. In the first place, physics is conceived apart from daily life and reserved for the few. During instruction increases the gap by deficiencies in reading comprension, poor transfer of mathematical knowledge to physics context and belief in memorization of "formulae" as the best way to learn physics.

Research in cognitive psychology has provided information for educational practice. A contribution of cognitive psycholoy to education has been to place the focus of research on learning strategies and on develop techniques for describing and evaluating knowledge structures, psychological processes and cognitive structures of individual learners (Mayer, 1992). Cognitive psychology assumes that learning is a complex, dynamic and idiosyncratic process, in which meaninful learning occurs when new knowledge interacts with previous cognitive structures. In order to do this, the learner must be disposed to learn and instructional materials must have logical meaning that, in an interchange process, can adquire psychological meaning for the learner (Ausubel et al, 1978; Novak, 1981). In accordance with this afirmation human knowledge is constructed, which implies meanings construction. Cognition is the process by which the universe of individual meanings is originated (Moreira, 1990a p.64) and this is much more than repiting definitions or memorizing equations. On the other hand, metacognition occurs when knowledge used in problem solving, process perception and decisions taken are relevant for learning (Gunstone, 1991). Metacognitive processes are personal constructions that can be improved if instruction is provided in a certain context, where each activity contributes to develop cognitive strategies and individual self-control.

Problem solving is a fundamental skill in physics because it involves the applications of concepts acquired during learning and, if they are not reduced to class problem repetitions, it is a way to evaluate meaningful learning. For problem-solving, conceptual mastery is a necessary but not a sufficient condition, cognitive and metacognitive processes development are also required (Andrés, 1991; Silveira et al, 1992). Moreover, comparative research between experts and novices suggest that students who sucessfully solve physics problems are characterized by their capacity to rapidily locate them in a appropiated context for their solution, qualitatively analize them and planning an effective, short and orderly solving process (Larkin et al, 1980; Chi et al , 1981; Glaser, 1992.

In this paper, the student's develop of metacognition under real classroom conditions was analized assuming the following premisses: (a) students have their own concepts on teaching and learning, purpose of each educational activity and their progress while they execute it; (b) these perceptios are generally inappropiate and prevent learning ; (c) metacognitive strategies improve learning and make it evident; (d) providing experiences for generating more adequated conceptions on learning process can minimize obliteration of new concepts and make residual the older ones.

METHOD

Subjects. The study was carried out under real classroom conditions during a trimester with 24 students from two physics courses assigned to the researcher at the Simón Bolívar University.

Strategies. The metacognitive approximation was formulated in three stages characterized by specific questions to students: (a) stage of sensitization: why is it important to learn to solve problems? (b) stage of self-information: what do I do? what should I do? (c) stage of self-control: is it adequate? what must I modify?

To structure instruction, contents were organized in conceptual maps (Moreira, 1990b), the logical meaning of instructional material was considered and related to student's professional orientation examples were used. During instruction concepts were initially related to preexisting concepts in the conceptual structure, integrating them with each other progressively to make up supraordering structures and, when it was possible, supraordering was undertaken to insure new learning. To model and analize solving processes, solved examples from texts and problem solving in class were used. Problems with a different level of complexity were selected in order to cover contents. According to the classification stablished by Reed (1987), similar problems (with similar stories and different solution) and isomorphus problems (different stories and same solution) were included. Problems were discussed latter emphasizing their structural and conceptual characteristics. Some of them were expanded, solved in random groups and discussed again.

Discussions were centered on the use of specific metacognitive strategies as location in a phisical context, identification of relevant concepts, planning, process control and self-evaluation. These strategies in turn were controlled using reflection and processes evaluation.

Toward the fifth week, a brain storming sesion on problem-solving strategies was applied, the strategies identified by students served as a basis to construct an valorative scale that was submitted to a pilot test with other similar students to detect difficulties and correct items. The final version was a

17 items double scale asking the same information in two different conditions, before and after studying tertiary physics.

Procedure. In the eighth week, inmediately after a summative evaluation, each student was given a copy of his/her answered test and a questionnaire to be answered in the classroom. In this questionnaire information was asked on physical context ubication, relevant concepts identification, planning, process control and self-evaluation (Figure 1).

1. Si alguien te hubiera preguntado en ese momento de que se trataba el problema, ¿que le hubieras respondido?

2. ¿Cuáles eran los datos y condiciones que permitían tomar decisiones adecuadas para ubicar el problema y pensar como resolverlo?

3. Para el momento de la prueba, ¿tenías suficientes conocimientos relacionados con el problema?

4. ¿Cuáles leyes físicas se podían aplicar? ¿Por qué

5. Describe brevemente el razonamiento que utilizaste para buscar la solución.

6. Describe las dificultades que tuviste durante la resolución del problema.

7. ¿Mantenías presente la totalidad del problema mientras lo resolvías?
   ¿En qué hechos se apoya tu respuesta?

8. ¿ En algún momento revisaste si tu procedimiento estaba correcto? ¿Cuándo?

9. ¿Verificaste si el resultado estaba correcto y completo?

Figure 1. Questionnaire to be answered in the classroom. In this questionnaire information was asked on physical context ubication, relevant concepts identification, planning, process control and self-evaluation

They were informed that I wanted to know how they solved problems in their evaluations and for this they were asked to answer the questionnaire with as much datail as possible. It was clarified that answers would be compared with their tests and that adjustment with their answers would be taken into account to assign the grade. Later, some individual interviews were carried out to complete information. Student's explanations were examined one by one and compared with the process followed to solve each problem.

In the tenth week, the valorative scale was applied. The variation in using strategies was stablished by the difference between selected values on each scale, so $D = B - A$. In this way D could have values from -2 to 2. The scale items are shown in Table 1 with frequencies of each possible value of the variation D and the amount V of perceived change. The amount V was calculated by algebraic sum of all values obtained for each item.

TABLE 1
Student's perception about their change in abilities

	Difference				
ITEM	-1	0	1	2	V
Carefully read the problem	1	13	8	2	11
Interpret the problem	2	14	5	3	9
Make a drawing or squemata	1	10	10	3	15
Identify relevant information	0	19	4	1	6
Search for what they ask	0	21	3	0	3
Write conditions of the problem	0	11	12	1	14
Locate it in a physics topic	0	7	15	2	19
Identify physical laws	0	7	16	1	18
Explain the conditions that allow its use	0	9	14	1	16
Remember definition or general equations	4	16	3	1	1
Use equations well	2	7	11	4	17
Plan an action to find unknown	1	15	7	1	8
Find an expression for the unknown	1	21	2	0	1
Carry out correct operations	1	21	2	0	1
Use the correct units	1	14	6	3	11
Verify if results are logical	0	3	17	4	25
Verify if operations are alright	0	4	15	5	25

N = 24

This valorative scale was applied with two purposes. On one hand, to confront students with their perception of solving processes, induce self-evaluation and detection of little used processes. By the other hand, to allow researcher knowing student's perception on the use of strategies that they themselves recognized to be important. Figure 2 shows the use of strategies as students percieved them.

Self-evaluation importance and detection of little used are evidents in Figure 2.

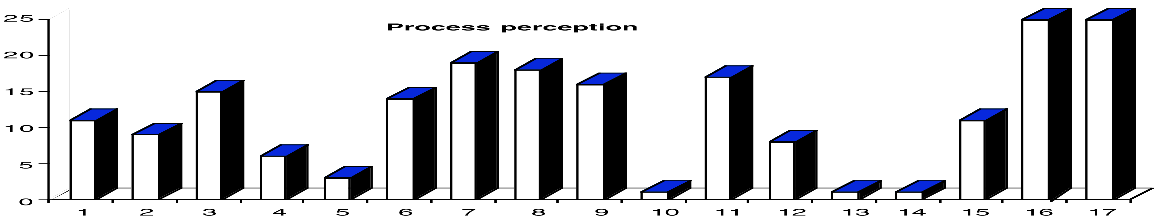
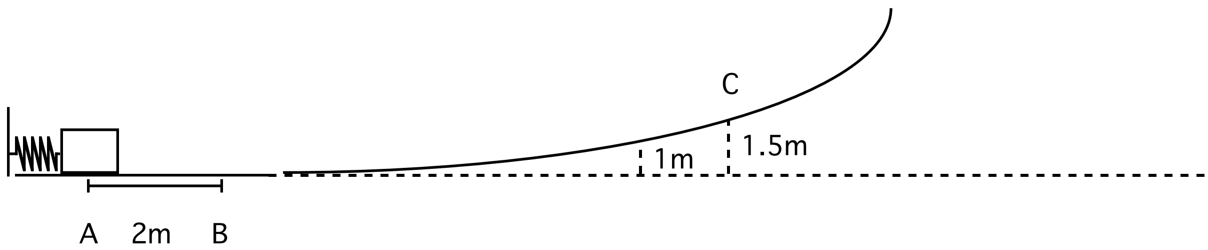


Figure 2. Histogram of increases in using processes as are viewed for students.

RESULTS

To get some evidence of metacognitive development was made an in deep qualitative analysis of student's problem solving processes, descriptions and perceptions. As an example of information that can be obtained using student's problem-solving, questionnaire and interview, one of solved problem in test is transcripted with a student solving process and quotations from interview.

Problem 3. The horizontal surface in this drawing presents friction from A to B. A block of mass 2.5kg is attached to a spring of spring constant k = 50N/cm, if the spring is streched 20cm and released, the block stops at 1.5m height. Calculate: a) the energy dissipated by friction, b) the kinetic coefficient of friction between block and surface, c) the speed of the block on reaching B, d) the speed of the block at 1m heigth.



Transcripción del proceso de solución del estudiante # 14

$Fr = \mu N$ $\Delta Em = Wnc$

$Fr = \mu mg$

$$Epr = \frac{KX^2}{2} = \frac{50N}{0,01m} \cdot \frac{(0,2m)^2}{2} = \frac{50N . 0,4m^2}{0,02m}$$

Epr = 1000 N.m

DEm = Wnc => (Epb + Ecb) - (Epa + Eca) = Wnc

c) $Ecb = 1/2\ mv^2$ Epf = mgh

$$V = \sqrt{\frac{2Ecb}{m}}$$ $= 2,5kg . 10m/s^2 . 1,5m$

v = 4,69 m/s = 27,5 Nm

Some explanations given by student # 14 in questionnaire and interview.

"The problem involves an object, is involved with a spring at one side that moves it along a surface with friction and that later is smooth, rising a specific height."

"The data and the conditions were the friction force, height at C, the potencial energy of the spring."

"At the time of the exam, I had not reviewed much about the spring and its potential energy, for that reason, I could not answer the two first ones ... "but I did answer the other two. "

"I used the law of conservation of energy because they gave me information on height, the energy of the spring, the force of friction and they served for the formula. "

"I couldn ' t keep in mind the total problem because I had to work it in parts."

"I didn 't review the procedure"... I think that I almost never do it."

At the beginning of the quarter this student only tried exercises with direct application and insisted on receiving formulae and not explanations, in addition he presented deficiencies in calculations. When this student tries to solve the problem, he writes the formula of variation of energy as work performed by the force of friction and calculates potential energy stored in the spring, but he does not manage to establish another point to establish the variation and calculate the non-consertative work. Consequently, he does not try to calculate the coefficient of kinetic friction. He establishes the ratio to calculate the velocity of the block at point B, applying conservation of energy. Nevertheless, he does not manage to apply the same criterion to find the velocity of the block when it is at a height of 1 m. The comparison between the processes that he used and what he informs shows that when the conditions vary within a same problem, he does not identify the range of applicability of the equation that he is using. He uses it in part c) where the arc between ponts B and C appears limited. It appears that he is not able to use the relevant aspects of the problem when the form of solution is not given and he must establish it. Moreover, a process of "going ahead and doing it " characteristic of the absence of planning is observed. Self-evaluation is another aspects that appears to be deficient and the interview permitted clarifying this. In the questionnaire, it is stated that "I reviewed the result that I obtained and it was alright", nevertheless the value obtained was incorrect through error from calculation the product. In the interview, he was asked how he had reviewed his result and he explained that he had confirmed that the conservation of energy was carried out and he knew that his operations were correct because he had performed them with a calculator.

DISCUSSION

The combined analysis of tests, questionnaire, and interview to all the group allowed the establishing of some qualitative results from the use of convergent strategies for producing changes in the manner of approximating and contending with Physics problems. The student's questions changed their focus. The request for "formulae for solving " gave way to questions on identifications of applicable physical laws and ajustment of general equations to specific cases. The perception of the students reflects this situation but it also evidences contradiction between what they believe and what they do in aspects relates to conditions of problems and self evaluation.

Troughout the course the errors due to deficient reading of the statements as unrequested calculations or use of different data disappeared. Nevertheless, on requesting the description of the problem the majority of the answers reffered to the topic and not to the situation set forth: "Conservation of energy, " "work and energy. " "work had to be calculated. " These answers are not trivial for the analysis of the metacognitive processes since the description implies verbalizing the context and the limitations of the problems. As a matter of fact it was observed that those who did not describe the solved problem frequently set aside the conditions and limitations during the solving process. This situation is confirmed with the answers obtained on asking what the data and conditions were that allow classifying the problem and thinking about how to solve it: almost unanimously they did not identify any condition whatsoever.

Another aspect that was observed, albeit in a low proportion, was the non differentiation between datum and information. Upon requesting the relevant data of the problem above, one student answered: "system of reference, the spring , the spring constant, friction, and distance". Another stated: "In order to solve I can use the spring, the strain of the spring, the height, and the force of friction", thus placing the *information* spring in the same category that the *data* spring constant and strain of the spring.

CONCLUSIONS

The only way to know if you are achieving the development of metacognition in the students is being able to monitor the use of the skills related to it throughout the course. The type of analysis used in this research allows a convergent focus in order to inquire into the use of metacognitive processes in a testing situation wich, because of its evaluative nature, blocks the non internalized processes.

The attempts to apply research methodologies described in the literature into the classroom usually are unsuccessful because of the administrative conflicts created in the college in providing adequate conditions. We need to know how to incorporate the theory to practice. Investigating in real classroom conditions requires methodological changes in order to obtain valid results without selection of samples and without control of variables. In other words, we must learn to maintain the focus in the midst of dynamic conditions. This work has been an attempt in this sense, but there remains much to be done in order that the application of the results of the theory at all educational levels might become a reality.

In order to improve our understanding of metacognition it is necessary to investigate the activation of mental images of the problems and the diffrerentiation between information and that wich constitutes a datum or a condition. As a contribution to classroom teachers it would be necessary to develop methods of qualitative analysis that would allow them to know if their work is being effective for the development of metacognition.

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