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SONORITY AS VARIATION: A STUDY ABOUT THE CONCEPTUALIZATION OF PHYSICAL NOTIONS IN UNIVERSITY STUDENTS.

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Abstract. Results of researches over conceptions and specific competencies of university students as regards acoustic waves and their conceptualization are put forward in this paper. The starting point is a theoretical scheme previously done [4] [5] that allows the linking and interconnection of theoretical contributions related with the cognitive psychology, the developmental psychology, problems solving, the linguistic and symbolical representation of concepts and their relation with the didactics. The corpus is made up mainly by answers to written works which have allowed analyzing implicit conceptions of students, especially those ignored or misunderstood by them. This is a qualitative research, in which data are grouped in categories that are not provided before the theoretical framework. Conclusions show the potentiality of the theoretical framework to interpret processes of meaning building of the level of sonority as variation, and for the design and improvement of instructional proposals tending to achieve a critical meaningful learning. **Key words:** Internal representations – Operational invariants – Reasonings – Acoustic waves – Conceptual fields

1. Introduction and theoretical framework

This work forms part of a program of greater scope whose aim is oriented to the search of signs that reveal the presence of operational invariants during the process of problems solving of Physics and their relation with mental representations.

As the solving process research goes on, links with the learning of concepts starts to appear as well as implicit relations with the meaning in its widest sense. In the detailed analysis of a problematic situation it can be inferred the presence of some implicit knowledge, traditionally difficult to be detected, whose quality and organization have a significant influence in those procedures that people developed in order to solve them.

A critical review of processes and results in the research of problem solving and the configuration of the theory of conceptual fields of Vergnaud either as alternative theoretical framework for the research in the solution of problems in Sciences [4] [5] or, plausible referent of integrating mental models of Johnson-Laird with Vergnaud action schemes [15] [11] are the ones that have allowed throwing some light.

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In previous researches over the process of teaching-learning of waves, in general, some authors have reported a series of difficulties with the propagation of waves and their links with the environment properties [14] [3], with the physics of sounding waves [12] [13] and with the mathematical description of waves and their superposition [10] [22], while other authors [20] [21] with waves energy and with representations over the mechanism of a wave propagating and the role of the propagation environment [1] [2].

The waving model is without doubts of great significance in the present scientific explanation of a lot of physical phenomena and its knowledge results necessary to interpret the principles of various technological applications.

The theory of Vergnaud conceptual fields is a psychological theory of concepts [17], a cognitivist theory of the process of conceptualization of the real. It is about a pragmatic theory in the sense that presupposes that the acquisition of knowledge is modelled by situations, problems and actions of the subject in those circumstances [18]. Besides, it is a theory of cognitive complexity, that considers the development of progressively dominated situations, of concepts and theorems necessary to operate efficiently in those situations and of words and symbols that can represent efficiently those concepts and operations for the subject, depending on its cognitive level.

G rard Vergnaud increases and redirects, in its theory, the piagetian focus of general logic operations of the general structures of the thinking towards the study of the cognitive functioning of the "subject-in-situation". Besides that, he takes as reference the own content of knowledge and the conceptual analysis of domain of that knowledge [18] [6].

On the other hand, for Vergnaud "problem is all that in some way or other implies on the subjects part the construction of a response or of an action that *produces a determined effect*" [16].

Accordingly, and following Vergnaud the fact of considering problems solving as disconnected from the formation of concepts is desacerted, it subestimates two aspects: the part of symbolic and conceptual representation present in the problems solving, on one hand; and the part of the problems solving that appears in the formation of concepts, on the other. Both elements form the same thing: the conceptualization.

Individuals developed between them forms of organization of the activity. The teaching problem seems to be in great part that of leaving the learner to develop his/her competencies.

Therefore, the key concepts of the theory of conceptual fields are, besides the own concept of conceptual field, scheme concepts, situation, operational invariants (theorem-in-action) and concept-in-action, and its conception of concept.

Implicit and symbolical representations are very useful in situations or contexts that require responses or automatized actions. The explicit representations allow to afford more complex activities.

Our aim is to study in detail those decisions that students take under different problematic situations and consequently, the search of concepts-in-action and theorems-in-action over which would be important to participate in order to help in improving the learning process in relation to the consensuated scientific model.

2. Materials and methods

This is a qualitative research where the groups are defined during the successive view of the corpus [8]. This supposes a work of immersion in what allows knowing by constant comparison a quality that describes it with the greatest fidelity. The aim is to find regularities in the conventional and functional use that students make of the notion of sounding sensation in the conceptual field of Classic Waving Mechanics, in the Acoustic theme.

In the design of the present research, two stages can be distinguished, which are called exploratory phase and principal stage.

In the exploratory study resolutions written by 4 students of the 3rd period of four months of Bioengineering career with the aim of carrying out a first approximation to the conceptual field. Participants: students with difficulties in problems solving in waves. The task:

- The intensity of sound for a sounding wave increased 1000 times. a) How much the level of sounding intensity is increased? b) How many times does the sounding pressure increases? Let's find the intensity of a sounding wave if, i) $\beta = 10\text{dB}$ and ii) $\beta = 3\text{dB}$.

Some difficulties detected were a marked attachment to the authority of the formulae, non-differentiation increase-ratio, confusion power-sounding pressure, assignation of magnitude attributes of to numbers, dissociation of mathematic and physical aspects in the modelling.

Later, a first data base made up with these answers allowed us to recognize some regularities which were used to propose possible lines of action.

In this second stage, resolutions written by 25 students (during the first test) were analyzed as regards the following problematic situation in its two modalities:

- A sonority measurer located in front of a horn of a sound system of 60 W, [120 W] indicates 70 dB [73dB]. In equal conditions, but placing it in front of a system of 120 W [60W], the measurer will indicate a) 120dB [60dB], b) 140dB [123dB], c) 63 dB, d) 73dB {70dB}, e) anything of the previously mentioned. Justify.

As we go deeper in this analysis we find that students follow certain concepts, theorems and rules of action to solve problems.

3. Results and discussion:

A student to solve this problematic situation needs to recognize that the sound propagates in any environment which reacts in elastic way thus transmitting vibratory energy. The energy of a mechanic wave is distributed in its wave front. This suggests a practical doubt: when a detector intersects a part of a wave front, it registers an amount of energy that depends on its own area of reception and on the time during which it can receive. Both things depend on the detector in particular, but it is required to be able to carry out the same measurements, independently of detectors. Therefore, the total energy that reaches a determined tool is not the thing that should be measured but the energy per unit of time and per unit of area, which is the power density or intensity (I). Besides, the auditive sensitiveness of intensity, volume or sonority depends on the spectrum of frequencies, duration and what is most important the sound intensity.

Theorems that put in action heterogeneous groups of students when they solve problematic situations in this conceptual field can be:

3.1. In case of considering the auditive response as linear

1st Category

Students grouped in this category consider proportional the relation between power and sonority level "β", making a rule of three (or a ratio). They interpret the human ear as a linear receptor in the range of audible frequencies. In terms of operational invariants the scheme-in-action can be:

- Concepts-in-action: power, decibel, proportion, rule of three, ratio.
- Theorems-in-action: **"If power is duplicated (or it is reduced to the middle), decibels are duplicated"**.

3.2. In case of being conscious of the lack of linearity of the human auditive response:

2nd Category

The relation between sonority level "β" and intensity for this group of students seems to be non linear. Although they write the partial (or total) mathematical expression, very frequently, they do not write units during the process of calculation, but go on operating with numbers. They provide, in this way a

great importance to the numerical value without knowing what is obtained, as it was noted in other work [9]. They interpret the human ear as a non linear receptor but non linked to the logarithmic function. The scheme can be described:

- Concepts-in-action: power, number, ratio, logarithmic function.
- Theorems-in-action: “**If the power duplicates (or it is reduced to the middle), the marker will not indicate the double.**”

3rd Category

Although they count with an appropriate physical model of the situation, they are too attached to fixed and conventional rules. They have not acquired the variation as comparison yet, fixing to the value of the basic conceptual standard of intensity and section. They produce a rigorous mathematical operative. The receptor physical model answers to a logarithmic scale in relation to the ratio of intensities (or powers). It seems that they need to carry out the calculation of the area to set links between intensity and power. They seem to have a sequential mental representation closely related with the intuition and with the step by step:

- Concepts-in-action: intensity, power, audition threshold, equivalence, ratio, magnitude, dependence (or independence) of the incipient information, variation.
- Theorems-in-action: “**If there is a diversity of variables, I work with all of them**”. In symbols: “ $\frac{I_2}{AI_0} \cdot \frac{AI_0}{I_1} \equiv \frac{P_2}{P_1}$ (for this situation)”

The following solution is an example of this category:

Student N°13

$$I = P/A$$

$$73dB = 10 \log \frac{I_1}{10^{-12} W / m^2}$$

$$7,3dB = \log \frac{I_1}{10^{-12} W / m^2}$$

$$10^{7,3} = \frac{I_1}{10^{-12} W / m^2}$$

$$I_1 = 1,99 \cdot 10^{-5} W/m^2 \approx 2 \cdot 10^{-5} W/m^2$$

$$A = \frac{120W}{2 \cdot 10^{-5} W / m^2} = 6 \cdot 10^6 m^2$$

$$I_2 = \frac{60W}{6 \cdot 10^{-6} m^2} = 1 \cdot 10^{-5} W/m^2$$

$$Ns = 10 \log \frac{1 \cdot 10^{-5} W / m^2}{10^{-12} W / m^2}$$

$$Ns = 10 \log 10^7$$

$$Ns = 7 \cdot 10 \log 10$$

Ns = 70 dB

4th Category

Apparently similar to the previous category but with an important difference in the incorporation of the relation present between the ratio of intensities and the ratio of powers without the explicit need of calculating the area to link it. The following resolution shows the previously said:

- Concepts-in-action: intensity, power, threshold of audition, equivalence, ratio, magnitude, dependence (and independence) of the partial information, variation.
- Theorems-in-action: “**If there is a diversity of variables, then, I get free of some of them until then calculation become functional**”. In symbols: “ $\frac{I_2}{AI_0} \cdot \frac{AI_0}{I_1} \equiv \frac{P_2}{P_1}$, I achieve independence from the area $\Rightarrow \frac{I_2}{I_0} \cdot \frac{I_0}{I_1} \equiv \frac{P_2}{P_1}$ ”.

Student N°20

<p>60W 70db 60W $I = P/A$ $A = \frac{P_{60}}{I_{60}} = \frac{P_{120}}{I_{120}}$ $I_{120} = P_{120} / A$ $I_{120W} = 2 \times 10^{-5} W/m^2$</p>	<p>70db = $10 \log (I/I_0)$ db ? $10^7 = I/I_0$ $170db = 1 \times 10^{-5} W/m^2$ $db_{120W} = 10 \log \frac{2 \times 10^{-5} W/m^2}{1 \times 10^{-12} W/m^2} = 73db$</p> <p>Double power gives $\approx 1\%$ more decibels due to those intensities applied with logarithms.</p>
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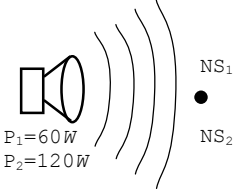
5th Category

They start including other relations and they do the transfer from other areas. They interpret the rate in intensities as a variation in the sonority with the meaning of the logarithm. In operative terms, they sum the increase (do not multiply, nor divide it). That is to say, they model physically and execute a powerful mental representation. They understand the ratio in intensity (or power) as an increase in the sonority level.

Here, in addition of achieving independence from the magnitude area, they recognize the influence of the variation by being independent from the standard base of intensities $I_0 = 10^{-12} W/m^2$. The following student proposes:

- **Concepts-in-action:** intensity, power, threshold of audition, equivalence, ratio, magnitude, (in) dependence from the information, variation.
- **Theorems-in-action:** **“If there is a diversity of variables, then, I disconnect from most of variables so that the calculation results functional”**. In symbols, $\frac{I_2}{AI_0} \cdot \frac{AI_0}{I_1} = \frac{P_2}{P_1} \Rightarrow I_2/I_1 = P_2/P_1$. **If I get free from variables, I can find the variation and not the absolute value of the magnitude”**

Student N°24

<p>$I_1 = P_1/A$ $I_2 = P_2/A$</p>		<p>$\Delta NS = 10 \log (I_2 / I_1) = 10 \log \frac{P_2 \cdot A}{A \cdot P_1} = 10 \log (P_2 / P_1) =$ $10 \log (120W/60W) \approx 3dB$</p> <div style="border: 1px solid black; padding: 2px; display: inline-block; margin: 5px;"> $\Delta NS = \approx 3dB$ </div> <p>By placing a source with a power of 120W the measurer of sonority will indicate 73dB. (70dB + 3dB)</p>
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A synthesis of the described analysis is included in fig. 1

1 st Category	32%
2 nd Category	8%
3 rd Category	28%
4 th Category	24%
5 th Category	8%
TOTAL	100%
Sample	25

Fig. 1. Frequencies of categories built to interpret schemes of action.

4. Conclusions

The solution of new problematic situations and partially new ones require meanings. The learning means acquiring information usable as conceptual tool that simplifies such problems solving. In this study the concept of theorem-in-action has been essential to understand how problems solving has its basis in a conceptual representation or quasi-conceptual of the reality and how it allows the analysis of procedures, mainly, in physical terms. An interesting aspect from the conceptual richness of the analysis and the students reasoning has been the identification and meaning of the dependence and independence of the information.

Our findings suggest that the students' capacity to generate solutions was due to put into action certain mental representations. Five categories have been built as a result of this analysis, from which three have practically the same concepts-in-action but different theorems in action. Students have developed more efficient forms of activity organization, which would lead to the acquisition of specific conceptions and competencies. A general competence that is intended to be developed is that of solving problems and we believe that a **critical competence** (concept used by [19]) in this sense, is the one achieved by these students.

It results evident that students that state a correct and complete solution do not only have built concepts from the conceptual field but also they have been able to consolidate and expand their specific schemes. Meanwhile, there is a group of 15 students that may be assumed that are at a transition stage, in which it is necessary to work in systematic and intentionally form, with specific strategies of the detected difficulties. A deep look makes possible to recognize some focus of difficulties or even more, some direction on which move.

We know that the learning built in a context do not "move" automatically to another one, but it constitutes a basis to build it in other context of greater complexity [7].

Even in its initial character, the obtained results show that there is a possibility of including qualitative changes in the classroom that, in the medium or long term, can influence in structural and/or structuring way in students' learning.

The door to a teaching that takes into account schemes-in-action present in the classroom takes all the risks of a professional commitment, a greater effort in the selection of tasks, search of resources and materials to be able to concrete the proposals and the scarce time available. But a teaching without commitment receives as counterpart an empty learning, lacking structures that allow going on growing. From our project we want to make an innovative approach in this sense.

5. References

- [1] BRAVO, S. y PESA M. 2004 Ola en el estadio: ¿movimiento ondulatorio? Una interpretación del razonamiento de los estudiantes. *VII Simposio de Investigadores en Enseñanza de la Física*. La Pampa Argentina).
- [2] BRAVO S. y PESA M. 2005 La construcción de representaciones sobre movimiento ondulatorio. Una interpretación a partir de la integración de la teoría de campos conceptuales

- de Vergnaud y los modelos mentales de Johnson- Laird. *Revista de la enseñanza de la Física*, 18 (2), pp. 25-42.
- [3] ESCUDERO, C. 1997 Vibraciones y ondas en polimodal: algunas consideraciones y limitaciones de los CBC y CBO. *VII Reunión de Educación en la Física REF 7*). Mar del Plata (Bs. As.)
- [4] ESCUDERO, C, y MOREIRA, M. A. 2004 *La investigación en resolución de problemas: una visión contemporánea*. Programa Internacional de Doutorado em ensino de Ciências (PIDEC). Texto de Apoio N° 23 da Universidade de BURGOS/UFRGS. Publicado en *Actas del PIDEC*, vol. 6, pp.41-90. Publicación en modalidad libro.
- [5] ESCUDERO, C. 2005 *Inferencias y modelos mentales: un estudio de resolución de problemas acerca de los primeros contenidos de Física abordados en el aula por estudiantes de nivel medio*. Tesis doctoral. Universidad de Burgos-Universidad Federal de Rio Grande do Sul.
- [6] FRANCHI, A. 1999. Considerações sobre a teoria dos campos conceituais. En Alcântara Machado, S. D. et al. *Educação Matemática: uma introdução* (pp. 155-195).
- [7] GARCÍA, R. 2000. El conocimiento en construcción. De las formulaciones de Jean Piaget a la teoría de sistemas complejos. España. Gedisa.
- [8] GLASER, B. y STRAUSS, A. L. 1967 *The discovery of grounded theory: strategies for qualitative research*. (Chicago: Aldine).
- [9] GONZÁLEZ, S. y ESCUDERO, C. 2007 Las unidades como parte de un campo conceptual. 1° Encuentro Nacional de Educación en Matemática (i ENEM), Tandil (Bs. As.)
- [10] GRAYSON, D. J. 1996 Using education research to develop waves courseware. *Computational Physics*, 10 (1), pp. 30-37.
- [11] GRÉCA I., MOREIRA M. 2002, Além da detecção de modelos mentais dos estudantes. Uma proposta representacional integradora, *Investigações em Ensino de Ciências*, Porto Alegre.
- [12] LINDER, C. J. y ERICKSON, G. L. 1989 A study of tertiary physics students' conceptualizations of sound. *International Journal of Science Education*, 11 (5), pp. 491-501.
- [13] LINDER, C. J. 1993 University physics students' conceptualizations of factors affecting the speed of sound propagation. *International Journal of Science Education*, 15 (6), pp. 655-662.
- [14] MAURINES, L. 1992 "Los estudiantes y la propagación de las señales mecánicas: dificultades de una situación de varias variables y procedimientos de simplificación". *Enseñanza de las Ciencias*, 10 (1); pp.49-57.
- [15] MOREIRA, M. A. 2002 A teoria dos campos conceituais de Vergnaud. *Investigações em Ensino de Ciências*. Brasil, Vol. 7 (1). Site: <http://www.if.ufrgs.br/public/ensino/revista.htm>
- [16] VERGNAUD, G. 1983 Actividad y conocimiento operatorio. En Coll, C. *Psicología genética y aprendizajes escolares* (pp. 91-104). (Madrid, Siglo XXI).
- [17] VERGNAUD. G. 1990. La théorie des champs conceptuels. *Recherches en Didactique des Mathématiques*, 10 (23): 133-170.
- [18] VERGNAUD G. 1994 *Multiplicative Conceptual Field: What and why*, Ghershon and Jere Edit. State University of New York Press.
- [19] VERGNAUD, G. 2007 Campos conceptuales. Minicurso en *1° Encuentro Nacional de Educación en Matemática (1ENEM)*, Tandil (Bs. As.).
- [20] WELTI, R. 1998 Obstáculos conceptuales en el aprendizaje de la energía de las ondas. *IV Simposio de Investigadores en Educación en Física (SIEF 4)*. La Plata (Argentina)
- [21] WELTI, R. 2002 Concepciones de estudiantes y profesores acerca de la energía de las ondas. *Enseñanza de las Ciencias*, 29 (2), pp.261-270.
- [22] WITTMANN, M. 2002 The object coordination class applied to wave pulses: analyzing student reasoning in wave physics. *International Journal of Science Education*, 24 (1).

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