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A study of social representations of quantum physics held by high school students through numerical and written word association tests

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Abstract

This paper presents findings of a preliminary research on possible social representations of quantum theory that might being shared by high school students. Its purpose was to identify and to characterize these social representations through numerical and written word association tests (NWAT and WWAT) and multidimensional scaling (MDS) techniques of analysis. The understanding of such representations might provide hints of the influence of the media on the students' ideas regarding scientific concepts. In school learning, these ideas are part of the students' prior knowledge, which, when these ideas act as subsumers, can play a key role, not necessarily in the sense of helping, in the occurrence of meaningful learning of quantum mechanics.

Keywords: quantum physics; social representations; meaningful learning.

Estudo de Representações Sociais sobre Física Quântica de estudantes de ensino médio, por meio da associação numérica e escrita de conceitos

Resumo

Este trabalho apresenta alguns resultados de uma investigação preliminar sobre possíveis representações sociais da teoria quântica que estariam sendo compartilhadas entre estudantes do Ensino Médio. O objetivo é identificar e caracterizar possíveis representações sociais utilizando testes de associação numérica e escrita de conceitos (TANC e TAEC) e técnicas de análise multidimensional para o estudo dos dados obtidos. A compreensão dessas representações pode fornecer indícios sobre a influência dos meios de divulgação sobre as ideias dos indivíduos a respeito de conceitos científicos. Tais representações integram o conhecimento prévio do aluno e, se constituírem subsunçores, terão papel fundamental, não necessariamente no sentido de contribuir, para a ocorrência de aprendizagem significativa da Física Quântica.

Palavras-chave: Física Quântica, representações sociais, aprendizagem significativa.

Estudio de las Representaciones Sociales en la Física Cuántica de estudiantes de secundaria, a través de asociación numéricas y escrita de conceptos

Resumen

Este artículo presenta algunos resultados de una investigación preliminar sobre las posibles representaciones sociales de la teoría cuántica que podrían ser compartidos por los estudiantes de secundaria. El objetivo es identificar y caracterizar las representaciones sociales posibles, utilizando tests de asociación numéricas y escrita de conceptos (TANC y TAEC) y técnicas de análisis multidimensionales para el estúdio de los datos. La comprensión de estas representaciones puede proporcionar pistas sobre la influencia de los medios de comunicación sobre las ideas de los individuos acerca de los conceptos científicos. Estas representaciones son parte de los

conocimientos previos del estudiante, y cuando actúan como inclusores, tienen un papel fundamental, no necesariamente para contribuir a la ocurrencia de un aprendizaje significativo de la Física Cuántica.

Palabras clave: la Física Cuántica, representaciones sociales, aprendizaje significativo.

Étude des représentations sociales sur la Physique Quantique pour les étudiants du secondaire, par l'association numerique et de l'écriture des concepts

Résumé

Cet article présente les résultats d'une recherche préliminaire sur les représentations sociales possibles de la théorie quantique qui pourrait être partagées par les étudiants du secondaire. L'objectif est d'identifier et de caractériser les représentations sociales possibles par les tests d'association numerique et de l'écriture des concepts (TANC et TAEC) et des techniques analytiques pour l'étude de données multidimensionnelles. La compréhension de ces représentations peuvent fournir des indices de l'influence des médias sur les idées des individus sur des concepts scientifiques. Ces représentations font partie de la connaissance préalable de l'étudiant, et quand ces idées agissent comme subsumant, peuvent jouer un rôle fondamental, pas nécessairement de contribuer à l'apparition de l'apprentissage significatif de la Physique Quantique.

Mots-clés: la Physique Quantique, représentations sociales, l'apprentissage significatif.

1. INTRODUCTION

The increasing scope of the media has allowed for the observation of a growing number of “scientific terms” in use nowadays, which account for the most different types of phenomena. Quite often, as these concepts are introduced in a highly simplified way, they do not conform to what the scientific community has already accepted as their accepted meanings, or even worse, with what scientists have repudiated as inadequate. Quantum physics, due to the appeal it has today in the media, can be a focus of public attention, so that a variety of meanings might emerge socially. That is, social groups can construct meanings that arise from the social interactions of their members, in such a way that these meanings become social-cognitive representations.

Within this context, information the media disseminates (which can be either beneficial or not) can bear a strong effect on prior knowledge formation, which, by the way, might not be scientifically acceptable; consequently, it can generate subsumers that do not favor new knowledge acquisition. These meanings, in turn, when the subjects incorporate them in their cognitive structure, can become an obstacle to the meaningful learning of a concept, according to the way the scientific community has already acknowledged it.

Knowledge produced in the scholarly scientific milieu constitutes the alleged *reified universe* (Moscovici & Hewstone, 1986; Sousa & Moreira, 2005) that follows supposedly objective rules with theoretical pertinence and methodological stringency. This highly regulated universe is responsible for knowledge production in highly specialized and hierarchical units.

On the other hand, relations originated by everyday life and common sense, where social representations are constructed, materialize the so-called *consensual universes* (ibid.). Knowledge constructed in such a universe does not have predefined rules or any objectivity whatsoever. On the contrary, it uses its own logic. Society generally participates of this universe in an egalitarian way: individuals express themselves according to their own values; theories are valued in relation to their potential to explain common phenomena and, when these theories are shared, they regulate ordinary behaviors, regardless of plausibility criteria.

Between these two universes, there are the media, such as the internet, movies, television, and radio, among many others that aim at translating knowledge stemmed from the reified universe to the population, which constitutes the consensual universe. In addition to these media, there are people who transpose, or transform the information, such as teachers, reporters, newspersons, anchorpersons, lecturers, amateur scientists, and many others. Social representations reflect the content of what circulates in this environment, since it is through this content that the population in general has access to knowledge that academic spheres produce.

As a result of the vast amount of information that circulates socially, scientific contents receive more and more attention, so that mastering these contents has often become a status indicator. Furthermore, disseminated contents, in general, refer to the reified universe, and people naturally think they have to take a stand for these contents, which become the raw material for the development of social representations. Thus, a new common sense emerges in the society, which “is permeated by reason and is submitted to the legitimate authority of science. It is a second-hand knowledge that spreads and constantly establishes a new consensus on each discovery and at each new theory” (Moscovici & Hewstone, 1986, p.

685). This new knowledge, be it a social representation or not, can act as a subsumer for meaningful learning.

2. THEORETICAL FRAMEWORKS

2.1. Meaningful learning

Meaningful learning theory, as proposed by Ausubel (Ausubel, 2000; Ausubel et al., 1978), refers to the process in which the student, in a formal learning environment, entrust him/herself of an organized body of knowledge. When a person learns meaningfully, he/she attributes meaning to the new information and relates it interactively to some knowledge specifically relevant that already exists and that is clearly available in this person's cognitive structure. This relevant prior knowledge is called "subsumer", which, according to Ausubel, is the most relevant variable for the success of meaningful learning. If the learner does not have adequate subsumers, or if those have been obliterated, the necessary conditions for meaningful learning do not exist, thus, we need to construct them, or we have to try to bridge this gap with the use of advance organizers.

Meaningful learning comprises the cognitive interaction between the learner's subsumers and the new knowledge, which can lead to changes in both — subsumers and new knowledge — that, in turn, originates new knowledge for the learner, whose features derive from this interaction. This linkage between new and prior knowledge is called "cognitive anchorage", since new information anchors to the one that has already been in the learner's cognitive structure. The logical meaning of a content gains psychological meaning and is incorporated into the learner's cognitive structure (Moreira, 1997, p. 20). This anchoring process is denominated assimilation.

Ausubel complements his theory with two additional processes: progressive differentiation — the subsumer becomes more refined and detailed while getting more specificity — and integrative reconciliation — responsible for the relations among subsumers while exploring their similarities and differences and recombining them. This author states "all the past learning experiences influence by having positive or negative effects in the new learning because of the impact upon the relevant properties of the cognitive structure" (Ausubel, 2000, p. 8). This means that they act upon the learner's prior knowledge. The theory of meaningful learning focuses on the idea of an interactive anchorage of new knowledge upon the previous one.

Meaningful learning theory focuses on the idea of the interactive anchoring of new knowledge to what the learner already knows. The theory of social representations, therefore, is closely related to the meaningful learning theory, as these representations integrate the learner's prior knowledge and they can facilitate, or hinder, the learning process. Since it is known that a subsumer might not correspond to the meaning that the scientific community has already accepted, we should verify what meanings a person holds in his/her cognitive structure, attempting at understanding how they are related and structured.

When we know about these subsumers, it is feasible, when needed, to modify them, and even to avoid them, so as to favor a meaningful anchoring process. Subsumers include various forms of knowledge and cognitive elements involved in this knowledge, such as concepts, images, assimilation schemes, misconceptions (alternative conceptions), mental models. The social representation of a concept is also embedded in this set of elements and it can participate in the cognitive process as a subsumer.

2.2. Social representations

A social representation "comprises a set of pieces of information, beliefs, opinions, and attitudes related to a given object. In addition to this, this set of elements is organized and structured" (Abric, 2001, p. 18). The object referred here is knowledge yielded by the reified universe, which we have already mentioned in the introduction of this paper that gets through to the population that constitutes the consensual universe.

Social representations present their organization around a central nucleus and a periphery. The nucleus is always consensual as well as shared, including here central and more stable ideas of the object, and determines the nature of linkages between these ideas. It also characterizes the identity of each group, since if the nucleus of two representations are different, we have two distinct representations. This means that it is the nucleus that endows with meaning a social representation. However, more accessible and flexible elements of the representation, including individual contradictions and incorporations, are stored in the periphery, allowing for actualization and adaptations of the representation to the context, thus protecting and complementing the nucleus.

The nucleus determines the value, function, and the existence of the periphery. Whereas the nucleus is essentially normative, the periphery has a functional character, enabling the linkage between the subject's reality and his/her representation. Therefore, a social representation is strongly rooted in the system of values shared by a group, though it also allows for individual contributions, according to each person's life experiences, which, in turn, permit the evolution of social practices and relations.

The individual represents reality, seizes it, and reconstructs it in his/her cognitive system. In this process, this appropriation of reality becomes integrated to his/her belief system, and bestows meaning to present and future attitudes. "It is a system of pre-decodification of reality since it determines a set of *anticipations and expectations*" (op. cit., p. 13).

Social representations are conceived in social groups, in which individuals communicate among themselves about an object, interacting with it and representing it. Nonetheless, not all groups share the same representation. This means that there is a plurality of social representations that are defined according to their linkages to the object and to emergency circumstances (Moliner, 1996).

The group must relate itself to the object to be represented, and this object must have value to the group, which stand as reasons to explain why its members seek to represent

such an object. Because of its complexity and of the social and cultural barriers that exist in the population, disseminated information might undergo changes and distortions in its transmission process. Thus, features of the object, which the subject (or the group) considers as relevant, may inhibit its global recognition. Access to information standardizes these aspects based on professional or ideological interests, and they affect the pertinence of representation, as well as the representation itself.

People construct a representation and seek information about an object only after they have taken a stand about it and in reason of this stand. This process takes time since there is a period in which the individual feels pressed to make up his/her mind though he/she does not know the object well enough. In case this objects presents a polymorphic interpretation, the individual adheres to the opinion of his/her group and shares it with the group members. The subject, thus, creates interactions and behaviors directed to the group, as well as from the group to the individuals. In addition to these, the group should also display an absence of orthodoxy, that is, it cannot be submitted to principles that control its thoughts and attitudes concerning the object, which in turn would prevent any search for alternative explanations.

After complying with these emergency conditions, two processes are involved in the development of a social representation. They help in understanding how social representations work.

One of the processes that acts upon the formation of a social representation is called *objectification*. It translates a concept or idea by means of images, allowing for the interpretation of the object. Some commons elements about the object are previously selected among data that are supplied along the communicative processes and, then, these elements are integrated in a coherent whole and retrieved by an individual.

Anchorage occurs simultaneously and it concerns the object insertion in a formerly constituted and familiar structure, providing the object with an intelligible context. That is how the object is translated into sense and meaning, instrumentalizing knowledge, which is then rooted in the cognitive structure.

Formalization of knowledge happens after the occurrence of those two processes and its goal is to acquaint the subject with the object, "the purpose of all representations is making familiar something that is non-familiar, or non-familiarity itself" (Moscovici, 2000, p. 54). The new object has to be grasped and explained with systems that are familiar to the subject, and this can guarantee the relation among basic cognitive functions, the social representation and its social function.

Summing it up, it is possible to state that knowledge is produced in the reified universes and, mainly through the media, it is extrapolated to the social context, which comprises the consensual universe, in a version that is supposedly accessible to this context. Subjects are always under pressure to take a stand in relation to the new information that keeps on turning up insistently in the media. Individuals, who want to manifest themselves about this new knowledge, have to process this information while inserted in a group that has a social dynamic, through the objectification and anchorage processes.

At the end of the process, there is a representation that has been socially constructed and shared and that many times is quite distant of the one that comes from the reified universe. Thus, a new and scientificized common sense arises, whose effects on comprehension and the explanation of reality can be used as subsumers, which can either favor or hinder meaningful learning of a certain content. Therefore, research on ideas about quantum physics that circulate in school and academic contexts can be justified, enabling the detection of possible social representations of this field of physics.

2.3. The media and quantum physics

The increasing scope of the media is one of those held responsible for the spread of "scientific" terms as a form to justify and explain everyday phenomena. "Quantum physics" constitutes one of such terms. Knowledge of these appropriations that circulate in the consensual universe plays a crucial role in the study of social representations since they can partake in their development.

The texts that follow are excerpts[1] from contemporary books that display, in their title, the expression "quantum" as a kind of a lure to readers. It is not the aim here to make a lecture on the worth of linkages between quantum physics and the themes that these authors have approached, or whether they could even qualify as intellectual impostures (Sokal & Briemont, 1997). It is neither the aim of this article to question the academic qualification of the authors in this area. This paper intends to demonstrate that a dispersion of information on this topic is a reality, and that these different kinds of appropriations do not constitute unanimity among physicists.

> *But if holism is to have any real meaning, any teeth, it must be grounded in the actual physics of consciousness, in a physics that can underpin the unity of consciousness and relate it both to brain structure and to the common features of our everyday awareness. I think that to achieve that, we must turn to quantum mechanics* (Zohar, 1990, p. 75).
>
> *The ideia of a 'quantum society' stems from a conviction that a whole new paradigm is emerging from our description of quantum reality and that this paradigm can be extended to change radically our perception of ourselves and the social world we want to live in. I believe that a wider appreciation of the revolutionary nature of quantum reality, and the possible links between quantum processes and our own brain processes, can give us the conceptual foundations we need to bring about a 'positive revolution' in society* (Zohar & Marshall, 1994, p. 22).

[1] Underlining is ours.

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> *I believe that human consciousness really is quantum mechanical in its origins, and that the mechanics of this quantum consciousness literally give our minds, our selves, and our social relations both a wave aspect and a particle aspect* (op. cit., p. 111).
>
> *The human organism has a quantum field that is composed of atomic sub-particles called neutrinos. At first, this might seem quite a strange and far-fetched statement, but it can be proven to be true, and the in depth study of quantum physics can provide for the theoretical subsidies that are necessary for its understanding. The features of this quantum field can be summed up into three main ones: 1) It is monopolar; 2) The field is mostly neutrinal; 3) The neutrinal field does not interact with electromagnetic fields* (Mattos, 2001, p. 60).
>
> *Actually, as we can infer from what has been previously described, only quantum physics can explain its active mechanisms [homeopathy]. Homeopaths will do their clients a favor if they explain scientifically to them how homeopathy works. This attitude, more in tune with our present time, would contribute to set more clearly the scope of action of this field of knowledge and, furthermore, it would contribute to increase the trust in its methods, which now appear as rather strange to the public in general* (op. cit., p. 191).
>
> *The energy of our bodies, by the way, amounts much more to energy than to solid matter, as it can seem at first sight. Quantum physics has already proven this when it shows the relation between mass and energy: $E=mc^2$. Based on all this, we can say that true intelligence is quantum because it goes beyond the emotional, material, and mental [...] the trend is that we will discover more and more about the relations that exist in the universe, which includes our quantum body that constitutes our personal universe* (Menezes, 2006, p. 19).
>
> *And it is precisely for applying and demonstrating in practice, more than twenty years ago, the concepts of quantum physics in the change of behavioral patterns that lead to a remarkable personal improvement* (op. cit., p. 22).
>
> *Quantum physics has brought the observer's awareness of his/her responsibilities for modifications in the behavior of particles to the science setting. This is what has been traditionally known as mind power, or power of thought, which, for a mechanicist scientist, appears to be plain mystic speculation* (Lima, 2007, p. 13).
>
> *Quantum physics offers an opening to spirituality and it, definitely, brings consciousness to the stage of scientific investigations. However, due to trendiness factors, there are today many people with no academic baggage whatsoever — people without the necessary cultural knowledge and who are incapable of solving an ordinary high school-level equation — passing themselves off as teachers of quantum physics and, thus, imputing to this science a deplorable image* (op. cit., p. 115).

As we can notice in these quotes, some approaches to quantum theory do not necessarily agree with the prevailing view among physicists, and this might favor the development of social representations, which, consequently, also disagree with prevalent beliefs. Moreover, the increasing sale and need of new editions of books related to quantum are noticeable, and they can show that there is a public interest in this theme.

Social representations of quantum physics can be a reality among some social groups, once emergency conditions are satisfied. There is much dispersion of information on this subject, as it could be seen before, and there is much pressure to interference among some groups, mainly among those who consume this kind of material. Furthermore, this theory has been a target to focalization because, in this process, the subject is interested in some of its aspects while he/she does not show any interest for others, so that this individual does not have a global view of the object of representation.

Considering that there is an international consensus, in the area of research in physics teaching, about the inclusion of topics of modern and contemporary physics, at high school level, it seems to make sense to search for what sort of ideas are spread among the population, and to call people's attention to these "quantum alternatives", because they might generate social representations.

If we want to understand the functioning, the evolution and the transformations that can occur within a social representation, we must know the dynamics of relations between their nucleus and its periphery. This comprehension can provide the bases for pointing out to what extent a social representation can work as a subsumer to learning processes, and how, with the information henceforth provided, it might be possible to provide for a representational change based on classroom practices.

3. METHODOLOGY

It must be taken into consideration that the social representations

> *circulate around everyday social communication and they differentiate themselves according to the social sets that develop them and use them. Because of all this empirical research on social representations does not yield replicable or generalizable results that can be applied to other contexts* (Sá, 1996, p. 22).

Thus, research on social representations requires the use a methodology that fits the case we want to study, mainly because of the lack of patterns to be followed. There are, instead, recommendations for the formulation of the instrument the research will use. In this case, we aimed at statistical data analysis, and the best option seemed to be the use of a large scope research tool that would allow us to collect data about as many subjects as possible.

We used a questionnaire (Moreira et al., 2009; Hilger et al., 2009; Hilger, 2009) that comprises two word association tests and, in the end, an identification stage of its respondents' schooling. There was a prior research to determine the ten (10) words to be used as stimuli in the questionnaire. It consisted of a pre-association activity (via

internet), in which the subjects were asked to spontaneously associate any words to the term *quantum physics*. Based on these associations, we developed a list with the most mentioned terms and, from them, we selected the ten words to appear in the questionnaire: five that were directly related to the theory — *quantum physics (QP), uncertainty, particle, probability,* and *quantum* — and five others — *soul, spirituality, thought, supernatural,* and *success*.

The first test presented in the questionnaire — Written Test of Word Association (WWAT) — consists of freely associating words to a given term, which allows for determining the semantic proximity between or among a set of the given concepts. The second test — Test of Numerical Association of Words (NWAT) — the respondent has to attribute a numerical value to each pair of the given words.

The significant advantage of having chosen those tests resides on the fact that both of them allow for a large number of participants, and that they enable statistical analysis. The test's strategy is quite simple and it has already been used in other studies in the area of research in physics teaching, such as Moreira et al., 2009; Borg & Groenen, 2005; Hilger, 2009; Gobara et al., 2002; Greca & Moreira, 2001; Greca et al., 2001; Rosa et al., 1993; Santos & Moreira, 1991.

In the analysis of responses, this research used techniques of multidimensional scaling (Hair et al., 2007; Borg & Groenen, 2005; Cox & Cox, 2001; Santos & Moreira, 1991; Kruskal & Wish, 1978). Using multidimensional scaling, we can generate geometrical representations, such as maps, which reflect the respondent's cognitive structure. These maps are obtained from similarity matrices, in which each cell reflects how close two concepts are. This proximity degree is directly gotten in the case NWAT, where each pair of stimulus-word receives a number that went from 1 to 7 — the bigger the value, the more different the two words. Table 1 shows a sample that can clarify the presentation form of NWAT. In order to get the degree of proximity, in the case of the WWAT, it is necessary to relate the number of words the subject repeated and the position in which these terms are listed (Santos & Moreira, 1991).

Table 1- A sample of word associations in the NWAT

	1	2	3	4	5	6	7
Spirituality and success							
Soul and quantum							
Probability and uncertainty							
Spirituality and thought							
Probability and success							
Spirituality and probability							
Quantum physics and supernatural							
Uncertainty and quantum							
Quantum and thought							

With the answers of each of the subjects, matrices were obtained with the average of similarity of each word pair. These average matrices, for each separate group, constituted the input data for the program of statistical treatment used here, which was the SPSS (Statistical Package for the Social Sciences). Configurations obtained from these two word association tests were analyzed and correlated.

In order to complete this process, this research project aimed at establishing which the elements that integrated the nucleus were and the periphery of these representations based on the responses to the WWAT. To make thing somewhat easier, an additional technique was used, according to the central nucleus theory (Sá, 1996), and it was simultaneously applied with the WWAT. It consisted in "asking the subject to act by him/herself, upon his/her own production, a cognitive work of analysis, comparison, hierachization" (Abric, apud Sá, 1998, p. 91). The subject was asked to hierarchically mark, with 1, 2, and 3, the three terms he/she considered as the most related to the term "quantum physics", among those he/she had already associated with it. These marked words would supposedly compose the nucleus, once the subject had selected them as the most important, while the others would constitute the periphery.

4. FINDINGS

The questionnaire was answered by 238 high school students. Seventy seven of them were in their first year of high school, 72 in the second year, and 87 in the last year, and all of them lived in the area of Porto Alegre, RS, Brazil. Usually, in the first semester of these three years of high school there are not specific contents related to quantum physics, and this was exactly the period stipulated for the application of the questionnaires. Thus, students did not have any contact, in class, with the research topic before their participation in this study.

The three grades (1st, 2nd, and 3rd) had very similar configurations for the NWAT, as figures 1 and 2 show, and it is possible to notice the existence of two sets of words: terms associated to physics, in general — in the left — and terms associated to everyday life — in the right. Similar results were also obtained and discussed by Moreira et al. (2009) and Hilger (2009) for configurations found for other research groups, also discussed these findings. On the other hand, configurations from WWAT related to high school students, can be found in Hilger et al. (2009).

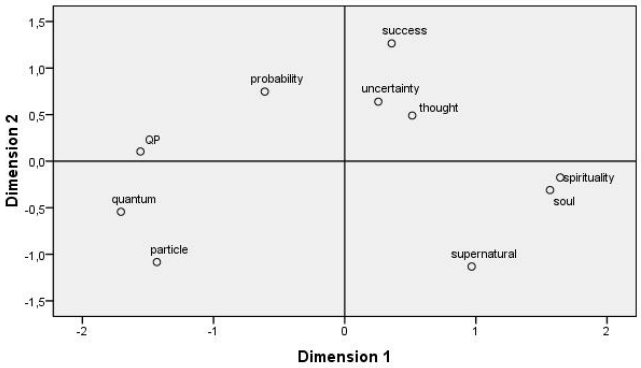

Figure1: Two-dimensional diagram obtained through NWAT with 1st year high school students. (stress 0,15070 e RSQ 0,91020)

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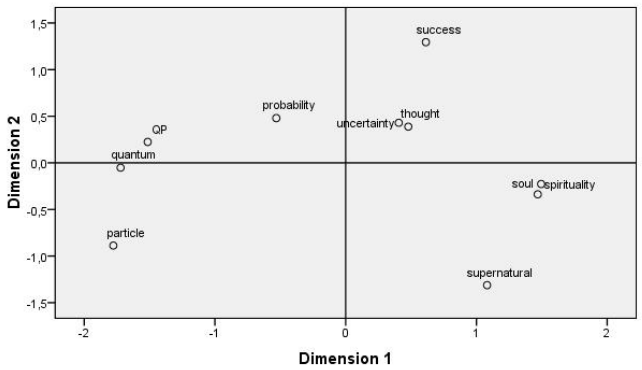

Figure 2: Two-dimensional diagram obtained through NWAT with 2nd year high school students. (stress 0,13579 e RSQ 0,93138)

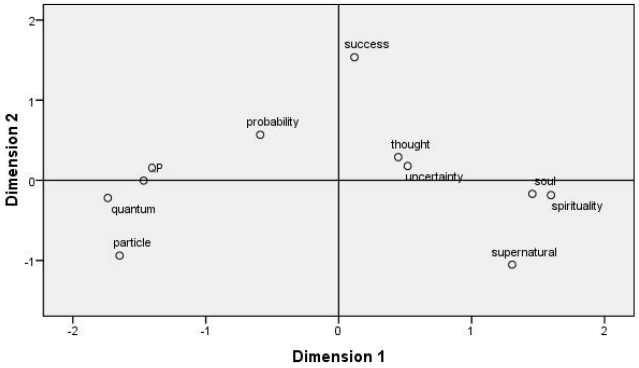

Figure 3: two-dimensional diagram obtained through NWAT with 3rd year high school students. (stress 0,12724 e RSQ 0,94006)

It was not possible to determine, through NWAT to what extent these two sets reflect associations that were related, or not, to quantum physics or to physics, in general, since the students numbered the word pairs according to their personal criteria. Nevertheless, it was verified that the term *uncertainty* was related to its everyday life meaning — of doubt — and not to the uncertainty principle, which "states that an experience cannot simultaneously determine the precise value of a specific moment component ..., as well as the precise value of the correspondent coordinate. Instead, precision ... is intrinsically limited by the measuring process itself" (Eisberg & Resnick, 1979, p. 98). This principle can be shown through different types of definitions, however, the form chosen here seemed adequate to facilitate the identification of the difference between the uncertainty principle and the common meaning students attributed to the term uncertainty.

In addition to the configurations presented so far, the students' ideas about quantum physics can be understood through the observations of the associations they made, in the three years of high school, in the written association test (WWAT). The obtained terms were classified into five categories, which are summarized in chart 1, so as to facilitate its understanding.

Frame 1 – Schemes for the found categories

Category:	Description:	Examples of term found
1	Discipline presentation	Calculus, Formula
2	Relationship with classes	Boring, Difficult
3	Content of the discipline	Gravity, RUVM
4	Questionnaire Terms	Particle, Supernatural
5	Divulgation	Vibration, Wáter

The first one of them concerns the presentation of the discipline physics itself, which is generally too mathematicized. The terms of this category, such as formula, calculus, sum, number, mathematics, and physics, have shown prevalence over the other categories. In the second category, we classified terms that point out to the way students relate themselves with classes, with words such as boring, difficult, and complex.

There are also present here relationships with the studied contents, such as classical physics, which constitute a distinct category. There are words here such as gravity, movement, force, fall, RUVM, velocity, weight — that appeared in the associations established in all the classes comprised in this research, especially in the first year of high school. It was only with the 3rd year students that terms, such as electron, electricity, tension, generator, and receptor, happened since at this level of study the content of electromagnetism is studied. There were associations, as well, with terms that the questionnaire itself offered, and this constituted the 4th category. This association type was more frequent with the 3rd year students.

In frame 2, there are two representative examples of written associations with the term "Quantum Physics" for each of the three high school years.

Frame 2 – Examples of associations related to the term "Quantum Physics"

Grade	Example 1	Example 2	Example 3	Example 4
1st	Formula1, Development2, Count3, **Thought**, **Water**	Quantity1, **Water**2, Force3, **Light**, **Gen**	**Intelligence**, Difficulty, Energy, Mechanics2, Number, Physics, Formula3, Calculus1, Uncertainty	**Inexplicable**, Count, Sensor, **Trip**, Cosmos
2nd	Matter3, **Thought**2, Number, Formula, **Mind**1	Energy1, Change3, Force, Capacity, All2, **Dimension**, **Thought**	Quantity1, Reaction2, **Attraction**3, Movement, Energy	Quantity1, **Water**2, Atlantic, Study, **Person**3
3rd	Strange, **Vibration**, **Mind**2, **Brain**, Contemporariness, Supernatural3, Computer science, **Human body**,	Particle2, **Fiction**, **Believe**1, Reality, Theory, Evolution, Velocity, Electricity3,	Quantum, Probability, **Curiosity**1, **Challenge**2, **Effort**, Time, Discovery, Science3,	Quantity1, Proportion2, Volume, Quantum, Particle3, **Spirituality**, Supernatural, **Willingness**,

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	Emotion, **Feeling**, Experience, Discovery, Probability1	Muon, Astronomy, **Religion**, Probability, Chemistry	**Thought Success**, Uncertainty, Supernatural, **Soul**, Real, **Pensive**	Accelerator, Space

The category we have considered the most relevant for this research on social representations is the one that deals with associations with words that appeared in texts, books, journals/magazines on quantum physics, such as thought, water, attraction, mind, brain, feelings, dimension, vibration, and so on. Oddly, the term "water" stands at the nucleus of representations of 1st and 2nd year students (Hilger, 2009), and it is also related to quantum physics in the movie What the bleep do we know?[2](Rocha, 2010).

From this broad association, we can infer that students need to take a stand about this topic, though, as they do not find answers to the situation in the classroom, they look for information in various means of communication, in which they get in touch with an alternative quantum, which is somewhat mystical and popular. We might also presume that this type of non-academic contact can affect their knowledge of quantum theory.

This kind of dissemination and transformation of scientific knowledge is unsettling, since it has already started to come into effect upon the students. In general, this approach is not accepted in the academic context of universities, but there has not been a formal preoccupation with the uncritical access of high school students to such contents.

Frame 3 presents the terms that compose the nucleus and the periphery (Hilger, 2009), which came from the WWAT for the representations in each of the three high school years. In this classification, we took into account, in addition to the number of repetitions of terms — usually used in social representation studies — the markings the students had made, according to their own preferences. As it was explained in the methodological description, we established that the marked terms would belong to the nucleus of the representation, together with terms that had been insistently repeated — with or without marking. It was also established that, in the periphery, would be the terms that had not been marked, though much mentioned (in a smaller quantity than the terms that were classified as nucleus).

Frame 3 – Nucleus and periphery obtained for the representations of the three years of high school.

	Nucleus:			Periphery:	
Type of marking or repetition	Words marked many times	Words not much marked	Words seldom marked and repeated words	Words repeated many times but	Words seldom repeated and unmarked:
				often unmarked	without marking:
1st year	Quantity, Formula, Calculus	Mathematics, Physics, Count	**Water**, Movement, Energy	Number, Study	Atom, Force, Quantum
2nd year	Quantity, Calculus	Force, Movement, Energy, Measurement	Study, **Water**, Number	Formula	Proton
3rd year	Quantum, Evolution	—	Particle, Probability, Quantity	Velocity, **Thought**	Electron, Uncertainty, Force

This type of organization reflects the already discussed categories, and points out to the existence of possible social representations among high school students that seem to turn them into a quantum physics not scientifically accepted, which is composed basically of pieces of information derived from the media. In this social representation, elements that have been associated are mixed up with the representations these students present for the discipline, the studied contents, and their relationship to the classes that have had.
It seems relevant to emphasize that

> *If our access to the research object occurs only through the participants' discourse, it might be really impossible to know whether their speeches are truly evidences of representations, or whether they have been produced just as a result of stimuli or momentaneous psychological states* (Sá, 1998, pp. 48-49).

Thus what we have in this research are just evidences that there are social representations for quantum physics. It seems farfetched to state that the components of the nucleus and of the periphery are exactly like the ones found here, or that the representation mirrors precisely the one that has been described: a quantum physics that blends in elements from classical physics, physics classes, as well as components that have been obtained though contacts with alternative theories. Although they might be mere evidences, it is possible to anticipate the relevance of social representations for the development of interventions, indifferently of being didactical, or not, with individuals.

5. FINAL REMARKS

According to the meaningful learning theory, knowledge is the most influential variable in learning, and getting to know the student's ideas on the teaching subject facilitates learning. Nowadays, many terms related to science, as quantum physics, for instance, are approached in society so that they can possibly trigger the student's interest on the subject. It seems natural that the teaching of physics devotes increasingly more time to modern and contemporary physics. However, in this case, the student does not individually construct his/her conceptions of a world to which he/she does not have direct access, as it happens with misconceptions or alternative conceptions (Driver, 1973; Viennot, 1979; Duit, 2009). Then, social representations emerge — and they are socially constructed — as a response of some particular groups to the flood of information and interpretations that attempt at transforming

[2] Directed by William Arntz, Betsy Chasse, and Mark Vicente; Produced by William Arntz and Betty Chasse. USA:Payarte, 2004, 109 min..

knowledge, which has been produced in a reified universe, in this case, the universe of Physics, into something familiar.

Because of the increasing amount of dissemination of texts, movies, and materials, which present alternative interpretations of quantum theory, diverse interpretations of this theory can arise. The focus of social representations allows for the study of these ideas, their structure, as well as how they develop and are shared.

According to the obtained data in this research, we can infer the power of influence of the media, as for example, the books whose excerpts were transcribed here, in these representations. There are several "alternative quantum physics" that are publicized in books, seminars, movies, and other means. As a result of this, social representations of quantum concepts are being constructed that might work as strong epistemological obstacles to the grasping of scientifically accepted meanings in this area. When we know that these are the current ideas and their influence upon the students' cognitive system, we can look for new paths to a potential change of this knowledge into its corresponding scientific equivalent.

Nevertheless, what we have presented here is an initial investigation, and there are also other studies being carried out that also point out to the existence of representations of quantum physics, which gives grounds for the need of more research on this area. Thus, it is relevant to understand the students' universe as a means to get hints to improve the pedagogical practice.

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