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Levels of feeling of reality of students, laypeople and scientists regarding objects of Popper's three worlds

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A B S T R A C T

In an attempt to understand "what is real" for students, some researchers have introduced the notion of feeling of reality into science education. In this work, we start from a conceptualization of feeling of reality based on Popper's Theory of the Three Worlds. Thus, the aim of this study was to investigate the levels of feeling of reality attributed by students, laypeople, and scientists to the objects of Popper's Three Worlds. Through the Reality Intensity Questionnaire (RIQ), we obtained quantitative and qualitative data from a sample of 458 students, a sample of 155 laypeople, and a sample of 189 scientists. The analyses were conducted using the multivariate clustering technique and descriptive statistics. The results showed that students, scientists and laypeople attribute different levels of feeling of reality to the objects of Popper's Worlds, both within each of the specific samples and between the samples. With the preliminary evidence presented, we indicate that in order to improve student learning, it is crucial to develop approaches that strengthen the feeling of reality of the concepts (W3 objects) being taught, using more tangible and concrete objects (W1 and W3.1) and integrating more abstract or subjective objects (W3, W2, W2.1).

Na intenção de compreender "o que é real" para estudantes, alguns pesquisadores introduziram na educação científica a noção de sentimento de realidade. Neste trabalho, partimos de uma conceitualização de sentimento de realidade baseada na Teoria dos Três Mundos de Popper. Assim, o objetivo deste estudo foi investigar os níveis de sentimento de realidade atribuídos por estudantes, leigos e cientistas aos objetos dos Três Mundos de Popper. Por intermédio do Questionário de Intensidade de Realidade (QIR), obtivemos dados quantitativos e qualitativos de uma amostra de 458 estudantes, uma amostra de 155 leigos e uma amostra de 189 cientistas. A análises foram conduzidas por meio da técnica multivariada de clusters e estatística descritiva. Os resultados demonstraram que estudantes, cientistas e leigos atribuem diferentes níveis de sentimento de realidade aos objetos dos Mundos de Popper, tanto dentro de cada uma das amostras específicas quanto entre as amostras. Com as evidências preliminares apresentadas, indicamos que para melhorar a aprendizagem dos estudantes, é crucial desenvolver abordagens que fortaleçam o sentimento de realidade dos conceitos (objetos do M3) que estão sendo ensinados, utilizando objetos mais tangíveis e concretos (M1 e M3.1) e integrando objetos mais abstratos ou subjetivos (M3, M2, M2.1).

I. INTRODUCTION

Relevant works that consider the ontological dimension in the investigation of conceptual change were developed by Chi (1992, 2008) and Slotta and Chi (2006). These studies seek to explore students' perceptions of "what real is like". Chi (1992) proposes the existence of three ontological categories: matter, events/processes and abstraction. The author argues that all ontological categories have specific attributes and behaviors, defined by laws and restrictions. She points out that the perception of reality of an ontological category is linked to its attributes and behaviours, and therefore entities of an ontological category cannot be physically transformed into entities of another, as each category is characterized by its own laws and restrictions.

According to Chi, one of the problems of science education is that, for scientists, many scientific entities fit into the ontological category of events, while students classify them as part of the ontology of matter, attributing incorrect characteristics to them, which makes learning difficult. However, Chi believes that it is possible for a conceptual change to occur within the same ontological category, as in the case of the change in perception of whales from fish to mammals, which is relatively well accepted by students, since both categories belong to the group of animals. On the other hand, changes that involve the transition from one ontological category to another are more challenging for students.

More recently, Volfson et al. (2019) introduced the concept of entropy into Chi's theory of ontological change. Chi et al. (2012) distinguish between two types of process phenomena: direct and emergent, stating that confusion between these two types is one of the main sources of conceptual misunderstandings on the part of students. Volfson et al. propose that considering direct and emergent phenomena as belonging to the same level of emergence scale could provide more information about scientific phenomena, in addition to allowing the use of entropy to assess the level of emergence of physical processes.

Another important approach to the ontological dimension in science learning seeks to delimit and analyze "what is real". In this context, Custódio (2009), Marineli and Pietrocola (2018), Pietrocola (2001) and Pinheiro (2003) highlight the multiple dimensions involved in the perception of an object as real. To investigate the different levels of reality attributed to objects in the world, these authors resort to the notion of feeling of reality. They consider that the feeling of reality opens the possibility for considerations of a socio-psychological nature about our relationship with the world, as we establish the reality of objects based on internal (sensations and mental representations) and external (norms, beliefs, conventions) criteria, often not adopting the rigid objective assumptions that philosophers point out in the debate on realism.

One of the major challenges in studying issues related to the feeling of reality is the fact that there is no general theory that addresses the phenomenon. However, the literature from different research traditions (Arendt, 2009; Bachelard, 1978; Berger & Luckman, 1999; Fourez, 1974, 1995; Marechal, 1938; Searle, 1995) indicates the relevance, for the emergence of the feeling of reality about an object in the world, of social interactions, sensory interactions, affective interactions and cognitive interactions carried out by an individual with these objects.

According to Brickman (1980), for example, an individual's behavior can be linked to the reality or unreality of objects, experiences, and all situations in the world. Behavior is based on an internal correspondence that is linked to feelings that reflect a person's internal state and in an external correspondence that is related to the consequences of a fact, both of which are necessary for the attribution of reality. Pietrocola (2001) associates the perception of something as real with the meaning and importance we attribute to that object in our reality. Pinheiro (2003) points out that students' low interest in Physics is related to the difficulty in connecting the object studied with their own realities, which often leads to a perception that these objects are not "real".

Dahlin et al. (2009), in turn, suggest that ontological inversion, i.e. that abstract mathematical/physical models are seen as more real than the concrete, lived experience on which they have their ultimate basis, and from which they have been abstracted, causes serious educational consequences. Ontological inversion can, on one hand, produce in many students a feeling of alienation from nature due to the implicit assertion that the nature we truly experience through our senses is not the "real nature". On the other hand, it can lead to alienation from science, because science seems to replace the understanding of the everyday concrete world with abstract models and mathematical formulas, and most people find such models strange and difficult.

Custódio and Teixeira (2024), Custódio et al. (2019) and Teixeira (2014, 2021) sought to strengthen the theoretical framework by integrating the notion of feeling of reality with Karl Popper's Theory of the Three Worlds (TTW). We believe that this integration can be promising for investigations into how the ontological dimension influences science learning, especially Physics. In this context, our objective is to answer the following research question: what are the levels of feeling of reality attributed by students, laypeople, and scientists to the objects of Popper's Three Worlds?

II. POPPER'S THREE WORLDS AND THE FEELING OF REALITY

Popper defended a comprehensive conception of realism. In his works, he supports the existence of the reality of material or physical objects (such as houses, notebooks, pens, among others), as well as that of mental objects, whether conscious or unconscious. For him, scientific theories and scientific objects are real entities, just like chairs, cars and people. One of his main arguments in favor of the reality of scientific theories is based on the explanatory function they perform in relation to natural phenomena, considering them as instruments for exploration. This implies the acceptance of a truth to be explored (Popper, 1987).

According to the Theory of the Three Worlds (TTW), reality is divided into three distinct worlds: World 1 (W1), which involves physical entities, both animate and inanimate, such as trees, seas, stars and animals, as well as special states and events such as forces, movements and light; World 2 (W2), which encompasses mental states, whether conscious or unconscious, such as dreams, the sensation of pain or ambition; and World 3 (W3), which refers to the products of the human mind, including scientific theories, ideas that give rise to works of art and projects and plans for the creation of artifacts (Popper, 2006; Popper & Eccles, 1995).

For Popper and Eccles (1992), the emergence of World 3 is directly related to the advent of language, since that which existed only in the human mind became something material, impersonal and subject to criticism. They state that "as long as thought is not formulated it is, more or less, part of ourselves. Only when formulated in language does it become an object that is different from ourselves and towards which we can adopt a critical attitude" (p. 43). Thus, the products of the human mind, when objectified through language, cease to belong to the world of subjectivities.

Popper's central argument in favor of the reality of the objects of the three worlds is based on the concept of causal effect. For him, all objects that cause changes in the physical world, perceived by the senses, are real, since they exert a causal effect on material objects, which includes scientific entities (Popper & Eccles, 1995). Electricity is a clear example of how theories can impact people's lives. When scientific knowledge unraveled the mechanisms of generation, transmission and storage of electrical energy, it became possible to transform and improve everyday experience, with a profound impact, especially on the technological changes that permeate today's society.

A central point in TTW is the interaction between the three worlds. For Popper, mental objects can interact with physical objects, or vice versa. For example, will or interest leads us to write down our ideas on paper, which represents an interaction between World 2, World 3 and World 1. Another example is the interaction between the content of a book, a World 3 object, and the reader, who experiences emotions, desires and interests, belonging to World 2. These mental objects can, in turn, generate new objects in Worlds 1 and 3, such as books, theories or works of art. According to Popper and Eccles (1995), "as objects of World 3, they can induce men to produce other objects of World 3 and thus act in World 1 [...]" (p. 62).

Popper's TTW also proposes an indirect interaction between World 1 and World 3, mediated by World 2, which serves as the link between these two worlds. Popper (2006) argues that this mediation manifests itself in the process of everyday choices, since all organisms, when interacting with the environment, solve problems through experimentation. Furthermore, World 2, in its conscious dimension, can influence the actions of the individual. Originally, consciousness had the function of indicating to organisms, and especially to human beings, whether their solutions to problems were right or wrong, using pain and pleasure as signals for learning.

Although Popper (2000) stated that "[...] the physical world 1 is entitled to be regarded as the most obviously 'real' of my three worlds" (p. 9), he also recognized the existence of different levels of reality for objects, linked to the feeling of reality. This feeling of reality is what allows some people to perceive objects in Worlds 1, 2, and 3 as more real than others. In the words of Popper (1979):

> But common sense also realizes that appearances (say, a reflection in a looking-glass) have a sort of reality; in other words, that there can be a surface reality— that is, an appearance—and a depth reality. Moreover, there are many sorts of real things. The most obvious sort is that of foodstuffs (I conjecture that they produce the basis of the feeling of reality), or more resistant objects […].But there are many sorts of reality which are quite different [...] (p. 37)

Like Popper, we agree with the existence of different levels of reality with distinct rules and laws regarding objects, and that these are not accessible to all people. However, we understand that knowledge of these realities is related to objectives, desires, activity and many other elements that build the relationship between the knower and knowledge and that depend on each individual. A person can build a paper airplane without needing aerodynamic knowledge, as this knowledge is not necessary for them to achieve their goal, that is, to make it fly. However, aerodynamic knowledge is real, acceptable, as it is used and approved by a scientific community, but it is not directly accessible in everyday life.

Thus, we have proposed that the feeling of reality is a firm conviction experienced by individuals that the objects of the world are real, based on an evaluation derived from sensory interactions, cognitive interactions, social interactions and affective interactions with the objects of the world. As a consequence, the level of the feeling of reality will vary from one object of the world to another, closely linked to the quality of such interactions. Such definition allows us to advance in the conceptualization of the feeling of reality, connecting it to Popper's TTW, since the feeling of reality is interpreted as an object of World 2, resulting from the quality of the four interactions (subjectively appropriated in W2), and capable of allowing individuals to grasp the reality of the objects of World 1, World 2, World 3 and their intersections. In other words, the feeling of reality is in itself a real object, as it allows human beings to act in World 1 (Custódio & Teixeira, 2024).

By considering the object chair, which belongs to world W3.1, we can elucidate how the four interactions help to interpret it as real. Sensory interactions, based on sight, reveal its characteristics such as shape, color and size, and interaction with other objects reinforces its reality. Touch allows us to perceive texture, weight and hardness, confirming its physical existence. Socially, the chair serves the function of providing seating, a common feature in different cultures, regardless of design. Cognitive interactions can generate new ideas about chairs, such as new designs or materials, based on scientific theories. Finally, affective interactions, such as attachment to a family chair, can intensify the feeling of its reality.

The main objective of our study was to investigate the levels of feeling of reality of students, laypeople and scientists about objects from worlds W1, W2, W3, W2.1 and W3.1. In addition, we aimed to compare the levels of feeling of reality attributed to the groupings formed by these objects through descriptive and cluster analysis. Considerations on the role of the quality of sensory interactions, cognitive interactions, social interactions and affective interactions in the attribution of levels of reality to objects in Popper's Worlds by research participants will be addressed in future work.

III. METHOD

III.1 Data collection instrument

To assess the level of feeling of reality of students, laypeople and scientists in relation to the objects in worlds W1, W2, W3, W2.1 and W3.1, we created the Reality Intensity Questionnaire (RIQ) (appendix), which contains 48 objects, as shown in Figure 1.

Many of the objects in the RIQ were inspired by the work of Pinheiro (2003), while others were taken directly from Popper's own notes, such as "book" and "toothache". The remaining objects were incorporated into the previous ones to complete and form the final set of the RIQ.

To construct the QIR, we used a four-point Likert scale, with point 1 representing objects considered unreal, points 2 and 3 indicating intermediate levels of reality, and point 4 being used for objects considered real. The choice of a four-point Likert scale is based on the intention to avoid the option of neutrality in the responses, which helps to obtain a clearer assessment. The QIR also includes a discursive question, which, for reasons of space, will not be analyzed in this article.

Before applying the questionnaire, we performed a semantic validation, which involved 12 high school students and two researchers specialized in science and technology education, who did not participate in the preparation of the questionnaire. These participants answered questions, offered criticism and comments, and identified possible misunderstandings or issues with the wording, allowing adjustments to be made before the final version. In addition, each group's list of objects was evaluated and approved by a researcher who was an expert in Popper's TTW.

FIGURE 1. Classification of the objects that compose the RIQ based on Popper's TTW.

World 1 (W1)	star, lightning, cloud, rain, air, tree, dog, magnet
World 2 (W2)	dream, thought, feeling, longing, love, ambition, friendship, memories
World 3 (W3)	numbers, spin, genes, chromosomes, electron, cell, atom, gravitational field, magnetic field, frictional force, gravitational force, mass, point mass, probability, photon, electric current
World 2 and 1 (W2.1)	aroma, toothache, noise, taste, colors, cold, tiredness, sleep
World 3 and 1 (W3.1)	cotton candy, chair, pen, glasses, musical score, sculpture, book, building design

III.2 Participants and data collection procedures

The objective of our study is to investigate what is considered real by different groups: students, scientists and laypeople. The first population is composed of students in the 1st, 2nd and 3rd years of high school in public schools. The second includes scientists working in basic research of the natural sciences (such as Biology, Physics and Chemistry) or in related fields (such as Engineering and health areas) at public universities in Brazil. The third population is formed by laypeople, i.e. individuals who are not attending high school, do not have higher education, are not enrolled in courses related to Biology, Physics, Chemistry or related areas, and do not use knowledge from these sciences in their daily activities.

To facilitate data collection among high school students, we chose two public schools located in the central area of Florianopolis: a federal school, which we will call "school A", and a state school, called "school B". Both serve students from different social classes. School A has approximately 1,000 students, of which approximately 700 are in elementary school and 300 in high school. We administered the RIQ to all high school students, obtaining a response rate of approximately 85%, corresponding to 255 questionnaires. School B has approximately 5,000 students, with approximately 2,000 in elementary school and 3,000 in high school. We applied the RIQ to a group of approximately 1,000 high school students, receiving a response rate of around 20%, or 203 questionnaires. Thus, the total number of questionnaires answered in both schools represents approximately 35% of the initial sample, totaling 458 students.

For the sample of scientists, approximately 2,000 professionals were selected to answer the RIQ, which was made available online. The response rate was approximately 10%, resulting in 189 participating scientists.

Data collection from laypeople was carried out in two ways: the first was indirect, by sending the RIQ to the parents of students in some classes. The second way was direct, by approaching laypeople in the communities. In total, approximately 650 questionnaires were delivered, with a response rate of approximately 24%, resulting in 155 lay respondents.

The research proposal was submitted to the Ethics Committee, through Plataforma Brasil (Brazil Platform), where it obtained approval and is identified under CAAE number: 14484113.2.0000.0121.

III.3 Data analysis procedures

We applied the multivariate clustering analysis technique to group the objects in W1, W2, W3, W2.1 and W3.1, with the aim of identifying similarities between the objects in the RIQ. In this context, the cluster analysis adopts an exploratory approach. The analyses were performed with data from scientists, students and laypeople, using the statistical software SPSS.

Cluster analysis is a data mining technique consisting of a set of multivariate approaches that seek to identify similarities or differences between objects, grouping them according to their patterns (Vicini, 2005). We opted for the hierarchical agglomerative method for grouping, in order to generate a dendrogram that would facilitate the visualization of the groups formed. Furthermore, this method does not require the researcher to predefine the desired number of clusters, unlike non-hierarchical methods.

We chose Ward's method as the clustering algorithm, using Euclidean distance as a measure of similarity (Hair et al., 2009). This metric proved to be suitable for our study, considering that the data were obtained using a four-point Likert scale. Ward's algorithm obtained satisfactory results when using Euclidean distance, creating more cohesive groups compared to other algorithms tested, as evidenced by the literature.

IV. RESULTS

IV.1 Scientist clusters

First, we will analyze the dendrogram obtained from the scientists' data, presented in Figure 2 below.

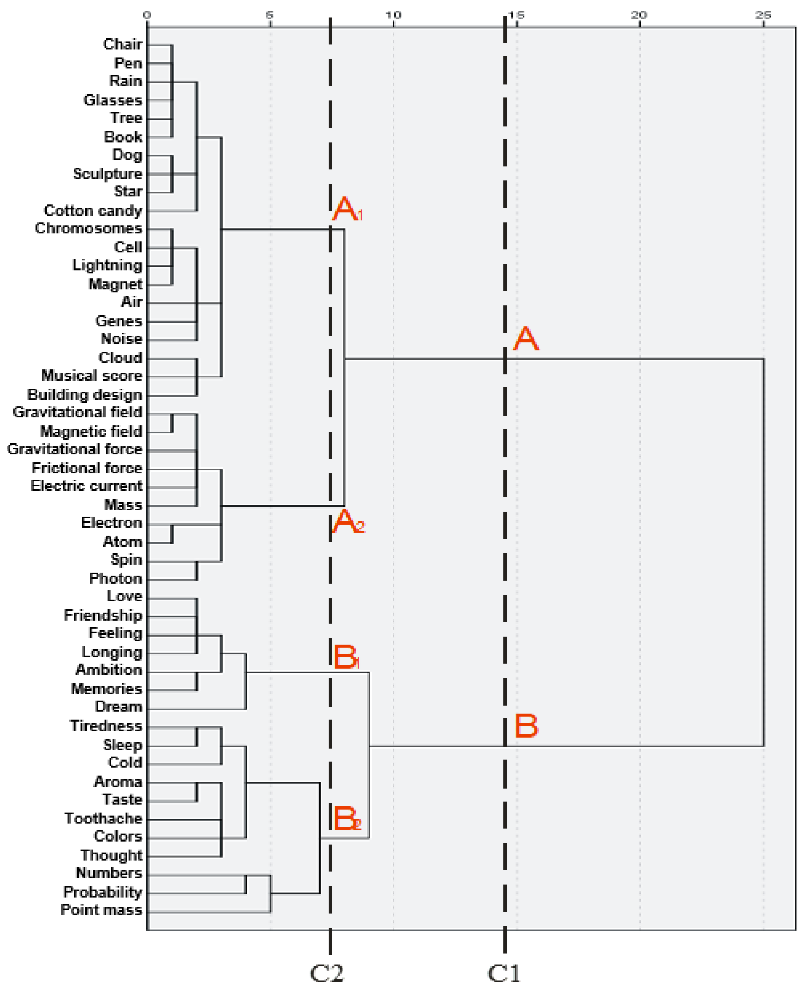

FIGURE 2. Dendrogram representing the clusters of the sample of scientists.

The groupings obtained using the clustering analysis technique will be analyzed based on two cut-off levels: C1 cut-off and C2 cut-off. This approach makes it possible to identify the characteristics of broader groups (C1 cut-off) and more specific groupings (C2 cut-off), providing a more refined analysis. This procedure will be applied uniformly to all dendrograms generated, covering clusters related to scientists, students and laypeople. In the cluster analysis carried out on the data obtained from scientists, the C1 cut-off shows the formation of two large groups, called A and B. Group A comprises 30 of the objects presented in the RIQ, corresponding to 62.5% of the total objects analyzed. On the other hand, group B includes the remaining 18 objects, representing 37.5% of the total. Figure 3 presents the detailed classification of the objects in each group, as identified in C1 cut-off.

FIGURE 3. Classification of objects according to C1 cut-off.

Groups	Objects
A	Tree, Book, Chair, Pen, Glasses, Dog, Rain, Lightning, Cell, Magnet, Sculpture, Star, Chromosomes, Air, Cloud, Cotton candy, Genes, Noise, Musical score, Building design, Electric current, Mass, Electron, Magnetic field, Gravitational force, Atom, Frictional force, Gravitational field, Photon, Spin
B	Feeling, Longing, Friendship, Love, Memories, Ambition, Dream, Toothache, Aroma, Colors, Taste, Sleep, Cold, Thought, Tiredness, Numbers, Probability, Point mass

An initial analysis of the groups formed by the C1 cut-off indicates that all the objects in group A, with the exception of the object "noise", classified in W2.1, are associated, according to Popper's Theory of the Three Worlds (TTW), with worlds W1, W3 or W3.1, representing, respectively, 100%, 81.25% and 100% of the objects included in the RIQ. Similarly, objects in group B, with the exception of "numbers", "probability" and "point mass", which belong to W3, are allocated to worlds W2 or W2.1, which represent 100% and 87.5% of the objects considered in the RIQ. To deepen our analysis, Table I shows the objects and their respective groupings, accompanied by their means.

TABLE I. Classification of objects according to the C1 cut-off and their respective means.

Group	Objects	Mean	Objects	Mean	Objects	Mean
A	Tree	3,95	Sculpture	3,88	Mass	3,76
	Book	3,95	Star	3,87	Electron	3,75
	Chair	3,94	Chromosomes	3,87	Magnetic field	3,72
	Pen	3,94	Air	3,87	Gravitational force	3,72
	Glasses	3,94	Cloud	3,84	Atom	3,72
	Dog	3,92	Electric current	3,84	Building design	3,71
	Rain	3,90	Cotton candy	3,83	Frictional force	3,68
	Lightning	3,90	Genes	3,79	Gravitacional field	3,67
	Cell	3,89	Noise	3,78	Photon	3,59
	Magnet	3,89	Musical score	3,76	Spin	3,58
B	Toothache	3,69	Thought	3,38	Probability	3,01
	Aroma	3,67	Tiredness	3,32	Love	3,01
	Colors	3,58	Numbers	3,27	Memories	3,01
	Taste	3,55	Feeling	3,10	Ambition	2,85
	Sleep	3,50	Longing	3,05	Point Mass	2,78
	Cold	3,40	Friendship	3,03	Dream	2,74

We will use the mean of each object as a measure of central tendency to assess the degree of feeling of reality attributed by scientists to these objects. Analysis of the means reveals that group A is mostly composed of objects that present higher means, close to the value 4, which indicates objects considered real. However, it is noteworthy that the objects "toothache", "aroma" and "colors", with means of 3,69, 3,67 and 3,58, respectively, belong to group B, even though they have means equal to or higher than those of objects in group A, such as "friction force", "gravitational field", "photon" and "spin". We can also note that the objects "toothache", "aroma" and "colors", despite having high means, are not in group A. This discrepancy can be explained by the fact that they are interpreted as sensations. Thus, from the scientists' perspective, these objects may not be at the same level of reality that characterizes the objects in group A.

Another important observation, based on the analysis of the means, is that not all scientific objects received high means. Three of them, “numbers”, “probability” and “point mass”, classified as scientific objects, had relatively low means, which resulted in their inclusion in group B.

In order to increase the accuracy of the analysis, we performed a new C2 cut-off between distances 5 and 10, since we observed a wider separation between groups A and B, indicated by the greater length of the vertical line connecting them. This separation reveals greater heterogeneity between the elements of each group, compared to the elements of the other groups. By analyzing the C2 cut-off, it was possible to perform a more refined classification of the groups, identifying four distinct groups, which we named: A1, A2, B1 and B2. Table II shows the arrangement of each object in its group, along with their means.

TABLE II. Classification of objects according to the C2 cut-off and their respective means.

Group	Object	Mean	Object	Mean
A_1	Tree	3,95	Sculpture	3,88
	Book	3,95	Star	3,87
	Chair	3,94	Chromosomes	3,87
	Pen	3,94	Air	3,87
	Glasses	3,94	Cloud	3,84
	Dog	3,92	Cotton candy	3,83
	Rain	3,90	Genes	3,79
	Lightning	3,90	Noise	3,78
	Cell	3,89	Musical score	3,76
	Magnet	3,89	Building design	3,71
A_2	Electric current	3,84	Atom	3,72
	Mass	3,76	Friction force	3,68
	Electron	3,75	Gravitational field	3,67
	Magnetic field	3,72	Photon	3,59
	Gravitational force	3,72	Spin	3,58
B_1	Feeling	3,10	Memories	3,01
	Longing	3,05	Ambition	2,85
	Friendship	3,03	Dream	2,74
	Love	3,01		
B_2	Toothache	3,69	Thought	3,38
	Aroma	3,67	Tiredness	3,32
	Colors	3,58	Numbers	3,27
	Taste	3,55	Probability	3,01
	Sleep	3,50	Point Mass	2,78
	Cold	3,40		

With this new classification, it can be observed that group A1 accounts for 41,7% of the elements in the questionnaire, that is, 20 objects. This group is composed of objects from W1 (8 objects), W3.1 (8 objects), W2.1 (1 object) and W3 (3 objects) worlds, and has the highest means. Group A_1 reflects the physical world (W1) and the materialization of objects from W3 in the physical world (W3.1), although three objects from this group (Cell, Chromosomes and Genes) belong to W3, and one object, “noise”, to W2.1. This indicates that objects from the physical world are perceived with a high level of feeling of reality by scientists.

For this sample, we consider it reasonable that the objects in W3, which have already been objectified, have a high level of feeling of reality. As for the object of W2.1, we can infer that “noise” is perceived more as a product of W1 than as a sensation originating in W2. Thus, group A_1 includes objects strongly associated with W1, even if some result from the interaction with W3 and W2, or are exclusive to W3.

Group A_2, in turn, represents 20,8% of the objects in the questionnaire, totaling 10 items. It is composed exclusively of objects from W3, all with high means of over 3,57. This suggests that scientists attribute a high level of feeling of reality to these objects. Group B_1, which corresponds to 14,6% of the questionnaire elements (7 objects), includes only items from W2, with predominantly lower mean scores than groups A_1 and A_2. This indicates a lower level of feeling of reality.

Group B_2, with 22,9% of the elements (11 objects), is formed by objects from worlds W2 (1 object), W3 (3 objects) and W2.1 (7 objects). The means for objects in group B_2 are mostly higher than those in group B_1, but still lower than those in groups A_1 and A_2, suggesting a higher level of feeling of reality than group B_1, but lower than that of groups A_1 and A_2.

IV.2 Student clusters

Cluster analysis for the student data generated the dendrogram shown in Figure 4.

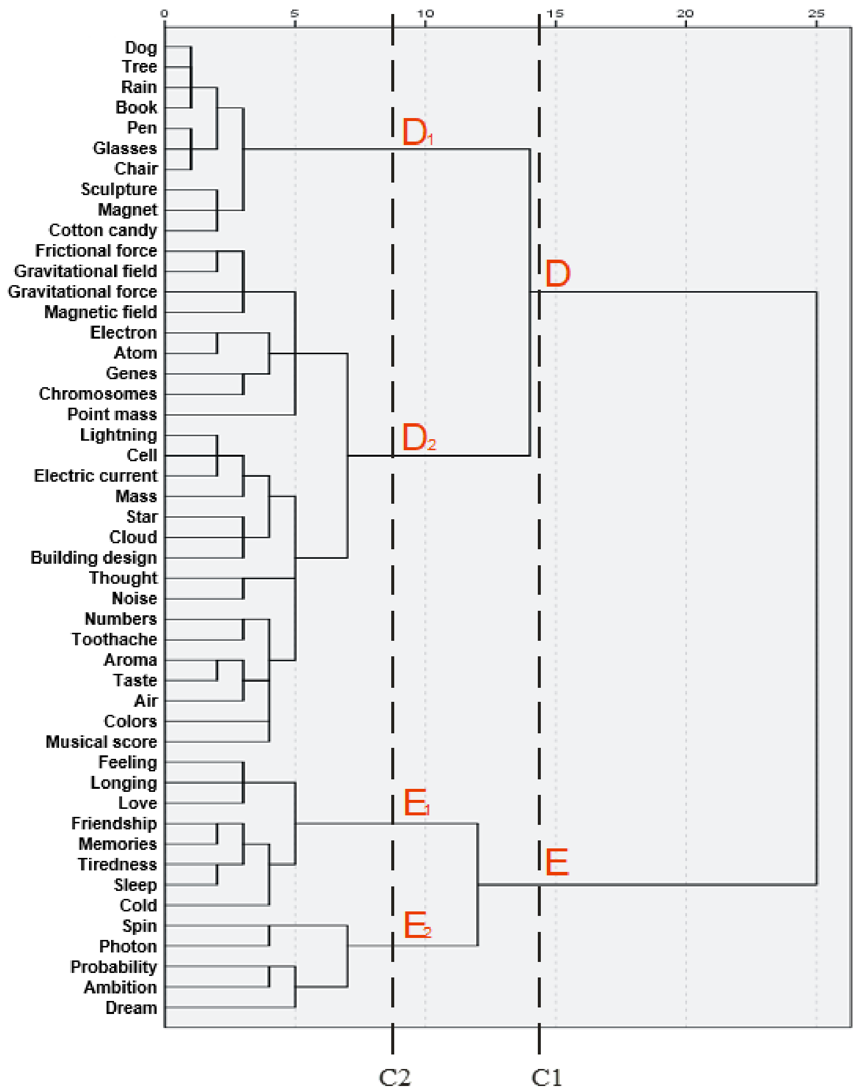

FIGURE 4. Dendrogram representing the clusters of the student sample.

As we did previously with the data obtained from the scientists, we made two cuts in the dendrogram. A C1 cut-off between distances 10 and 15, which formed two large groups, and a C2 cut-off between distances 5 and 10 so that we could make a more accurate analysis of the groups formed. The cuts were made at these distances because the vertical line that separates the groups indicates the heterogeneity between them, therefore, the greater the distance, the lower the similarity between the objects within each group.

The C1 cut-off shows that the objects can be classified, based on the students' data, into two compact groups, which we will refer to as D and E. Group D consists of 35 objects from the RIQ, representing approximately 73% of the total objects, while Group E comprises 13 objects, totaling approximately 27% of the RIQ objects. In Figure 5, we present the classification of the objects into their respective groups according to the C1 cut-off.

FIGURE 5. Classification of objects according to C1 cut-off.

Groups	Objects
D	Tree, Book, Chair, Pen, Glasses, Dog, Rain, Lightning, Cell, Magnet, Sculpture, Star, Chromosomes, Air, Cloud, Cotton candy, Genes, Musical score, Building design, Electric current, Mass, Electron, Magnetic field, Gravitational force, Atom, Friction force, Gravitational field, Toothache, Aroma, Colors, Taste, Numbers, Thought, Point mass, Noise.
E	Feeling, Longing, Friendship, Love, Memories, Ambition, Dream, Sleep, Cold, Tiredness, Probability, Photon, Spin.

By analyzing, based on Popper's TTW, the groups formed from C1 cut-off, we can see that group D is formed by 100% of the objects belonging to W1 and W3.1; 81,25% of the objects from W3; 12,5% of the objects from W2 and 62,5% of the objects from W2.1. Likewise, group E is composed of 37,5% of the objects from W2.1, 87,5% of the objects from W2 and 18,75% of the objects from W3.

In order to improve our analysis, we will use the mean of each object to obtain more information about each group. Table III below shows the classification of the objects into their respective groups and means.

TABLE III. Classification of objects according to the C1 cut-off and their respective means.

Group	Object	Mean	Object	Mean	Object	Mean
D	Tree	3,92	Cell	3,64	Gravitational force	3,41
	Dog	3,91	Star	3,64	Atom	3,40
	Book	3,86	Toothache	3,59	Frictional force	3,36
	Chair	3,85	Building design	3,55	Genes	3,34
	Rain	3,85	Air	3,53	Electron	3,33
	Pen	3,84	Electric current	3,52	Musical score	3,32
	Glasses	3,83	Taste	3,51	Noise	3,29
	Sculpture	3,72	Numbers	3,49	Magnetic field	3,28
	Magnet	3,72	Cloud	3,48	Gravitational field	3,27
	Cotton candy	3,69	Aroma	3,45	Thought	3,21
	Mass	3,67	Chromosomes	3,42	Point mass	3,16
	Lightning	3,67	Colors	3,41		
E	Sleep	3,40	Cold	3,15	Dream	2,61
	Feeling	3,21	Memories	3,14	Photon	2,55
	Tiredness	3,20	Love	3,04	Spin	2,21
	Longing	3,19	Ambition	2,80		
	Friendship	3,19	Probability	2,78		

When analyzing the means of the objects in each group, it is clear that, in general, the objects in group D have higher means than those in group E. However, it is worth noting that some objects in group E, such as "feeling", "tiredness", "longing" and "friendship", have higher means than the "point mass" object in group D. In addition, the object "sleep" stands out, with a higher mean than nine objects in group D, including "friction force", "genes", "electron", "musical score", "noise", "magnetic field", "gravitational field", "thought" and "point mass". With a more detailed analysis, we observed that the C2 cut-off resulted in the formation of four subgroups: D1, D2, E1 and E2, as illustrated in Table IV.

TABLE IV. Classification of objects according to the C2 cut-off and their respective means.

Group	Object	Mean	Object	Mean
D_1	Tree	3,92	Pen	3,84
	Dog	3,91	Glasses	3,83
	Book	3,86	Sculpture	3,72
	Chair	3,85	Magnet	3,72
	Rain	3,85	Cotton candy	3,69
D_2	Mass	3,67	Gravitational force	3,41
	Lightning	3,67	Colors	3,41
	Cell	3,64	Atom	3,40
	Star	3,64	Frictional force	3,36
	Toothache	3,59	Genes	3,34
	Building design	3,55	Electron	3,33
	Air	3,53	Musical score	3,32
	Electric current	3,52	Noise	3,29
	Taste	3,51	Magnetic field	3,28
	Numbers	3,49	Gravitational field	3,27
	Cloud	3,48	Thought	3,21
	Aroma	3,45	Point mass	3,16
	Chromosomes	3,42		
E_1	Sleep	3,40	Longing	3,19
	Feeling	3,21	Cold	3,15
	Tiredness	3,20	Memories	3,14
	Friendship	3,19	Love	3,04
E_2	Ambition	2,80	Photon	2,55
	Probability	2,78	Spin	2,21
	Dream	2,61		

This new classification reveals that group D_1 is composed of 20,8% of the elements, totaling 10 objects – 4 from W1 and 6 from W3.1. These objects have the highest means, indicating a strong degree of feeling of reality on the part of the students, in a similar way to the scientists' cluster. Group D_2, on the other hand, comprises 52,1% of the elements, with a total of 25 objects, including 4 from W1, 13 from W3, 1 from W2, 2 from W3.1 and 5 from W2.1. The objects in this group have lower means than those in group D_1, but, for the most part, they have higher means than those in groups E_1 and E_2, suggesting a higher feeling of reality compared to the objects in these two groups.

The coherence of group D_2 can be explained by analyzing the worlds to which some of its objects belong. Objects such as "lightning," "star," "air," and "cloud" belong to W1, but unlike other W1 items grouped in D_1, these were considered by students as less concrete. This is partly due to the distance of some of them (such as "star" and "cloud") or their reduced tangibility (such as "lightning" and "air"). Similarly, the objects "building design" and "musical score", which belong to W3.1, could be grouped in D_1, since they represent more abstract versions of W3 in relation to objects such as "pen". Finally, objects such as "taste," "aroma," "colors," and "noise" belong to W2.1 and form a consistent grouping, since they reflect interactions between the physical world and subjective sensory perception. The grouping of many W3 objects in group D_2, close to items from the physical world in the dendrogram, reinforces the students' good perception of the reality of these objects.

It can also be observed that the objects of W2 or W2.1 do not exhibit higher levels of reality than the objects of W1, except for the object "toothache", which has a higher mean than the object "cloud". Although most W3 objects have reality feeling levels similar to those of W1, scientific objects such as "probability", "spin", and "photon" present low means, suggesting a lower degree of feeling of reality.

In group E_1, we have 5 objects from W2 and 3 objects from W2.1, totaling 16,7% of the grouped elements. This group is formed by objects whose means are lower than those of groups D_1 and D_2, indicating a lower degree of feeling of reality. However, it is interesting to note that the objects "sleep", "feeling", "tiredness", "friendship" and "longing" have higher means than the object "point mass" in group D_2.

Finally, group E_2 is composed of 10,4% of the grouped objects, with 2 from W2 and 3 from W3. This group contains the objects with the lowest means, which reflects the lowest level of feeling of reality perceived by the students.

IV.3 Clusters of laypeople

The cluster analysis for the laypeople's data generated the dendrogram shown in Figure 6. As with the clusters of scientists and students, two cuts were made. The C1 cut-off divided the objects in the dendrogram into two large groups, F and G, in order to obtain a more general view of the objects in each group. The C2 cut-off divided the objects into four smaller groups, F_1, F_2, G_1 and G_2, serving for a more precise analysis of the condition of the objects in the grouping. We can observe, taking as reference the C1 cut-off, group F formed by 30 of the RIQ objects, representing 62,5% of the existing objects and group G formed by 18 of the objects of the same questionnaire, containing 37,5% of the objects.

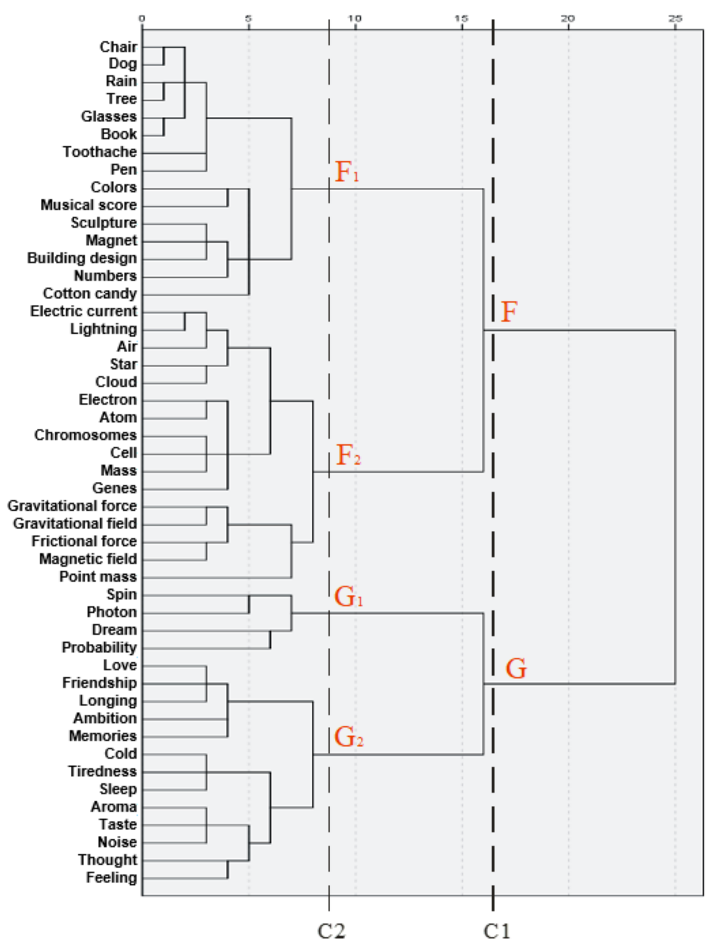

FIGURE 6. Dendrogram representing the clusters of the laypeople sample.

Figure 7 shows the objects belonging to groups F and G, according to the C1 cut-off. When we first analyze the groups formed, from the C1 cut-off, taking Popper's TTW as a basis, we observe that group F is formed by 100% of the objects belonging to W1, 100% of the objects belonging to W3.1, 81,25% of the objects that form W3 and 25% of the objects belonging to W2.1. In group G we verify that it is formed by 100% of the objects that belong to W2, 75% of the objects belonging to W2.1 and 18,75% of the objects that form W3.

FIGURE 7. Classification of objects according to the C1 cut-off.

Groups	Objects
F	Tree, Book, Chair, Pen, Glasses, Dog, Rain, Lightning, Cell, Magnet, Sculpture, Star, Chromosomes, Air, Cloud, Cotton candy, Genes, Musical score, Building design, Electric current, Mass, Electron, Magnetic field, Gravitational force, Atom, Friction force, Gravitational field, Toothache, Colors, Numbers, Point mass.
G	Feeling, Longing, Friendship, Love, Memories, Ambition, Dream, Sleep, Cold, Tiredness, Probability, Photon, Aroma, Taste, Thought, Noise, Spin.

In order to refine our analysis, we will use the mean of each object as a basis for obtaining more detailed information about each group. Table V below shows the classification of the objects into their respective groups, along with their respective means.

TABLE V. Classification of objects according to the C1 cut-off and their respective means.

Group	Object	Mean	Object	Mean	Object	Mean
F	Tree	3,97	Numbers	3,65	Chromosomes	3,47
	Chair	3,94	Electric current	3,65	Cotton candy	3,46
	Rain	3,94	Cell	3,65	Genes	3,37
	Dog	3,93	Magnet	3,65	Atom	3,34
	Glasses	3,89	Air	3,64	Gravitational force	3,31
	Pen	3,85	Mass	3,61	Electron	3,30
	Book	3,85	Building design	3,61	Frictional force	3,29
	Toothache	3,79	Colors	3,60	Magnetic field	3,28
	Lightning	3,77	Cloud	3,54	Gravitational field	3,12
	Sculpture	3,75	Musical score	3,52	Point mass	3,08
	Star	3,70				
G	Taste	3,60	Cold	3,34	Ambition	2,69
	Aroma	3,54	Thought	3,25	Photon	2,59
	Noise	3,52	Love	3,19	Probability	2,56
	Sleep	3,46	Friendship	3,14	Dream	2,34
	Feeling	3,42	Longing	3,13	Spin	2,18
	Tiredness	3,37	Memories	3,06		

As shown in Table V, the objects in group F, for the most part, have higher means than the objects in group G. However, we observe that some objects, such as "taste", "aroma", "noise", "sleep", "feeling", "tiredness", "cold", "thought", "love", "friendship" and "longing", belong to group G, although their means are equal to or even higher than those of objects in group F. Examples of this are the objects “cloud”, “musical score”, “chromosomes”, “cotton candy” and “point mass”, which are part of group F, but have lower means than some objects in group G.

Additionally, we observe that group G is predominantly composed of objects that are related to external sensations, linked to the human senses, or to internal sensations of an individual nature. The exception to this trend are the scientific objects “photon”, “probability” and “spin”, which, despite being more abstract, are part of this group, probably due to the way laypeople perceive them in the context of reality.

By observing the C2 cut-off, it was possible to perform a more detailed classification of the groups, resulting in the formation of four new distinct subgroups within F and G, which we call F_1, F_2, G_1 and G_2. Table VI shows the distribution of each object in their respective groupings, accompanied by their means.

TABLE VI. Classification of objects according to the C2 cut-off and their respective means.

Group	Objects in group	Mean	Objects in group	Mean
F_1	Tree	3,97	Sculpture	3,75
	Chair	3,94	Magnet	3,65
	Rain	3,94	Numbers	3,65
	Dog	3,93	Building design	3,61
	Glasses	3,89	Colors	3,60
	Pen	3,85	Musical score	3,52
	Book	3,85	Cotton candy	3,46
	Toothache	3,79		
F_2	Lightning	3,77	Genes	3,37
	Star	3,70	Atom	3,34
	Electric current	3,65	Gravitational force	3,31
	Cell	3,65	Electron	3,30
	Air	3,64	Frictional force	3,29
	Mass	3,61	Magnetic field	3,28
	Cloud	3,54	Gravitational field	3,12
	Chromosomes	3,47	Point mass	3,08
G_1	Photon	2,59	Dream	2,34
	Probability	2,56	Spin	2,18
G_2	Taste	3,60	Thought	3,25
	Aroma	3,54	Love	3,19
	Noise	3,52	Friendship	3,14
	Sleep	3,46	Longing	3,13
	Feeling	3,42	Memories	3,06
	Tiredness	3,37	Ambition	2,69
	Cold	3,34		

The new classification reveals that group F_1 represents 31,25% of the grouped elements, with a total of 15 objects. Of these, 4 belong to W1, 1 to W3, 2 to W2.1 and 8 to W3.1. These objects, for the most part, present higher means than the objects in the other groups, indicating a high degree of feeling of reality.

Group F2, in turn, is composed of 16 elements, representing 33,33% of the total. Of these, 4 objects are from W1 and 12 from W3. These objects also have high means, signaling a high degree of feeling of reality. It is interesting to note that some objects in this group, such as “lightning”, “star”, “electric current”, “cell”, “air”, “mass”, “cloud” and “chromosomes”, have higher means than the object “cotton candy”, which belongs to group F_1.

Group G_1, in turn, is made up of 4 elements, representing 8,33% of the total. These objects are “photon”, “probability”, “dream” and “spin”. With the lowest means among all groups, these objects indicate a low level of feeling of reality attributed by laypeople, reflecting a distant or less concrete perception of these items.

Finally, group G_2 is composed of 13 elements, representing 27,09% of the total. Of this total, 6 objects belong to W2.1 and 7 to W2, and their mean values are relatively high, close to those of the objects in group F2, suggesting a considerably high feeling of reality.

We also observed that, for laypeople, scientific objects (W3) tended to have means similar to those of objects in W1, which points to a high degree of perception of the reality of these objects. However, three scientific objects – "photon", "probability" and "spin" – belong to group G_1 and have means of 2,59, 2,56 and 2,18, respectively. These means indicate a lower degree of feeling of reality attributed to these objects.

Another finding is that, for laypeople, most of the objects in W2 and W2.1 belong to group G_2, and some have higher means than the means of objects in groups F_1 and F_2, thus indicating a high degree of feeling of reality. Perhaps this occurs because group G_2 is formed by objects that represent external sensations linked to the senses, such as "taste" and "aroma" or individual internal sensations, such as, for example, "friendship" and "longing".

V. DISCUSSION

Descriptive and cluster analysis indicates that for scientists, objects belonging to W3 present a level of feeling of reality that is very close to that of objects in W1, both of which are considered more tangible and concrete. This indicates that even though W3 objects are more abstract and often related to more complex concepts, they are still perceived with a high degree of objectivity and realism by scientists, similar to W1 objects, which are directly related to the physical world. On the other hand, objects classified in W2, which involve more subjective aspects and are not directly related to the five human senses, such as "feeling", "longing", "friendship", "love", "memories", "ambition" and "dream", tend to be associated with lower levels of feeling of reality. This suggests that these objects, although real in the scope of human experiences, are perceived as less real in the scientific context.

Detailed analysis of the clusters generated points to a possible ordering of the groups based on the levels of feeling of reality. Group A_1, composed of objects from W1, W3.1 and some highly objectified W3 objects, such as those from the physical world and those that materialize from W3 concepts, presents the highest levels of feeling of reality. Next, we have group A_2, formed predominantly by W3 objects, which, despite being more abstract, are perceived in a relatively objective manner by scientists. Group B_2, which includes objects from W2.1 and more abstract items from W3, presents a lower level of feeling of reality, but still higher than group B_1, which is composed almost exclusively of objects from W2. The latter, because they involve sensations and mental objects, are classified as having the lowest levels of feeling of reality, reflecting a perception that is more distant from scientific objectivity.

For the students, the analysis showed that group D_1 had the highest means, indicating a high degree of feeling of reality. This group includes objects from W1, such as "tree" and "dog", as well as items from W3.1, which are also considered to have a high feeling of reality by the students, in a similar way to the trend observed in the group of scientists. Group D_2, in turn, includes a mixture of objects from W1, W3, W2, W2.1 and W3.1, with lower means than group D_1, but still higher than groups E_1 and E_2. The objects in D_2, such as "lightning", "star", "air" and "cloud", belong to W1, but are perceived as less concrete due to their reduced tangibility or distance. The grouping of many objects from W3 in group D_2 suggests a good perception of reality of the more abstract items, reflecting a greater complexity in the interaction with the physical world.

Groups E_1 and E_2, with lower means, indicate a lower level of perception of reality, with group E_2 representing the objects with the lowest means, such as "ambition", "probability" and "photon", which are perceived as feelings (W2) or more abstract (W3). Thus, a probable hierarchical order of the groups can be understood as a graduation of feelings of reality, from the more concrete (W1, W3.1) and scientific items closer to the students' contexts (W3) of group D_1 to the more subjective and more abstract scientific items of group E_2 (W2, W3).

Finally, for laypeople, the F_1 group, which includes objects such as "tree", "chair" and "book", belonging to W1 and W3.1, had the highest means, indicating a high degree of feeling of reality attributed by laypeople. In particular, concrete objects such as "dog" and "rain" stand out, being perceived in a more tangible and realistic way. The F_2 group also had a high perception of reality, with high means, especially among the W1 and W3 objects. Objects such as "lightning", "star" and "electric current" are perceived in a concrete and very real way by laypeople, with higher means than other items in the F_1 group, such as "cotton candy". Despite belonging to W3, objects such as "cell" and "mass" also stand out in this group, reinforcing the perception of reality, although in a more abstract way than those in the F_1 group.

Group G_1, on the other hand, includes objects from W2 and W3, which have lower means than the other groups, suggesting a low level of feeling of reality. In relation to the objects of W3, this is mainly due to their abstract and distant nature, as they have an immediate connection with the everyday experiences of laypeople. Group G_2, which includes objects from both W2 and W2.1, has relatively high means, close to those of objects from groups F_1 and F_2. This indicates that objects that involve sensory perceptions and emotional experiences, both external (such as "taste" and "aroma") and internal (such as "friendship" and "longing"), are seen in a very real way by laypeople, possibly because they connect with subjective aspects of human daily life.

Furthermore, it is possible to verify that the means obtained for the objects W1, W2, W3, W2.1, and W3.1 from the levels of reality assigned by students and laypeople are, for the most part, lower than the means obtained with the scientists' data. Since we are particularly interested in students' feeling of reality when faced with scientific objects (W3), it is worth analyzing them specifically. From tables I, III and V we can conclude that only the objects "numbers" and "point mass" had higher means among students and laypeople than among scientists. This suggests that scientists attribute a higher level of feeling of reality to scientific objects compared to students and laypeople. This result is plausible, considering that scientists' daily lives and research largely involve these scientific objects. In addition, we observed that the means assigned by laypeople to most of the scientific objects are very similar to the means of the students.

VI. CONCLUSIONS

The results of our exploratory study showed that students, scientists and laypeople attribute different levels of feeling of reality to the objects of W1, W2, W3, W2.1 and W3.1. Therefore, associating this analysis with the learning process, it can be suggested that, to improve students' learning, it is crucial to develop approaches that strengthen the feeling of reality of the concepts (objects from W3) being taught, by using more tangible and concrete objects (W1 and W3.1) and integrating more abstract or subjective objects (W3, W2, W2.1), so that students can perceive relationships between the physical world, their subjective and everyday experiences.

Pietrocola (1999) says that "the classroom should contain activities which move from an immediate reality (forged by common sense) to a reality idealized by science" (p. 20). This requires becoming aware of a new reality, accessed through the physical knowledge learned. This brings us to a fundamental question: Can there be learning without accepting the reality of the entities that populate scientific theories? We believe that the ontological stability of the world plays a fundamental role in understanding its intelligibility. Scientific explanations, by their nature, are built on the basis of abstract and unobservable entities, such as atoms, viruses, waves, genes, electrons and point masses. In this way, understanding Science goes beyond simply looking for patterns in nature; it involves a change in the way we conceive of the physical world, a way of thinking that transcends immediate sensory experience.

Thus, the notion of Feeling of Reality combined with Popper's Three Worlds seems promising for effective learning, based on the incorporation of didactic strategies in the classroom that promote quality cognitive interactions, social interactions, sensory interactions and affective interactions with objects from Popper's Three Worlds, focusing on increasing the level of feeling of reality about the scientific object under study (Custódio and Teixeira, 2024). Only a student who has internalized the reality of scientific objects can establish meanings that are less perishable, that is, meanings that are not abandoned after the class or the test. Distrust about the reality of scientific objects, or a fleeting feeling of reality, can be detrimental to the endeavor of scientific education.

While agreeing with the approach of Chi and colleagues (Chi, 1992, 2008; Chi et al., 2012; Slotta & Chi, 2006), which aims to promote students' conceptual understanding through the shift of ontological categories, we believe it is necessary to expand students' feeling of reality regarding scientific objects. In other words, it is important not only to promote the shift of ontological categories (such as from matter to event) but also to didactically influence the perception of objects as real, within the correct categories. Thus, we suggest that future research explore the relationship between the being-there (existence) and the being-thus (essence) of scientific objects in the perception of students, in order to achieve a more complete understanding of the process of knowledge acquisition, choice, and retention.

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APPENDIX. Reality Intensity Questionnaire (RIQ)

Indicate the degree of reality you consider to be related to each of the objects listed below. (Mark your answer with an X on each line). In this questionnaire you will use a four-point Likert scale ranging from **Not Real** (1) to **Real** (4) with two intermediate points (2 and 3).

		Not Real			**Real**
1	Star	1	2	3	4
2	Dream	1	2	3	4
3	Numbers	1	2	3	4
4	Aroma	1	2	3	4
5	Cotton candy	1	2	3	4
6	Electric current	1	2	3	4
7	Lightning	1	2	3	4
8	Thought	1	2	3	4
9	Spin	1	2	3	4
10	Toothache	1	2	3	4
11	Chair	1	2	3	4
12	Photon	1	2	3	4
13	Cloud	1	2	3	4
14	Feeling	1	2	3	4
15	Genes	1	2	3	4
16	Noise	1	2	3	4
17	Pen	1	2	3	4
18	Probability	1	2	3	4
19	Rain	1	2	3	4
20	Longing	1	2	3	4
21	Chromosomes	1	2	3	4
22	Taste	1	2	3	4
23	Glasses	1	2	3	4
24	Point Mass	1	2	3	4
25	Air	1	2	3	4
26	Love	1	2	3	4
27	Electron	1	2	3	4
28	Colors	1	2	3	4
29	Musical score	1	2	3	4
30	Mass	1	2	3	4
31	Dog	1	2	3	4
32	Ambition	1	2	3	4
33	Cell	1	2	3	4
34	Cold	1	2	3	4
35	Gravitational force	1	2	3	4
36	Sculpture	1	2	3	4
37	Tree	1	2	3	4
38	Friendship	1	2	3	4
39	Atom	1	2	3	4
40	Tiredness	1	2	3	4
41	Frictional force	1	2	3	4
42	Book	1	2	3	4
43	Magnet	1	2	3	4
44	Memories	1	2	3	4
45	Gravitational Field	1	2	3	4
46	Sleep	1	2	3	4
47	Building design	1	2	3	4
48	Magnetic Field	1	2	3	4

Argue about the criterion/criteria you used to classify the objects listed into their degrees of reality.