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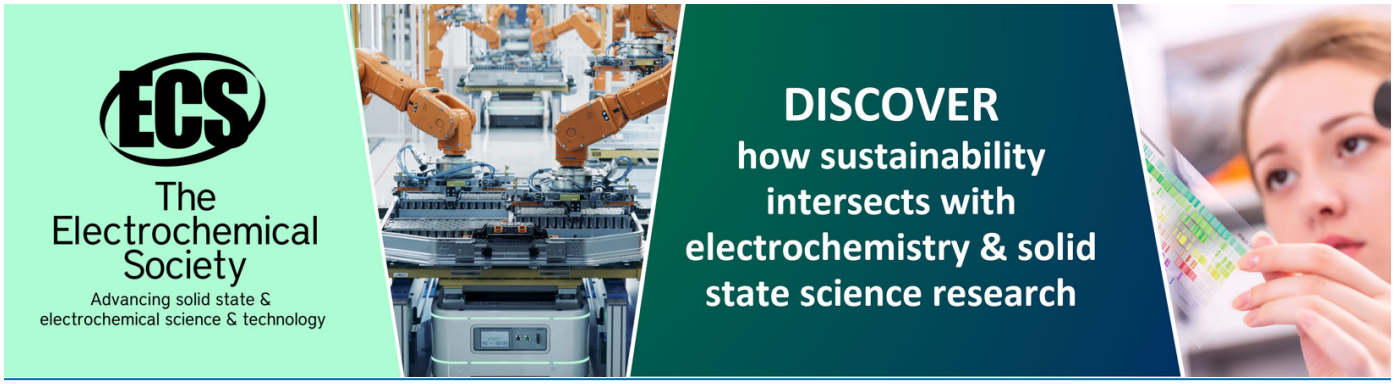

Exploring students' attitudes towards physics and their association with gender

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Abstract. The purpose of this study was to analyse gender differences in the attitudes towards physics in the framework of the Semiotic Cultural Psychological Theory (SCPT). According to this theoretical perspective, attitudes represent how individuals interpret their experience, through the mediation of generalized meaning with which they are identified. A view-of-physics questionnaire was used as instrument to collect data with 1562 (723 females) high school students. Using multiple correspondence analysis and cluster analysis, we identified four generalized meanings of physics: (a) interesting and important for society; (b) a quite interesting, but badly taught subject at school and not completely useful for society; (c) difficult to study and irrelevant for society; and (d) a fascinating and protective niche from society. The association between gender and the identified cluster was assessed by a chi-square test, which indicates a significant overlap between females and cluster (c).

1. Introduction

Over the past twenty years, there has been an increasing concern about women and minorities underrepresentation and career aspiration in physics-related fields [1]. Some authors suggested that girls refuse the identification in the role of physicist, because they perceive an incongruency between the feminine identity and the physics identity [2]. Building on stereotypes research, previous studies hypothesized that the image of physics consists in the superposition of three (negative) stereotypes: masculinity, difficulty, heteronomy (i.e., the perceived lack of intellectual freedom or creativity) [3].

However, these studies fail to recognize that attitudes towards physics can be determined by the specific cultural context in which an individual develops his/her experience with physics. Moreover, they do not provide any clues about the mechanism underlying the adoption of a certain stereotyped view of physics, or for the development of a certain physics identity. In this paper, we suggest opening the black box, namely, to go beyond the manifestations of representations and take into account how the cultural context related to physics works.

To this aim, we will consider such manifestations as a result of a cultural process, influenced by students' experience and system of values, which, in turn, are relevant for understanding how the process occurs. On such basis, we propose to analyze the students' attitudes towards physics in the framework of the Semiotic Cultural Psychological Theory (SCPT) [4], a socio-cultural psychological model

originally aimed at quantitatively describe the dynamics underpinning the manifestations of culture, and in particular how one's own views shape the experience of reality.

2. Theoretical framework

2.1. Attitudes towards physics

The Semiotic Cultural Psychological Theory (SCPT) is a socio-cultural psychological model, which integrates aspects of psychoanalysis, dynamic systems theory and pragmatic semiotics [4]. In the SCPT theoretical perspective, psychological processes consist in sensemaking processes of the world that, in turn, shape experience. A sensemaking process is an interpretation process that links the emotional level of experience with the formal level of cognition. Such process is guided by generalized meanings, namely, intuitive, not rationally justified assumptions concerning what the world is and how it works. These assumptions include opinions, values, beliefs, attitudes concerning facts and objects of the social and physical world and represent generalized functions of individuals' sensemaking of the world. In this perspective, sensemaking is inherently social, embodied, contextual and situated. In other words, people feel, think, and act not by following context-blind universal computational rules, but by enacting sensemaking in terms of, and within the constraints of, generalized meanings which encompass people's experience as a whole. On such empirical base, individuals can be typified in terms of the set of generalized meanings they identify with. In other words, generalized meanings can be used for mapping and explaining variability in the individuals' attitudes embedded in a cultural milieu. Such attitudes represent how individuals interpret their experience through the mediation of the meaning with which they are identified.

In particular, on the one hand, a group of individuals can be described in terms of the set of generalized meanings that correspond to the cultural milieu in which the individuals are rooted; on the other hand, differences in views among groups of individuals can be explained in terms of these generalized meanings. Hence, at phenomenological level, SPCT allows to investigate how individuals differ in their worldviews, namely implicit lenses through which the individual's relation with the world is interpreted, and in the behavioral manifestations depending on the generalized meaning they share and carry out. In other words, the focus on sensemaking process in the SCPT allows us to consider the personal identity and its aspects not as a static entity, but as a semiotic process of construction and negotiation in becoming.

Using the SCPT perspective, we will model the physics culture as a semiotic space, characterized by certain generalized meanings, which we assume to be informed by school and university experiences (e.g., performance in physics), peer interactions, exposure to media communication, family background, utility value and success expectancy, etc. Generalized meanings of physics will be assumed to affect individuals' experience with the physical science, for instance the intention to choose physics at undergraduate level.

3. Research question

The main aim of this study is to characterize the manifestations of representations of high school students' experience with physics in terms of generalized meanings using the SCPT perspective. Then, we will analyse their association with the gender. The specific research question is:
RQ: How are the identified generalized meanings of physics related to gender?

4. Methods

4.1. Sample

A convenience sample of 1562 students (723 females, 46.3%) from 30 different schools in a large town in South Italy was involved in the study. Average age was 16.9 ± 1.2 years.

4.2. Instrument

A 36-item Views of Physics (VOP) survey was used as instrument to collect data. VOP items were selected from previous instruments (see [5]) to capture participants' sensemaking process of their experience with physics. Items were chosen to facilitate the elicitation of perceptions and opinions concerning micro- and macro-experiences with physics, as well as of the views about the trustworthiness of physicists' research. The VOP dimensions were: 1) the perceived value of physics in today's society (4 items, e.g., "We need to understand physics because it has an important effect on our lives"); 2) the recognition of the difficulty of physics (6 items, e.g., "Physics requires many mathematics knowledge and skills"); 3) the intrinsic interest in physics (4 items, e.g., "Physics drives my curiosity"); 4) the personal relevance to work with physics (3 items, e.g., "I am interested in doing research in physics"); 5) the relevance of learning physics at school (4 items, e.g., "Physics learned in school can be applied to daily life"); 6) the recognition of physicists' role in society (9 items, e.g., "Physicists can solve many of the problems of today's society"); 7) the value of physicists' careers (6 items, e.g., "Physicists can do many jobs").

For each item, the students were asked to state whether they agreed with the reported statement using a 5-point Likert scale (not at all; not very; fairly; mostly; strongly). The survey was submitted online. Cronbach's alfa of the VOP was 0.87, which indicates a good reliability of the instrument.

4.3. Data analysis

We first used multiple correspondence analysis, which is an extension to categorial variables of factorial analysis (see [6]) to identify patterns of associations between students' responses.

Then, using the factorial scores obtained from the multiple correspondence analysis, we performed a hierarchical cluster analysis (CA) aimed at identifying emerging response profiles associated with different groups of individuals based on the multiple correspondence analysis of responses to the VOP instrument. This type of analysis is common in the SCPT framework [7]. The CA procedure used as clustering criteria the similarity of the scores associated with individuals belonging to the same cluster and maximum dissimilarity of the scores associated with individuals belonging to different cluster: therefore, all the factorial dimensions extracted were used. Furthermore, the CA procedure is hierarchical-divisive and provide exclusive, complete, and heterogeneous clusters. Two criteria were used for choosing the number of clusters of the final solution: 1) a qualitative criterion, according to which the best partition is that for which the subsequent subdivision in the dendrogram sequence produces a limited increase of the between clusters/total inertia ratio; 2) a quantitative criterion, according to which the best partition is that for which the subsequent subdivision in the dendrogram sequence produces at least one cluster with less than 5% of cases of the sample.

To infer a plausible interpretation of each cluster, we first looked at those items and the corresponding modalities (e.g., not at all; strongly…) with the highest association with the cluster. The association between the modality of an item and the cluster is calculated through a *t-test.* We then checked if the identified items belonged to the same VOP dimension (see section 4.2): in this case, we used the corresponding modality to provide a tentative interpretation of the cluster. By iterating the same procedure for all the items with the highest associations with the cluster, we linked the descriptions through suitable logical connectives, providing the final interpretation of the cluster. When items of the same VOP dimension characterized the same cluster but with a different modality, we refined the description of the cluster building on the differences between the views reflected in the items.

By means of the described procedure, each identified cluster corresponds to a specific pattern of individual's responses that tends to appear redundantly across the sample. Thus, in accordance with the SPCT framework, we considered each cluster as a marker of a given generalized representation of physics.

Finally, to answer our research question, we performed a *chi-square* test of association to inspect possible associations between the identified clusters and gender.

5. Results

The summary of the response profiles characterizing the four emerging clusters is reported in Table 1. We also report the first 10 items and the corresponding modalities with the highest association with each identified cluster. In Table 2, we provide a brief description of the cluster and our interpretation. In Table 3, we report the association between the emerging generalized meanings and gender. The association is statistically significant, $\chi^2 = 26.214$, $df = 3$, $p < .001$, mainly due to the significant association between girls and the *Difficult and irrelevant for society* cluster (Bonferroni corrected alpha level = 0.01).

Table 1. Main modalities of the four clusters identified.

Cluster 1 (N=452, 28.9%)	**Modality**	**t-value[a]**	**Cl./Mod. [b] (%)**	**Mod./Cl. [c] (%)**
PHYSICS – I am enthusiastic when studying it	Mostly	6.70	40.94	77.22
PHYSICISTS – Are held in high esteem in today's society	Mostly	6.58	43.62	74.71
PHYSICS – Drives my curiosity	Strongly	6.18	60.40	64.29
PHYSICS – I think that it is interesting	Strongly	5.93	58.39	63.97
PHYSICISTS – In today's society there is great impulse in hiring them in different companies	Mostly	5.82	40.94	71.76
PHYSICS – What I learn at school affects and is relevant for daily life	Mostly	5.70	32.89	76.56
PHYSICS – I prefer it over other subjects	Mostly	5.60	34.90	74.29
PHYSICISTS – Are in very high demand in today's society	Mostly	5.34	33.56	73.53
PHYSICS – Relevance lies in its usefulness in solving practical problems	Mostly	5.19	53.69	62.50
PHYSICISTS – Are regarded very highly in today's society	Mostly	5.14	34.90	71.23
Cluster 2 (N=559, 35.8%)				
PHYSICS – I think that it is interesting	Fairly	8.73	46.22	82.09
PHYSICS – Drives my curiosity	Fairly	7.12	40.34	75.00
PHYSICISTS – Are held in high esteem in today's society	Fairly	6.23	55.46	58.93
PHYSICISTS – Are in very high demand in today's society	Not very	6.05	41.18	66.22
PHYSICS – I am enthusiastic when studying it	Fairly	5.84	47.90	60.64
PHYSICS – Is relevant for our country's progress	Fairly	5.65	40.34	64.00
PHYSICISTS – In today's society can earn a lot from economical viewpoint	Not very	5.61	32.77	69.64
PHYSICISTS – Are very trustworthy	Fairly	5.33	37.82	63.38
PHYSICISTS – Are important for the development of today's society	Fairly	5.31	31.93	67.86
PHYSICS – We need to understand it because it has important effects on our lives	Fairly	5.08	47.06	56.57

Cluster 3 (N=207, 13.3%)				
PHYSICS – I am enthusiastic when studying it	Not at all	9.92	77.14	69.23
PHYSICS – What is learned in school can be applied to daily life	Not at all	8.56	54.29	82.61
PHYSICS – I think that it is interesting	Not at all	8.43	51.43	85.71
PHYSICS – I am interested in choosing a career based on it	Not at all	8.32	85.71	38.96
PHYSICS – I prefer it over other subjects	Not at all	8.04	74.29	46.43
PHYSICS – What I learn at school affects and is relevant for daily life	Not at all	7.61	60.00	56.76
PHYSICS – Using the knowledge learned at school, I can explain natural phenomena to people	Not at all	7.24	45.71	72.73
PHYSICS – I am interested in working in a field that requires a deep knowledge	Not at all	7.19	68.57	42.11
PHYSICS – Drives my curiosity	Not very	6.80	45.71	64.00
PHYSICS – Drives my curiosity	Not at all	6.00	34.29	70.59
Cluster 4 (N=344, 22.0%)				
PHYSICS – What is learned in school can be applied to daily life	Strongly	9.66	91.18	47.69
PHYSICS – What I learn at school affects and is relevant for daily life	Strongly	8.01	73.53	47.17
PHYSICS – The questions in school tasks are important because they concern real world problems	Strongly	7.91	70.59	48.98
PHYSICS – I am enthusiastic when studying it	Strongly	7.59	79.41	37.50
PHYSICS – I am interested in working in a field that requires a deep knowledge	Strongly	7.42	76.47	38.24
PHYSICISTS – Can do many jobs	Strongly	7.37	94.12	26.45
PHYSICS – Using the knowledge learned at school, I can explain natural phenomena to people	Strongly	7.37	79.41	35.53
PHYSICS – I think that it is interesting	Strongly	7.28	97.06	24.26
PHYSICISTS – Can solve many of the problems of today's society	Strongly	7.16	85.29	30.21
PHYSICS – Contents are too abstract	Not at all	7.12	88.24	28.30

[a] The t-values indicate the association between the modality and the cluster. Higher t-values indicate higher associations;
[b] Cl./Mod. indicates the percentage of students associated to the modalities who belong to the clusters;
[c] Mod./Cl. indicates the frequencies of the modality within each cluster are also reported.

Table 2. Interpretation of the four identified clusters and corresponding generalized meanings.

Cluster ID	Generalized Meaning	Interpretation
Cluster 1	Interesting and important for society	This cluster is characterized by a high level of idealization and value: physics is interesting because it intrigues, but also because it is important for the development of society, both from a cultural point of view and for technological applications; it therefore influences the daily life of each of us and it is therefore necessary to know it. Society can trust the progress of physics and the contribution of physicists.
Cluster 2	Quite interesting, but not useful for society	In this cluster, the main modality is "fairly" for items in both affirmative and reversed formulation. Physics seems to qualify as a discipline among many others, with not too tangible effects on society although it retains residues of personal interest and charm. Such attitude brings to a discouraging view of physicists, regarded as underrated by society.
Cluster 3	Difficult and irrelevant for society	Students in this cluster think that physics is difficult to learn, it arises little interest and it is of little importance for society. Even in consideration of future developments and employment opportunities, physics seems to be less attractive than other subjects. Physicists are perceived of little use to society, they are not requested by the job market and hence are poorly paid. Furthermore, their research often lead to erroneous conclusions. In this cluster, a profoundly negative and widely generalized assessment of physics is observed, including all aspects of interest and motivation, both social and individual.
Cluster 4	Niche that protects from society	This cluster is characterized by a very pragmatic and utilitarian view. Physics is considered in many ways a useful resource, also in daily life. The work of physicists is considered as useful and, even though already appreciated by society, it still deserves higher consideration. Hence, it is believed that physics offers great opportunities of stimulating employments, with high wages. Physics is neither complicated nor abstract; on the contrary, its importance precisely lies in its own applications and in the problems that it can solve. The interest in applications is what most differentiates the fourth cluster from the first, that is instead characterized by inclination for theory and fundamental aspects.

Table 3. Association between generalized meanings of physics and gender.

	Generalized Meaning			
Gender	Interesting and important for society	Quite interesting, but not useful for society	Difficult and irrelevant for society	Niche that protects from society
Girls (%)	42.0	45.8	62.3	43.0
Boys (%)	58.0	54.2	37.7	57.0
Adjusted standardized residual	-0.3	-2.2*	5.0***	-1.4

** $p < .05$; *** $p < .001$*

6. Discussion

While our results about generalized meanings of physics confirm prior findings about attitudes towards physics [8-9], they also extend prior knowledge in the field, since the identified generalized meanings can be seen as the elementary constituents of the sensemaking process underlying students' experiences with physics.

To validate our results, it is worth comparing the profiles of the students in each emerging generalized meaning with the "interest toward science" profiles identified in the international ROSE project [10]. We will limit our comparison to the three more general profiles emerged in that study. In particular, students in the "*physics interesting and important for society*" cluster (28.9% of the sample) have traits similar to the "unselective enthusiast" profile, in particular the school-commitment, the positive view of the role of science and scientists in society, the view that science is not difficult. However, there are also some differences: in particular, the view that science is not more interesting than other school subjects. The students who belong to the "*physics difficult and irrelevant for society*" generalized meaning (13.3% of the sample) have many similarities with the "unselective reluctant" profile in that they share: a very low interest in science, a dislike of science as school subject, a low recognition of the role of science and scientists for society. The students in the generalized meaning "*physics quite interesting, but not useful for society*" (35.8% of the sample) have many traits in common with the Schreiner's "unselective undecided" profile, which is characterized by passivity, in-between positions and unclear views. Finally, the "*physics niche that protects from society*" cluster (22.0% of the sample) may identify a specific characteristic of physics in creating closed systems, as it does not match the Schreiner's profiles. Such comparison supports the validity of our findings and the potential application of our framework also in other sciences and in international contexts.

We also found that the above generalized meanings are significantly associated with gender. This evidence confirms prior results about attitudes towards science of high school and college students [11-12]. In particular, for the "*physics difficult and irrelevant for society*" cluster, the percentage of boys is statistically lower than that of the girls. This result confirms prior studies according to which physics is perceived as difficult especially by girls [13-14]. Overall, we can infer that the latent dimensions of sense of the experience with physics are correlated with the adoption of a masculine stereotyped view of physics, where physics is seen as a discipline grounded on content knowledge, rational discourse, and substantial mathematical rigor.

7. Conclusions

Our results suggest that the attitudes towards physics can be categorized into four general clusters, which we called generalized meaning according to the SCPT framework. The students in our sample view physics alternatively as: 1) interesting and important for society; 2) interesting, but not useful for society; 3) difficult and irrelevant for society; 4) a niche that protects from society. The four cluster well align with the literature. We also found that the generalized meanings of physics are significantly associated with gender. Namely, the gender issue in physics can be related to the semiotic construction of the subject-physics relationship. Although, in general, generalized meanings may vary according to the socio-cultural context, the results of our study suggest that students' attitudes towards physics may be at the basis of the gender-biased enrollment in physics-related careers. This is a significant result, which would be interesting to test in other international contexts through similar studies.

In conclusion, we note that the limited sample stratification prevents us to infer any structural relationship between the emerged generalized meanings and other contextual variables, as prior knowledge in physics, prior involvement in physics activities, so further studies that will explore these relationships are needed. As further step of our research, we will take into account science performance and metacognitive variables to deepen the mechanisms underlying the development of the students' attitudes towards physics.

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