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Epistemological Functions of Emotions and Their Relevance to the Formation of Citizens and Scientists

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***Abstract*—**Pedagogy of science historically has given priority to teaching strategies that mobilize the cognitive mechanisms leaving out emotional mechanisms. Modern epistemology, cognitive psychology and psychoanalysis begin to argue and prove that emotions are relevant epistemological functions. They are 1) the selection function: that allows the perception and reason choose, to multiple alternative explanation of a particular fact, those are relevant and discard those that are not, 2) heuristic function: that is related to the activation cognitive processes that are effective in the process of knowing; and 3) the so-called content-bearing function: it argues that emotions provide the material reasoning that is subsequently transformed into linguistic propositions. According to these hypotheses, scientific knowledge seems to come from emotions that meet these functions. This paper argues that science education must start from the presence of certain emotions in the learner if we want to form citizens with a scientific or cultural future.

***Keyword*—**Epistemic emotions, science education, formation of citizens and scientists, epistemic functions of emotions.

I. Introduction

SCIENCE education still requires a deep understanding of the psychological and epistemological mechanisms involved in its learning and application. In 1973, Viennot [1], a physicist and specialist in science education, reported disappointing results on the effectiveness of science teaching in French elementary and higher education in her doctoral thesis. She found empirically that the learning of scientific content is poor [1]. These results were confirmed after for Third International Mathematics and Science Study (TIMSS), the Programme for International Student Assessment (PISA) and the Organization for Economic Cooperation and Development (OECD).

According to these organizations, students of basic education not learn significantly the science content they receive in school [2], [3]. The results obtained in the mathematics and natural science exams indicate that students at these levels do not know how to solve problems in which they should make use of scientific concepts. Generally, in this situation, the people tend to go to intuitive solutions, common sense and show a poor understanding of the concepts. According to [4] the performance of students in many countries is lower than expected. Given this, the question arises: Why invest so much in science education if students then forget the concepts, do not use scientific procedures and methods, or do not distinguish when they should be used? As says [5] "despite all the years that children and youth spend in school, through high school, middle to upper and university studies, there is a scientific illiteracy in people" (p.36). A considerable percentage of basic education students do not act based on scientific knowledge. When faced with problems that would imply the implementation of such knowledge, they prefer to resort to pseudoscience or intuitive knowledge. So, [5] notes that these results are obtained not only in developing countries but also in developed countries like the US, Canada and Britain. The author refers to a research study conducted in the USA in which the ability of students at different levels to "say something intelligible" on the concepts of "molecule", "atom", "byte" and the results were disappointing. At the doctoral level only 18% of students gave satisfactory answers. In university level students, only 12% got it right or their answer was similar the scientific concept and in pre-university level, only 3% got it right. Therefore, scientists, psychologists, philosophers, and educators need to rethink science education. Better arguments should be provided to the question of what the value of teaching science to is so many people.

Science education has been mainly preparatory, i.e., it has focused on training future scientists. It has been a propaedeutic preparation aimed at training scientists rather than citizens with scientific culture. However, the preparatory to basic science education should not be the only one. About four decades ago (in the early 1980s), the "Science, Technology and Society" or STS movement emerged [6]. This movement, through the United Nations Educational, Scientific and Cultural Organization (UNESCO), proposed reforming the national school curricula of the world's regions to a less propaedeutic pedagogy. It advocates science education centered on values and attitudes stemming from this human activity. It focuses a little more on the possibility of interpreting the world from its complexity and applying some knowledge in the understanding of modern problems such as health and its care, environmental problems and technology management, and also to act responsibly in political issues. They prefer to focus on skepticism of form, rigor, love for "truth".

This paper proposes something important: in the prevailing models of science teaching there is a pedagogical lack in the mobilization of psychological mechanisms underlying the thinking and production of scientific knowledge and the complex nature of its contents. The absence of these psychological mechanisms in the learning of scientific content prevents its appropriation, in particular, in what this activity

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demands of the mind, for example, the execution of logical and critical thinking.

Fortunately, a philosophical movement from naturalized epistemology to the pedagogy of science is beginning, starting from elementary questions such as: What makes a person learn scientific content or produce scientific knowledge? What happens in the mind of the learner and what happens in the mind of the producer? This look at the psychological specializes in finding out what happens cognitively, socially and emotionally in the mind when it is involved in scientific activity.

The contributions on the role of cognitive and social mechanisms are very interesting in the construction of scientific knowledge, but this paper will focus on the role of a basic psychobiological mechanism: emotions. The contributions from the philosophy of emotions and psychology [7]-[13] are proving to be very interesting and shed light on an effective pedagogy of science, from basic education.

In order to defend the relevant role of emotions, the following definition is used as a starting point: Emotions are psychobiological reactions of an individual to an event. Some fundamental qualities attributed to them are: 1) they have a qualitative sensation different from a visceral pain, 2) they have cognitive antecedents, 3) they have an intentional object, 4) they involve a physiological arousal, 5) they bring physiological expressions, 6) they have a valence in the pleasure-pain dimension and 7) they involve a tendency to action. Some interesting hypotheses from the philosophy and epistemology of emotions that educational psychologists should take into account will be presented [14].

According to [7]-[13], emotions have important epistemological functions. According to [13], the first is the selective function, the second function is the heuristic one and the third function states that emotions carry content that they provide to the mind and then the mind transforms them into linguistic propositions. From this hypothesis, emotions, like our sense organs, allow us to access essential contents of phenomena. It is interesting that the content of our representations also come from our perceptual mechanisms and reason [7] can also come from the emotions.

Another point to note is that there are emotions that support cognitive processes and others that do not. Emotions that seem to have a positive impact on cognitive processes are called epistemic emotions [10], [11], [13]. Some candidates come to mind: curiosity, intellectual courage, love for truth, thoroughness, humility, enjoyment to know, interest, hope, pleasure for verifying and even boredom. Hookway [9] mentions others, they are doubt and anxiety. Each one seems to have an input in the production of knowledge and the behavior and design method. For example, doubt leads to the first possible explanation of a strange fact, fear is an instinctive risk assessor, anxiety appears to have a role in designing the method as well as in certain frozen search processes and boredom or weariness can draw their own lines of research abandoning others that are not of our interest [11]-[13].

II. On the Selective Function of Emotions

According to [15] in the act of knowing, one of the cognitive mechanisms at work is the one that leads to the search for causal relationships between events. The alternatives, evidences and/ or reasons that can be considered as causes of a phenomenon can be diverse and very numerous, so that for our understanding it is very costly, computationally speaking, to take them all into account. We need a mechanism that reduces the number of possible alternatives. Damasio [16] have shown that patients with frontal lobe damage (where the emotional neural circuitry is located) when faced with a task in which they must decide (and therefore evaluate alternatives), their deliberations and inferences are endless because they take into account all possible alternatives. Moreover, patients fail to make the decision. Damasio then proved that mental activity is capable of functioning on its own, but inefficiently. This allowed him to infer that if rational activities, such as decision making or problem solving, were affected when the limbic system was damaged (the brain site where emotions concur), then they had a role in the effectiveness of rational deliberation. When the emotional biological display malfunctions, mental activity ceases to function effectively on its own. Emotions "contribute something" and it seems that they provide the individual with information to decide what to take into account and what not to take into account, within an exhaustive range of possibilities. Damasio and colleagues [16] inferred that emotions act significantly on inferential activity. They give the possibility of reducing the range of alternatives and to distinguish what is important from what is not, therefore, the emotions have an important role in the cognitions. They [16] say that is good or bad. This feature is supported by [13], also by cognitive psychologists as [17], [18]. Emotions bring with them patterns of relevance and prominence of things, induce the knower to choose the best strategies of investigation and research, guide and focus attention and enhance the retrieval of information in memory [17].

Returning to epistemic emotions, people interested, curious, anxious or with a genuine doubt about a topic would have access to the most meaningful explanatory reasons and discard those that are not. These emotions would allow a more relevant selection of explanatory reasons. One could also think the opposite, if we are not interested, curious, anxious or uncertain about some object of knowledge, our deliberative capacity would be quite inefficient and tedious. These are interesting proposals [18] by cognitive psychologists about the relationship between emotion and cognition. For them, the emotions influence our judgments because they allow mental activity in memory access attributes of objects that are consistent with its valence (pleasure or displeasure). According to the hypotheses of [18] the representations stored in memory have for the cognizing subject either positive or negative characteristics. The positive emotional states of the subject would select the positive attributes of the object and if he is under negative emotional states, he chooses the negative attributes [18], and vice versa, when we are under negative affective states or unpleasurable we become accessible to the negative characteristics of the object. This is consistent with Aristotle's suggestion that when we are angry, we classify things in one way and when we are affable, we classify them in another way.

Continuing along this line of thought, emotions provide content for interpreting "reality".

III. The Heuristic Function of Emotions

Heuristics are considered a system of mental rules and strategies that work in problem solving but seem to skip some algorithms or make them explicit avoiding an excessive computation of cognitive resources [19]. When it is said that emotion plays this role one might think that it is because it contains the set of these rules. In decision making, emotions, by functioning heuristically, spare the mind the explicitness of these algorithms, providing the possibility of arriving at a "quick" decision.

Emotions provide relevant information to the mental activity and make it "skip" a set of unnecessary deliberative phases. It allows concentration on the central aspects of the problem. It offers the possibility for cognitive resources to be mobilized on relevant issues and not on trivial matters. In summary, the heuristic function of emotions seems to be 1) to make available to reason, immediately, the most plausible possibly causal elements in the explanation of a phenomenon, discarding, for some reason, those that seem not to constitute an explanatory cause and 2) in doing so it gives cognitive processes the possibility to act on the most relevant information. They seem to eliminate from the algorithms information that is not substantial in understanding or solving a problem.

IV. On the Hypothesis that Emotions Provide Content to the Mind

The third hypothesis is particularly interesting. It argues that emotions are carriers of contents (representations and forms) [13] that reason will later convert into linguistic statements. This means that like our perceptual mechanisms, emotions manage to capture properties of the world that are difficult to perceive by our sense organs, they function as another source of information from the outside that we transfer to our cognitive processes for their rational deliberation. Emotions are then able to detect properties of the cognizable reality (whose nature is difficult to specify) and provide it to the intellect. The latter will be in charge of translating it into linguistic propositions or into a language understandable to the members of a community. The linguistic construction must arise from a translatable material. This hypothesis from [9] refers to the first representations that we make to the understanding of a strange fact, they seem to come from sensations for which we not have clear arguments. Under these circumstances, our emotions seem to provide relevant material for reason. It is important to specify that this can be successful or not, the history of science seems to show that in most cases, that first impression is not accurate but it allows to infer little scientists whose sensation was or is successful. That means that after converting the contents of that sensations a theoretical body language was understandable that also had a correspondence with reality. What is then obtained as a result of an emotional sensation present in the search for a scientific explanation of a given subject, seems to be an important content that must be transformed into a linguistic statement. Subsequently, empirical verification can be sought, but we already have material possibly related to the essential properties of the phenomenon to be explained. This makes us think then that some of our emotions, especially the epistemic ones, bring relevant information about the world, about the essential qualities of the object we want to know, and when they are present in the epistemic agency, we can have access to this information. So, appealing to them is not inappropriate, it is important to trust the information they provide, not to underestimate it, perhaps it is not so far from the properties that give rise to the phenomenon of interest. Now the intriguing question that arises is not only the nature of those properties carried by the emotions but how did this information get to them?

According to these assumptions, emotions are involved in complex cognitive operations typical of scientific activity; for example, in the rational evaluation of evidence [9], in the construction of scientific categories [10], in the freezing of processes of searching for possible causes of the phenomena under study [12] among other things. Thus, it does not seem very plausible to think that emotions are only carriers of basic contents to reasoning, but of more complex information [17], [18].

V. Conclusions

Considering the epistemic functions of emotions described above, it can be inferred that school science education, the formation of scientists and citizens with scientific culture, does not take them into account. Perhaps it does, but only intuitively, not systematically. Fortunately, science pedagogy has incorporated in the classroom argumentative communication, field practices, problem-based learning, project-based learning and the application of the Socratic method. This is an attempt to make room for epistemic emotions, but in an underhanded way. These are strategies that lead students to practice and experience the ways in which science is done. They make room for epistemic emotions to be unleashed such as genuine doubt, interest, curiosity, the pleasure of living in a world of "possible certainties".

It is important to mention that from these hypotheses negative valence emotions acquire not only value but also negative valence emotions such as fear, uncertainty, boredom, anxiety, among others. They are also mechanisms that participate in the practice of knowledge construction, for example, they mobilize resources for the methodological design, the construction of categories, the attachment to a scientific attitude and the overcoming of possible obstacles on the way to a valid, true or plausible knowledge.

It is encouraging that the philosophy and epistemology of emotions as well as psychology are making explicit the functions of what was considered, for a long time, a stumbling block to rationality. Emotions seemed to stand in the way of scientific knowledge. Of course, there are emotions that are harmful, but others are essential for the execution of this activity. These proposals seek to activate epistemic emotions, those that constitute what Bachelard called the scientific spirit. When a subject is curious, interested and desirous of learning

or knowing, it is much more likely that the cognitive processes that allow access to the most relevant evidence, discard those that are not, and also provide the content to linguistically translate the first mental representations of the phenomenon, will be activated. On the contrary, if students are neither curious, nor interested in the subject, nor have the desire to know, it will be difficult to activate the cognitive processes or have access to the essential forms of the phenomenon.

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