International Journal of Engineering Science Invention (IJESI)
ISSN (Online): 2319-6734, ISSN (Print): 2319-6726
www.ijesi.org ||Volume 11 Issue 8 August 2022 || PP 17-24

Epistemological Beliefs about Natural Sciences on Students for the Bachelor's Degree of Medical Bioengineering

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ABSTRACT: *Epistemological beliefs are to be associated to activities realized by the subjects on a daily basis. In order to achieve the goal of identifying epistemological beliefs that the students for the bachelor's degree on Medical Bioengineering about natural sciences have, an observational, cross-sectional and descriptive study has been carried out, in which the "Questionnare about natural sciences" elaborated by Pecharromán and Pozo, was applied to 62 students that took the "Natural Sciences Epistemology" course at the time of the application. The variables of the study were knowledge nature and knowledge acquisition. 75.81% expressed their agreement with the constructivism principles, 56.5% selected constructivism as epistemological preference, 56.45% of the students, use criteria of truth based on the objectivism, 95.16% reject immediate knowledge and 67.74% restricted knowledge, meanwhile 90.32% expresses some agreement with shared knowledge. It is concluded that the profile of natural sciences' beliefs that the students of Medical Bioengineering posses is characterized by the constructivism as the epistemological preference and the objectivism as the fundamentals for justifying their epistemological beliefs*

KEYWORDS -*constructivism, epistemological beliefs, medical bioengineering, natural sciences, objectivism****.***

Date of Submission: 04-08-2022 Date of Acceptance: 17-08-2022

I. INTRODUCTION

Understanding education in the fields of engineering, as a process that makes learning easier, as the development of skills through the acquisition of knowledge, abilities, values, beliefs and habits [1], the professional formation in the fields of Medical Bioengineering is developed in three fundamental axes [2]: the axis of engineering, the axis of sciences and the axis of philosophy.

Trough philosophy's axis, the student develops epistemological skills linked to their sociocultural environment and the professional field of future development, integrating from their horizon of understanding the knowledge of engineering along with the knowledge of natural sciences, medical sciences and the ethical fundamentals of the profession; which contributes to strengthen and develop different beliefs in the student, that will guide their actions in the many varieties of scenarios they will go through their lives.

Nowadays the importance of natural sciences is acknowledged as an essential base for the development of knowledge in a cutting-edge such as the Medical Bioengineering. The analysis of the science-education relationship is realized around four approaches: 1) the evaluation of the students' conceptions of the nature of natural sciences, 2) development, use and evaluation of the curriculum designed to improve these conceptions, 3) evaluation of the attempts to improve the teachers' conceptions, 4) identification of the relationship between teachers' conceptions, their classroom practices, and the students' conceptions [3]. This implies that the students generate different conceptions through the learning of the principles of natural sciences, as such the beliefs, modified as they advance through their studies, area influenced by the differences in the curriculum as well as the teaching and learning strategies used in educational scenarios that characterized each course conforming scientific knowledge [3]. This evolution of the scientifical beliefs conception has been reported in the initial formation from educational students and it's characterized as an uneven process, due to a major difficulty to modify the most ingrained conceptions from the most basic levels of education [4].

In the actual learning field, sustained teaching in the exposure of scientific conceptions during the teachers' classes and the passiveness from the students persists [5,6], which demonstrates the lack of use different learning models due to the incomprehension of these models from the teachers [6,7]. In this matter, it's important to develop the scientifical contents through activities along time, addressing the fundamental influence factor in the teachers' practice defined by Martin et al [8], that is, strengthening the adaptative function that helps the individuals to understand and define the context as to achieve social interest problem

solving centered teaching, promoting as well, the interest from students towards natural sciences and improving their comprehension [9]; thus contributes to promote quality in scientific education at different educational levels, considering students beliefs towards science [10], based on two principles: the relationship described between the students' beliefs of natural sciences and their epistemological comprehension of them, this being the way they construct and justify the students' knowledge [11]. Following this thought, a question emerges: which is the epistemological belief that the Medical Bioengineering students have?

Silva and Herrera denote that "epistemological beliefs are personal conceptions from the nature, acquisition and justification of knowledge" [12];thus, the nature of the natural sciences refers to the inherent values and assumptions derived from the development of scientific knowledge, such that an individual's beliefs about whether scientific knowledge is immoral, empirically based, the product of human creativity, or frugal, provides an overview of the conception that this individual has regarding the nature of the natural sciences [13].In this sense, epistemological beliefs are recognized as socio-cultural constructions that subjects build through school learning, knowledge of scientific content and the type of reasoning that the student develops, in a way that influences processing and understanding. of knowledge in addition to the evaluation and use of the information received in their daily lives [14]. Thus, the epistemological beliefs related to the natural sciences that the student builds through the learning acquired at school and the informal learning that he acquires outside the classroom, represent the fusion of horizons of understanding related with scientifical knowledge, scientifical language, cultural practices, the role in their community and the power relationships in which they engage.

In this context, the study was realized with the purpose to identify the epistemological beliefs that the students for the bachelor's degree on Medical Bioengineering have about natural sciences.

II. METHOD AND MATERIAL

An observational, cross-sectional and descriptive study was carried out, in which the "Questionnaire on natural sciences" prepared by Pecharromán and Pozo [15] was applied to 62 students who took the subject of Epistemology of Natural Sciences that is taught in the Bachelor of Medical Bioengineering of the Faculty of Medicine of the Autonomous University of the State of Mexico.

The study variables were nature of knowledge and acquisition of knowledge. The "nature of knowledge" variable included the following domains: certainty of knowledge, epistemological preferences, epistemological justification, and truth criteria. In relation to the "certainty of knowledge", three epistemological positions are considered: objectivism, relativism and constructivism. For the variable "acquisition of knowledge", three types of knowledge were produced: immediate, restricted and shared.

The "Questionnare on Natural Sciences" is conformed by 22 items with a Likert-like scale of 6 points (see Annex I). The first 6 items estimate the agreement in relation to objectivists, relativist and constructivist beliefs. The remaining 16 items were distributed to assess the agreement-disagreement relationship of each statement related to scientific knowledge acquisition. From these, 6 items explored the immediate knowledge, 5 items explored the beliefs of restricted knowledge and another 5 items had the purpose to explore beliefs of shared knowledge.

The questionnaire also included a multiple selection item allowing us to identify, recognize and discriminate the epistemological preference of the student, followed by an item, followed by a short text-type item, aimed at exploring the epistemological justification for their choice of the previous item. Finally, to explore the "truth criteria" the student is shown a fictitious situation and is asked to select an option about who is right and is asked to express how to fit who may be right.

The application of the questionnaire was carried out through the internet, using the google forms tool through the following link: https://forms.gle/Y2TpBx3LWs8HJZJN9

For the analysis of the results obtained, the questionnaire was graded by calculating the mean score of each of the 22 items that make it up; and subsequently response frequencies and percentages were obtained. Items related to short text responses were categorized for each of the responses issued by the students using the categorization proposed by Pecharromán and Pozo [15], and which is presented in Annex II. From this categorization, the frequency was also obtained and the percentage was calculated.

III. RESULTS

Certainty of scientific knowledge on natural sciences

The belief about the certainty of scientific knowledge in natural sciences that students possess was explored in three epistemological currents: objectivism, relativism and constructivism, assessing the level of agreement according to the principles exposed in the questionnaire items.

Table 1 shows the frequency of the average of the Lickert scale used to assess the level of agreement of the students for each of the epistemologies explored. In relation to objectivism, it can be seen that 70.97% of the students refer to some level of agreement; while 53.22% express some level of disagreement with the principles of relativism, while 75.81% indicate some level of agreement with the principles of constructivism.

Table 1. Frequency of the level of agreement expressed by the students about the epistemologies explored in the study

Level of agreement	Objectivism		Relativism		Constructivism	
	No.	%	No.	%	No.	%
Complete disagreement	3	4.84	8	12.90	1	1.61
Strong disagreement	4	6.45	8	12.90	7	11.29
Light disagreement	11	17.74	17	27.42	7	11.29
Light agreement	23	37.10	22	35.48	23	37.10
Stron agreement	18	29.03	6	9.69	17	27.42
Complete agreement	3	4.84	1	1.61	7	11.29

Source: Own elaboration

Epistemological preference

25.8% (16 students) expressed their preference for the objectivist position, 17.7% (11 students) reported their preference for the relativist position, and 56.5% (35 students) indicated their preference for the constructivist position.Table 2 shows the proportion of students distributed according to the principle related to the selected epistemological position.

Table 2. Frequency of the epistemological principle selected by the students about the epistemologies explored in the study

Epistemological Posture	Epistemological Principle	Frequency	Percentage
Objetivismo	Knowing facts	3	4.83
	Always valid	13	20.98
Relativism	Everything is the same worth	4	6.45
	Culture based	7	11.29
Constructivism	Not everything is the same worth	5	8.06
	Critic progress	30	48.39

Source: Own elaboration

Epistemological justification

In order to analyze the justification enunciated by the students for the choice of an epistemological principle related to objectivism, relativism or constructivism, the categorization of each of the justifications was carried out considering whether the justification clearly expressed the selected epistemological principle, or else, if it had nuances with any of the other epistemological positions.Table 3 shows the frequency identified in each case analyzed. In relation to objectivism, it can be seen that the clearly objectivist justification predominates; on the other hand, the justifications enunciated by the students who have a preference for relativism, it was possible to identify that 54.54% of the justifications are predominantly relativistic, but with constructivist nuances; whereas only 40% of the students who selected constructivism expressed a clearly constructivist justification.

Table 3. Frequency of the justification elaborated by the students about the selected epistemologies.

Epistemology	Justification	Frequency	Percentage
Objectivism	Clearly objectivist	7	43.75
	Predominantly objectivist with relativist nuances	3	18.75
	Predominantly objectivist with constructivist nuances	6	37.5
	Total	16	100
Relativism	Clearly relativist	2	18.19
	Predominantly relativist with objectivist nuances	3	27.27
	Predominantly relativist with constructivist nuances	6	54.54
	Total	11	100
Constructivism	Clearly constructivist	14	40.00
	Predominantly constructivist with objectivist nuances	11	31.43
	Predominantly constructivist with relativist nuances	10	28.57
	Total	35	100

Source: Own elaboration

Truth criteria

The truth criteria used by the students included in the study was assessed through a fictitious situation in which it is assumed that two students "are arguing about a question of natural sciences or physics", then they are asked if they think that both will be right in their opinions. 29% consider that both students are right, while another 29% consider that neither of the two students in discussion are right. The remaining 42% of the students considered another option.

When analyzing the foundation they provided when questioning how they could know who is more right or who is in the truth, using the criteria to categorize the type of criterion (see Annex II), it was identified that 56.45% of the students use truth criteria based on objectivism; 38.66% truth criteria based on relativism and only 3.23% on constructivism (see Table 4). Only one student indicated "not knowing" how to determine who might be right.

Table 4. Frequency of the truth criterion stated by the students.

Epistemology	Truth criteria	Frequency	Percentage
Objectivism	Clearly Objectivist	28	45.16
	Predominantly objectivist with relativist nuances	1	1.61
	Predominantly objectivist with constructivist nuances	6	9.68
Relativism	Clearly relativist	1	1.61
	Predominantly relativist with objectivist nuances	19	30.65
	Predominantly relativist with constructivist nuances	4	6.45
Constructivism	Predominantly constructivist with objectivist nuances	2	3.23
Does not know		1	1.61
Total		62	100

Source: Own elaboration

Knowledge acquirement

Beliefs about the acquisition of scientific knowledge in natural sciences possessed by the students were explored through agreement regarding a set of statements that allowed assessing immediate knowledge and the distribution of knowledge known as restricted knowledge and shared knowledge. Immediate knowledge is valued for its simplicity and immediacy, so its teaching is direct and simple to be understood easily and immediately. Restricted knowledge refers to the abilities and skills of intelligent people and scientists. Shared knowledge is valued through the reflection of scientific communication.

Table 5 shows the frequency of the average of the Lickert scale used to assess the level of agreement of the students for each of the types of knowledge explored. In relation to immediate knowledge, 95.16% of students express some level of disagreement. On the other hand, 67.74% of the students reject the possibility of restricted knowledge, while 90.32% express some level of agreement with shared knowledge.

Table 5. Frequency of the level of agreement expressed by the students about the acquisition of knowledge of the natural sciences.

Level of agreement	Immediate Knowledge		Restricted Knowlede		Shared Knowledge	
	No.	%	No.	%	No.	%
Complete disagreement	3	4.84	0	0	0	0
Strong disagreement	32	51.61	8	12.90	0	0
Light disagreement	24	38.71	34	54.84	6	9.68
Light agreement	3	4.84	18	29.03	29	46.77
Strong agreement	0	0	2	3.23	25	40.32
Complete agreement	0	0	0	0	2	3.23

Source: Own elaboration

IV. DISCUSSION

Even though the study of beliefs in the field of sciences is a topic of interest in the international literature [16], there are no research reports that explore beliefs in the field of natural sciences in students of Medical Bioengineering or in the field of Biomedical Engineering; hence the importance of the study presented, although for the time being, it has been limited to an observational and descriptive design. Nevertheless, the obtained results offer the possibility of opening horizons of comprehension that will later translate in future lines of research, as discussed below.

The students that participated in the study show a major acceptance to the epistemological principles of constructivism followed by objectivism and more than half of the students reject relativist postures. The

acceptance of constructivist principles is a characteristic of university students as denoted by Pecharromán y Pozo [15] with Spanish students of Biology, Mathematics and Psychology. In a more recent study with psychology students, Pecharromán et al reported equivalent results [17]. However, it is important to point out that Medical Bioengineering students are willing to accept the principles of objectivism, which may be associated to the type of education received.

The same tendency expressed in the acceptance about the certainty of knowledge, the students selected constructivism as epistemological preference more frequently, which implies that the students assume thinking strategies to establish the correspondence between theory and practice, the knowledge of natural sciences and reality, as well as problem-solving tasks. Taking this into note, the possibility of contextualizing the knowledge imparted in the school classroom has been reported, which makes it easier for the student to develop, from the change of their beliefs, alternative ways of knowing [18] in addition to building paradigmatic frameworks that allow them to base their action frameworks.This is consistent with the coherence between the selected epistemological preference and the epistemological foundation expressed by the students. In this case, it is observed that the clearly constructivist justification predominates among those who selected constructivism as their epistemological preference, while those who selected objectivism also expressed clearly objectivist justifications, and those who expressed their preference for the principles of relativism, most of their justifications, while predominantly relativistic, had constructivist overtones.

Although these results are consistent with what is reported in the international literature [15,17], they expose belief systems that are associated with the ways of thinking and arguing that students use to explain reasons in problem analysis and decision making [19], in addition to expressing the relationship with the learning of science, particularly in areas of training such as Medical Bioengineering in which disciplines from the area of Engineering, Natural Sciences, Medical Sciences and Philosophy converge. In this sense, it is important to explore the association between epistemological beliefs and other cognitive learning processes associated with conceptual change.

In relation to truth criteria, the students expressed justifications primarily objectivist to argue who is right in a discussion related to natural science content, followed by justifications oriented towards relativism and very few students oriented their justifications towards constructivism. These results are compatibles with what has been reported in first-semester psychology students [17], however, Medical Bioengineering students were taking the subject of Epistemology of Natural Sciences that is taught in the 6th semester of the educational program. Through the truth criteria that students tend to use, the mechanisms that they use in their cognitive procedures to assimilate new information are expressed, linking it with previous knowledge and their levels of experience to resolve and take a position against knowledge that leads to epistemological ruptures, so they may adapt their belief systems through clearly defined patterns that integrate their personal epistemology[20].

On the other hand, the fact that students reject immediate knowledge and restricted knowledge, reflects the importance they give to the training process in the field of Medical Bioengineering as they have recognized the complexity of the object of study, noting the need to share the knowledge through strategies that allow them to integrate the knowledge of Engineering, Medical Sciences, Natural Sciences as well as fundamental elements of philosophy (ethics, bioethics and epistemology). In this scope is explained that they will express a better acceptance to shared knowledge.

V. CONCLUSION

The results obtained in the study through the "questionnaire on the natural sciences" provide elements that allow configuring and substantiating the profile of epistemological beliefs that the students of the Medical Bioengineering degree have. Thus, this epistemological profile of the students about the beliefs in Natural Sciences is stated in the following terms: the epistemological position related to the certainty of knowledge and the epistemological preference is constructivism, although the epistemological justification is most frequently observed in the "clearly objectivist argumentation". To identify who is right in an academic-scientific discussion, students resort to objectivist criteria, and to acquire knowledge they accept the processes implicit in "shared knowledge", rejecting "immediate knowledge" and "restricted knowledge".

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ANNEX I

Beliefs About the Natural Sciences [15]

We all have ideas as to how things work and have hear theories about the universe, the atoms, the cells etc. Also, we have been taught in college many natural laws in science and the answers to these questions.

Next, you are offered some phrases that refer to the value you give to the knowledge you have about these topics. Read them slowly to understand as accurately as possible, since you will be asked to choose the one with which you most agree and indicate your degree of DISAGREE-AGREE with each of the statements, taking into account the following scale:

Complete disagreement	Strong disagreement	Light disagreement	Light agreement	Strong agreement	Complete agreement
1	2	3	4	5	6

There are no better or worse answers, point our what you think.

		1	2	3	4	5	6
1.	Most of the time, once the facts and scientific details are known they can clearly state what happens in reality.						
2.	We all have opinions about the phenomena of nature. All opinions about these phenomena (mine, yours, scientists) are equally true and valid.						
3.	There is no scientific statement that is completely true since each scientist starts from their experience, but not all scientific statements are equally valid and acceptable.						
4.	A proven scientific Discovery or law is true and always will be						
5.	Current scientists give some explanations; in other times and cultures they gave others. All these theories are equally valid and true.						
6.	Scientists, with effort, can make it to an increasingly approximate knowledge of what happens in nature, but they can never, never be totally sure of their theories.						

From the past statements, the one I agree the most is the: 1st, 2nd, 3rd, 4th, 5th, 6th.
Explain why you have chosen this option.

		1	2	3	4	5	6
7.	There are people that were born with special abilities for Sciences.						
8.	I like scientifics or Science teachers that clearly explain how things work and do not get bogged down in other possible explanations.						
9.	If you can not find a clear answer to a scientific riddle, you'd better stop mulling over it.						
10.	I believe that my colleagues have enough knowledge to give an opinion on scientific matters						
11.	It is a waste of time to get bogged down in scientific questions that do not have a quick and easy solution.						
12.	I think I am just as competent, no more and no less, than anyone else, whether they are professors or whatever they are, when it comes to judging scientific questions.						
13.	I believe that talks or classes that deal with scientific issues are important for my training						
14.	If you don't pick up a problem or a science question at first, it's of little use to go around the question						
15.	Intelligent people are those who best understand scientific questions						
16.	When two scientists argue about a topic, each one is partially right and they should seek an agreement.						
17.	To a large extent we are born or discover within ourselves the scientific laws, it is not necessary that they teach us						
18.	Scientists see the facts as they are that is why they can tell us the truth						
19.	There are scientific explanations that are clearly true but in many points each scientist thinks what he thinks						
20.	Even if I was sure of some scientific explanations (atoms, gravity etc.), I would listen with interest if someone thinks otherwise in case I was wrong						
21.	Although we do not know many things, scientists do or they will end up discovering it.						
22.	If two scientists discuss and give different explanations about a fact of nature, at least one of them will be wrong.						

Two classmates are arguing about a Natural Sciences or Physics question.

Do you thing that both will be equally right or truth in their opinions?
1. Yes 2. No 3. Other (Explain)

How can you determine who is right or has the truth?

ANNEX II
Criteria for Categorizing Justifications for the Principles [15]

Objectivism

- Clearly objectivist: The truth is directly attested by the facts or is demonstrated through processes such as experiments, tests, etc... that can be laborious.
- Predominantly objectivist, but with relativist nuances: It clearly states that there are established truths but there are issues in which all opinions are equal and are subjective (an "objective pluralism"). Affirms that in the discussion the two opinions can be valid since they refer to different aspects of reality; in this way the subjects accommodate themselves to the reality of different opinions, but still maintaining the belief in an absolute truth, derived from experience. The protagonists have different experiences, not because of any subjective factor, but because the outside world is fluctuating and multifaceted."
- Predominantly objectivist, but with constructivist nuances: They affirm that the truth cannot be considered one hundred percent in everything and one cannot be totally sure because there are changes in the object and progress is being made in science, but it does not imply a change in theories; the insecurity of knowledge is due to the fact that the object has "difficult" and dark parts. In the socio-historical domain, those who admit that historical knowledge is insecure and there is no one hundred

percent truth "because no one has lived" are situated here; they clearly admit that, if the facts were seen or observed, the objective truth would be known.

Relativism

- Clearly relativistic: All opinions are equally valid and true because each subject has their opinion or each group has equally valid positions.
- Predominantly relativistic, but with objectivist nuances: It emphasizes that all opinions are equally valid, that it is not possible to know who is more right or true, but it also alludes, secondly, to some truth criteria
- Predominantly relativistic, but with constructivist nuances: You can accept the consideration of truth within an educational and cultural context, but clearly point out that all cultures and opinions are equal. Explicitation of a cultural relativism.

Constructivism

- Clearly constructivist: They indicate that there may be different paradigms, theories or interpretations, that more or less justified knowledge can be given, although reality itself is never known. The subject builds the object and is itself built. In the social domain, those who speak of different readings and interpretations are situated here. You can arrive at a relative truth.
- Predominantly constructivist, but with objectivist nuances: It affirms that the truths are progressing, but also points out that there are changes in theories. They acknowledge that opinions are loaded with subjectivity, but that not all opinions are equally justifiable, while seeming to point out that there might be some "truths" as such.
- Predominantly constructivist, but with relativist nuances: On one hand, they choose positions that are not absolutely relativist but rather constructivist (items 5 and 6) but at the same time fundamentally point out the subjective factors of knowledge.

Yoselin del Carmen Martínez-Chávez, et. al. "Epistemological Beliefs about Natural Sciences on Students for the Bachelor's Degree of Medical Bioengineering." *International Journal of Engineering Science Invention (IJESI)*, Vol. 11(08), 2022, PP 17-24. Journal DOI- 10.35629/6734