THE NATURE OF PHYSICS: OPPOSING VIEWPOINTS
AND IMPLICATIONS FOR CLASSROOM PRACTICE

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Physics teachers have their own beliefs and ideas about the nature of their discipline, which may or may not be compatible with the way the nature of science is presented in the literature, and may or may not inform their teaching. In this paper, qualitative evidence is presented to support the idea that the different ways teachers see the nature of their discipline influence their classroom practices, especially the inclusion of context and cultural relevance.

Introduction

Because of their professional preparation and experiences with science, physics teachers have their own ideas about the nature of physics. They may perceive physics as universal and objective or multicultural and subjective, or consider scientific knowledge as solid or in constant flux. Physics teachers may see scientific truth as unreachable or accessible given enough time and sophisticated instruments. They may see theories as permanent and powerful explanations or temporary rationalizations. Physics teachers may see science and religions as complementary or antagonistic, or see experiments as controlled and infallible or biased and impossible to demarcate. They may see science and technology as independent constructs (theory versus practice) or in close association (technology driven by science/science driven by technology). Physics teachers may or may not differentiate between science and pseudo-science. Needless to say, there is not necessarily a “right” way of thinking about the nature of our discipline.

Although not everybody agrees on the details of what should be included in a definition of the nature of science, Lederman (1999) indicated the following aspects of the nature of science as important in science education: (a) scientific knowledge as tentative, subjective, and empirically-based, (b) science involves inference, imagination, creativity, observation, and (c) scientific knowledge is socially and culturally embedded. Educational researchers are still debating whether there might be a relationship, complex and hard to grasp as it might be,
between the teachers’ science conceptions and their view of the nature of their discipline, and their classroom practices.

For example, Gess-Newsome and Lederman (1995) suggested that teacher intentions, content knowledge, pedagogical knowledge, students’ needs, teacher autonomy, and time might be important factors in the translation of the science teachers’ philosophical ideas into appropriate instructional strategies and activities. Similarly, Smith and Neale (1989) proposed that content knowledge and classroom management were important in how the teachers’ ideas about science informed their educational decisions. In contrast, other researchers suggest that teachers’ ideas about their discipline do not necessarily influence their classroom practice (see for example, (Abd-El-Khalick, Bell, and Lederman, 1998; Brickhouse, 1990; Duschl and Wright, 1989).

Objectivism and Relativism in Science Education

Snively and Corsiglia (1998) produced an excellent summary of the tension between those who have different beliefs and ideas about the nature of science and science teaching. On one side, researchers such as Atwater and Riley (1993) and Stanley and Brickhouse (1994) support the idea that “multicultural science is seen as important both because it can provide valuable scientific knowledge and because it can function as a pedagogical stepping stone, especially for multicultural students of science” and that “modern Western science is just one of many sciences that need to be addressed in the science classroom” (Snively and Corsiglia, 1998, p. 5). On the other side, researchers such as Good (1995) and Matthews (1994) support the idea that modern Western science is the “last and greatest of the sciences” and see multiculturalism in science as “faddish or heretical”. They also believed that modern Western science is taken to be
universal and should be taught at the expense of indigenous science (Snively and Corsiglia, 1998).

Their diverging opinions originate in their contrasting definitions of science. The universalistic group defines science as a single set of rules to guide the practice of theory justification, while the relativist group defines science as a rational perceiving of reality. The basic difference between these definitions is that the first group see science as a “collection of thoughts”, while the other see science as a “method of thinking” (Snively and Corsiglia, 1998, p. 10). Interestingly, important documents in science education reform, like the National Science Education Standards (National Research Council, 1996), endorse the universalistic position of the natural sciences:

“Science distinguishes itself from other ways of knowing and from other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism, as scientists strive for the best possible explanations about the natural world (p. 201).”

Also, Project 2061’s Science for All Americans (1989) present universal science as the correct worldview.

The purpose of this article is to provide qualitative evidence that might support the position that the beliefs and ideas teachers have about physics and the scientific enterprise do influence their decision of modifying their physics content presentation and teaching methodologies, as suggested by Gess-Newsome and Lederman (1995), Smith and Neale (1989), and others. This evidence was collected from interviewing 20 high school physics teachers from the east, south and west of Puerto Rico, a Commonwealth with close political and historical ties with the United States.
Viewpoint One:

“Physics concepts should not be adjusted to a particular culture; it is the culture that must adjust to the physics concepts.”

Some of the teachers interviewed believed that physics, as a universal science, should be objective and not reflect local particularities or biases that might mislead students about the discipline, that is, might limit the students’ perspective and focus. Teachers with this type of mentality perceived physics’ laws, theories and principles as “universal and globalized science” and do not have cultural specificity. One of the participants argued that, for example, “kinematics and acoustics are the same in Puerto Rico, the United States or Japan” and that an “objective amoral foundation that transcend frontiers” is needed to understand physics, as opposed to limiting ideological and sociocultural aspects.

Take for example, statements by Maria and Pablo (pseudonyms), who said that the laws of physics are the same for everybody and that can be taught in any culture. They also mentioned that students must be exposed to a variety of physics examples and applications, not just those relevant to the local culture:

Maria: “Physics can be combined with any type of culture. You can adapt physics to the culture of any country by finding examples from that culture because the laws of physics are the same for everybody. You must know how to apply them.”

Pablo: “I try to find general examples from physics topics, examples that can happen in any place, not just in Puerto Rico. I think that if there a student from here, from my classroom, that will study physics, I try to make it more universal, not so specific or limiting myself to my culture. For example, they cannot see a rocket launch in Puerto Rico, I need to talk about other places. I try to show them more universal examples, something that can happen anywhere in the world.”
Teachers who have this perception of the nature of physics also believe that teaching using context or culture might water down the physics content those students need to master when they go into college and that they will face failure when taking university physics courses. They also suggested that limiting students to local examples might limit the students’ focal length and vision of future in the evolution and development of the human knowledge. One of the participants mentioned that he considered physics as a natural, not a social science, which means that the subjectivity of the social sciences should not interfere with the objectivity of modern science.

Although the interviewed teachers were not observed to assess whether their teaching styles and classroom practices were consistent with their philosophy of physics, their answers to these and other research questions suggest that their teaching style emphasize a close following of the textbook, the coverage of material, the presentation of generic examples and applications, and the separation of context/culture and the learning of physics.

**Viewpoint Two:**

“Changes are not made to the concepts, but to the situations that make us understand those concepts.”

Other physics teachers have an opposite view of the nature of physics and the inclusion of culture and context. They expressed being aware of the benefits of using a contextual and culturally relevant perspective in the physics classroom in terms of student motivation and academic achievement. They mentioned that the applied nature of physics would be more obvious to students with this approach, that the creation of mental connections between the physics concepts and their local environment might enhance their physics understanding, that students might be motivated and have ownership of their knowledge, that physics knowledge
would be really learned and not just memorized, and that Puerto Rico has enough history, culture and social settings for contextual and culturally relevant teaching to be a successful reality.

Take Cesar for example, who stressed the importance of everyday examples to create relevance and contextualization, and Eduardo, who believed that the use of everyday examples and relevance are essential to establish a tie between the physics topics and the students’ lives:

Cesar: “[To contextualize my teaching] I establish their everyday lives, making relevancy out of what they already know, like a running car, a chair that moves or falls, things like that establish relevance and depart from students’ previous experiences to take them to something more concrete [concepts].”

Eduardo: “One of the secrets for success in teaching a physics class is to make students see the pertinence and applicability of the class to their daily lives. As a consequence, it is important to bring to the class everyday examples, situations, and problems and observe their relationship with the topic studied at that time.”

In terms of the relationship between culture and the learning of physics, Ismael and Leonardo mentioned examples of Puerto Rican culture that could be introduced in the physics class. Ismael talked about “Paso fino”, a horse sport historically famous in the island. Leonardo used a historical event to talk about potential and kinetic energy:

Ismael: “Yes, I think so. I am very Puerto Rican. For example, our national sport is “Paso fino”. Then, it is comfortable [more familiar to students] when you provide elements and experiences related to horses [in the physics class]. Almost all students are interested in horses. Even slow students are more motivated.”

Leonardo: “When I am talking about energy, I tell my students that they usually associate energy with objects that are moving fast, and that error can cost their lives. [In
class] I talk about this event that happened in Central Mercedita [a sugarcane growing and processing facility], a locomotive was pulling ten or twelve sugarcane wagons with a steel cable. They were moving at about 2 mph because the locomotive was barely able to move the wagons. People near the locomotive were making fun of the locomotive, but then the cable snapped and cut in half three persons, just like a knife. So, was there danger or not? I am combining history, real events, and physics.”

As with the teachers who defend the first viewpoint, these teachers were not observed either. However, their statements answering these and other research questions suggest that their teaching style make them less dependent on the textbook, more focused on everyday physics applications, and the inclusion of the local culture and context as an important component in the learning of physics.

Implications for Classroom Practice in Arkansas

Although interview data was collected from Puerto Rican teachers, it is very likely that physics teachers in the United States also have their own beliefs and ideas about what physics is and how should be taught. Teachers with a universalistic perspective might focus on covering material and generic examples. They might present physics as a solid and static body of knowledge gathered mostly by Western white males and might avoid locally relevant examples and the inclusion of diverse cultures.

On the other hand, teachers with a relativistic perspective might focus on relating the physics content with the experiences and life events of their students. They might present physics as an evolving field, with contributions from a variety of groups, including women and non-Westerners.
Also, since the relationship between beliefs and ideas about the nature of science and teaching practices is not proven yet, there might be teachers whose teaching strategies and educational philosophy are not congruent. An example of this might be physics teachers who teach about cosmology and the Big Bang, or physical science teachers who teach about fossils and geological time, but have a creationist philosophy.

I think it is necessary for physics teachers to reflect and evaluate on their vision of the nature of science and if it is compatible to their classroom actions. Teachers should also be aware of the different “cultures” present in their classroom (In multicultural education, culture is not limited to ethnicity or race, but also include gender, class, geographical setting, etc.) and whether their ideas and beliefs are in conflict with the realities of the school and the community. Finally, I think is important for physics teachers to critically examine the current reform movements and how they might be affecting negatively those different cultures in their classroom.

References


**THE NATURE OF PHYSICS: OPPOSING VIEWPOINTS AND IMPLICATIONS FOR CLASSROOM PRACTICE**

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General Characteristics of the “official” Nature of Science
(From Science for all Americans)

- The World Is Understandable.
- Scientific Ideas Are Subject To Change.
- Scientific Knowledge Is Durable.
- Science Cannot Provide Complete Answers to All Questions.
- Science Demands Evidence.
- Science Is a Blend of Logic and Imagination.
- Science Explains and Predicts.
- Scientists Try to Identify and Avoid Bias.
- Science Is Not Authoritarian.
- Science Is a Complex Social Activity.
- Science Is Organized Into Content Disciplines.
- There Are Generally Accepted Ethical Principles in the Conduct of Science.

First Issue: Is Science Universal or Regional?

A “Universalistic” Definition of Science: “The systematic observation of natural events and conditions in order to discover facts about them and to formulate laws and principles based on these facts. Science is also the organized body of knowledge that is derived from such observations and that can be verified or tested by further investigation.”

A Multicultural Definition of Science: “Knowledge established as systems of explanations and as ways of doing, which have been accumulated through generations in distinct natural and cultural environments” (D’Ambrosio, 2000). “Methods, thought processes, mind sets values, concepts, and experiences by which
non-Western groups understand, reflect, and obtain empirical knowledge about the natural world” Cajete, 1986).

What are the similarities and differences between these definitions of science?

Second Issue: To what extent physics teachers’ ideas and beliefs about what science is (and is not) influence their teaching?

**Viewpoint 1:** Some research suggests that there is a relationship between the teachers’ perception of what science is (and is not) and their classroom practice (Gess-Newsome and Lederman, 1995; Smith and Neale, 1989).

Example: Physics teachers who believe that science ideas are tentative and subject to change and teach science in that context (talks about phlogiston theory, aether, geocentric model of the solar system, Dalton’s model of the atom. etc.)

Example: Physics teachers who believe that science cannot provide answers to all questions, and teach science in that context (talks about classical versus quantum physics, theories about the earth’s magnetic fields, or the origin of the Moon).

Example: Physics teachers who believe that scientists try to identify and avoid bias, and teach science in that context (Talks about ethical aspects of research, and unethical practices that should be avoided).
Viewpoint 2: Some research suggests that there is not a relationship between the teachers’ perception of what science is (and is not) and their classroom practice (Abd-El-Khalick, Bell, and Lederman, 1998; Brickhouse, 1990; Duschl and Wright, 1989). This means that the classroom practices and the teachers’ science philosophy do not match.

Example: Physics teachers who believe that science ideas are tentative and subject to change but teach science by emphasizing immovable laws and theories that work all the time (Newton’s laws, Kepler’s laws, Hooke’s law, law of conservation of momentum, law of conservation of energy).

Example: Physics teachers who believe that science cannot provide answers to all questions, but teach science emphasizing the infallibility of the knowledge accumulated for many years, or teach science as the only way to find the right explanations, or argue that it just a matter of time and the refinement of apparatus and equipment to obtain all the answers we look for.

Example: Physics teachers who believe that scientists try to identify and avoid bias, but present science as unbiased and free of error, while in reality bias may arise when a scientist has some goal other than (or in addition to) finding an accurate model of nature, such as increasing profits, furthering a political cause, or protecting funding.

Opposite Viewpoints: The Case of Puerto Rico
Some of the teachers interviewed believed that:

- Physics should be objective and not reflect local particularities that might limit the students’ perspective and focus.
- Physics’ laws, theories and principles are “universal and globalized science” that do not have cultural specificity.
- An “objective amoral foundation that transcend frontiers” is needed to understand physics.
- Teaching using context or culture might water down the physics content those students need to master when they go into college.
- Physics is a natural, not a social science, which means that the subjectivity of the social sciences should not interfere with the objectivity of physics.

In contrast, other teachers believed that:
There are benefits in using a contextual and culturally relevant perspective in the physics classroom in terms of student motivation and academic achievement.

- The applied nature of physics would be more obvious to students with this approach.
- The creation of mental connections between the physics concepts and their local environment might enhance their physics understanding.
- Physics knowledge would be really learned and not just memorized if context and culture are included.
- Puerto Rico has enough history, culture and social settings for contextual and culturally relevant teaching to be a successful reality.

Implications for Classroom Practice: Physics teachers should:

- Identify to what extent their beliefs are consistent with a universalistic or multicultural science worldview (Example TOUS).
- Be consistent between their beliefs about the nature of their discipline and their classroom practices, regardless of their specific worldview (In my opinion, having a universalistic or multicultural vision of science might not be critical, but being inconsistent can produce confusion and misconceptions in science students).
- Physics teachers should be aware of the different “cultures” in their classroom (ethnicity, race, gender, class, geographical setting) and their diverse learning styles and adjust their teaching accordingly.