WILSON J. GONZALEZ-ESPADA
High School Physics Teaching in Puerto Rico: A Quantitative and Qualitative Analysis of Context and Cultural Relevance
(Under the direction of J. STEVE OLIVER)

The purpose of this study was (a) to examine whether Puerto Rican physics teachers used context and culture in their classroom despite the textbook's origin (i.e. United States) and, if so, (b) to determine what factors influence the teachers' decision to make their classes contextual and culturally relevant. This study was informed by a critical theory theoretical model and by a cultural relevance theoretical framework. The methodology of this study was mostly quantitative, although a qualitative component was included to complement the statistical analysis and provide valuable context.

The univariate tests found that: (a) difference in physics content presentation was statistically related to the teachers' experience teaching physics, class size, and whether they believe they have the freedom to change their teaching methods, (b) difference in teaching methodologies was statistically related to gender and academic preparation in physics, and (c) the participants' confidence in their physics knowledge was related to their academic preparation in physics.

The analysis of the short-answer questions revealed that: (a) most teachers are convinced that teaching physics with a contextual and culturally relevant emphasis can be done and might lead to better achievement by students; however some form of professional support is needed for those teachers that lack knowledge about the subject matter and of Puerto Rican history and culture, (b) most teachers are very critical of the textbook they are using because of translation, difficulty and relevance issues, and (c) the teachers' view of the nature of science and their perception of the students inform their decision of supporting or rejecting contextual and culturally relevant perspectives.

The analysis of interviews provided additional evidence of how teachers made their content teaching culturally relevant and contextual and of their overall dislike for the text. Also, it was found that: (a) teachers' perception of student apathy for the book (b) although there is a range of perspectives regarding both education and ideology among the teachers, there is a generally favorable recognition of the importance of including local culture and context in the physics curriculum by teachers from all political ideologies.

INDEX WORDS: Cultural relevance, Contextual teaching and learning, Puerto Rico, High school physics, Science education.

HIGH SCHOOL PHYSICS TEACHING IN PUERTO RICO:

CONTEXTUAL AND CULTURAL ISSUES

by

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DEDICACION

Aunque admito que soy el resultado del esfuerzo, la cooperacion y la solidaridad de todas las personas que han tocado mi vida, me obliga el amor de padre a dedicar el producto final de mis muchos años de sacrificio y estudio principalmente a mis hijos Javier, Angel y Jesus (que en paz descanse). Ellos, junto a Rosita, mi querida esposa, han sido la razon principal que me ha llevado a culminar mis estudios doctorales.

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"No caeré; mas si caigo, entre el estruendo
rodaré bendiciendo
la causa en que fundí mi vida entera;
vuelta siempre la faz a mi pasado
y como buen soldado,
envuelto en un girón de mi bandera".

Luis Muñoz Rivera (1902) Parentesis (fragmento)

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CHAPTER 1

INTRODUCTION

Overview

Educators generally agree that education is not an objective system, but a rather complex interaction that takes place in a specific socio-cultural context (Pai & Adler, 1997). In other words, culture and education are interrelated, and act reciprocally upon each other (Halls, 1990). Throughout recent history, countries have developed their own educational system taking into consideration the general goals of the state and the culturally accepted knowledge of different discipline areas. As a consequence, educational systems of any two countries will have some common characteristics and some distinguishing characteristics. Those distinguishing characteristics are rooted in the "social, cultural, political and economical contexts in which people learn and educational institutions function" (Pai & Adler, 1997, p. 3).

There are some cases, however, when countries decide to look for ideas in the educational systems of other countries, often based on the questionable premise that through education, modern scientific knowledge can be brought into other countries with "little concern with culture" (Cobern, 1998). This may be considered as a valid way to both modify and update a particular educational system with the positive aspects of other systems, and avoid approaches that were not useful before. As long as the process is one of modification, adaptation, and refinement, it should turn out a better educational system. But when the process is one of copying and transplantation, in the sense of transferring or relocating from one place to another, then a conflict may arise between those distinguishing characteristics of the importer and exporter countries. As Cobern (1998) states: "Transferring a … curriculum is one thing. Employing it with the desired effect is quite another" (Cobern, 1998, page 15). Thoughtless implementation of curricula that is not culturally congruent is a result of unsound educational policies, and leads to ineffective school practices and unfair assessment of learners (Pai & Adler, 1997).

Science education researchers suggest that most developing countries are using "superficial adaptations of essentially Western curricula" as their educational systems (Cobern, 1998, p. 16). They also report that, if we want science education to be meaningful and effective, it must aggressively consider the cultural context in which the educational system is embedded, and the society which it will serve (Cobern, 1998; Wilson, 1981). The problem of science curriculum transplantation without examining the distinguishing aspects of both countries was also well stated by Court (1972):

> New curricula in science typically are developed, tested, and directed towards the school system of their country of origin. However, not all countries have the personnel, or the financial means, to indulge in such development. These countries, therefore, have to depend on other countries, which are economically and academically in a more favorable position to develop new curricula, to help them if they wish to advance the status of their own school science programs. However, the school systems of different countries reflect different social systems and cultures and hence have idiocyncracies (sic), which may be unique, or at least not shared by the country whose curricula they may be importing. Such

> importation, therefore, can be fraught with the dangers of irrelevancy and impracticality if due attention is not paid to the differences, and similarities of the two social systems and cultures involved. (p. 1)

One of the artifacts of curriculum transplantation are textbooks. The importance of textbooks and teaching materials has long been recognized, as in the following quote from a UNESCO document (UNESCO, 1949):

> Although teachers directly influence the attitudes of students, and although those who make programmes of study determine, to a large extent, the content used in the classroom, it is from textbooks that most children obtain a connected view of human history and culture and the world in which they live. (p. 9)

Although science textbooks from around the world look very similar, it is also true that each country must provide their unique socio-cultural framework to situate the science concepts presented in the text (Cobern, 1998). Of course, this assumes that the books are free of errors or biases in the concepts covered. For American textbooks, this is not the case.

It is well known (at least since the late 40's to early 50's) that American textbooks were far from perfect, in terms of portrayal and treatment of cultural groups and inter-group relations, and content. UNESCO (1949) cited a study by the American Council on Education, Committee on the Study of Teaching Materials in Inter-group Relations. This group examined 267 elementary and secondary school textbooks in the social studies, science, and literature, as well as some introductory college textbooks and children's books, and reached the following conclusions (UNESCO, 1949, p. 52):

- While intentional bias is usually absent, errors of omission are sometimes serious,
- Sociological information about minority groups is often neglected,
- There is over-emphasis on conformity to set social standards and insufficient attention to the constructive aspects of cultural diversity,
- Minority groups are generally inadequately treated.

More recently, the American Association for the Advancement of Science (AAAS) Project 2061, using a research-based framework about how students learn science, evaluated nine popular middle school science textbooks, focusing on which of those had the greatest potential for helping students learn key ideas in earth science, life science, and physical science. AAAS concluded that not one of the nine middle school science textbooks evaluated rated satisfactory in this goal (Roseman, Kesidou, Stern, & Caldwell, 1999):

> Textbooks covered too many topics and didn't develop any of them well … the texts included many classroom activities that either were irrelevant to learning key science ideas, or didn’t help students relate what they were doing to the underlying ideas. (p. 243)

The conclusions of these studies help support the argument that inadequate textbooks might have a negative educational and sociological impact on all students, but particularly on minority groups who use them. Although the first study is not recent, there is reason for me to believe that this statement still holds true at the beginning of the 21st century.

The purpose of this study was to explore two main topics in relationship to physics education in Puerto Rico. First, I examined whether high school physics teachers use contextual and culturally relevant strategies in their classroom. In addition, I determined what factors influence the willingness of those physics teachers to modify their teaching methodology and physics curriculum so that the physics portrayed in the translated textbooks used in school become meaningful to Puerto Rican students. By meaningful, I mean contextual and culturally relevant to the Puerto Rican culture.

Historically, the structure and nature of science curricula in developing countries has followed closely that of their colonial forbearers, becoming not much more than a highly decontextualized and theoretical curricula (Gray, 1999). This has happened to Puerto Rico throughout its colonial history, being a colony of Spain from 1493 to 1898 and a colony of the United States from 1898 to 1952. Some scholars even argue that Puerto Rico is still a quasi-colony of the United States under its Commonwealth status (Trias-Monge, 1997; Carr, 1984; Johnson, 1980). As a consequence, the colonial educational system of both Spain and the United States have shaped and influenced the Puerto Rican educational system for more than 400 years.

Even though Commonwealth status allows Puerto Rico to have an autonomous form of government, which makes decisions about the educational system, there is still evidence of the influence of the United States on Puerto Rican education (Solis, 1994; Negron de Montilla, 1990; Eliza-Colon, 1989). In recent years, some countries have moved to develop contextually realistic programs (Gray, 1999). Unfortunately, this has not been the case in Puerto Rico.

The selection and use of textbooks is one of several aspects of Puerto Rican education that reflects American influence. In the particular case of science, the Puerto Rican Department of Education is actually using Spanish translations of textbooks from the United States, published by U.S. commercial companies. These textbooks are not revised, adapted, and updated in any way, other than the translation. It is highly possible that commercial publishing companies believe that since "members of each group [Hispanics in this case], share common cultural, linguistic, and racial characteristics and needs" (Pai & Adler, 1997, p. 182) they are equivalent or identical. It seems to be more economically beneficial for a publishing company to have a generic science textbook in Spanish that can be sold in as many Latin American countries as possible, instead of having many textbooks based on the particular and distinguishing characteristics of the cultures of different Latin American countries.

Unfortunately, this practice might not be educationally beneficial because the school, community, and home experiences of a Puerto Rican student might be quite different from those of a Mexican student, for example. Those experiences, in turn, will be different from the school, community, and home experiences of a student from the United States, who was the original target of the English version of the textbook. Given the fact that culture and education are interrelated (Halls, 1990), it is important to examine what Puerto Rican high school physics teachers are doing to modify a foreign textbook into concepts that attend the cultural experiences of their students.

Theoretical Model

For this research study the term theoretical model was defined in several complementary ways. Gage (1985) defined a theoretical model as an integrated cluster of substantive concepts, variables, and problems attacked with corresponding methodological approaches and tools. In contrast, Guba and Lincoln (1994) define a theoretical model in the following way:

> A paradigm [theoretical model] may be viewed as a set of basic beliefs … that deals with ultimates or first principles. It represents a *worldview* (emphasis as in the original) that defines, for its holder, the nature of the "world" the individual's place in it, and the range of possible relationships to that world and its parts … the beliefs are basic in the sense that they must be accepted simply by faith (however well argued); there is no way to establish their ultimate truthfulness. (p. 107)

Finally, Kincheloe, Slattery and Steinberg (2000) defined a theoretical model by arguing that it is "a constellation of concepts, values and techniques that a scientific community or dominant culture uses to makes sense of itself and its world" (p. 65).

For this research a critical theory model was chosen. As in many aspects of educational research, various definitions of critical theory are readily available. For example, in their seminal paper, Guba and Lincoln (1994) defined critical theory in the following way:

> [Critical theory is a worldview in which the researcher] critiques and transforms the social, political, cultural, economic, ethnic, and gender structures that constrain and exploit humankind, by engagement in confrontation, even conflict. (p. 113)

McLaren and Giarelli (1995) have their own definition of critical theory:

> Critical theory is, at its center, an effort to join empirical investigation, the task of interpretation, and a critique of this reality. Its purpose is … to improve human

> existence by viewing knowledge for its emancipatory or repressive potential. (p. 2)

Critical theory can also be defined as a type of research or theory in which social and cultural criticism is paramount (Kincheloe and McLaren, 1994). These researchers argued that critical theory rests on a number of assumptions. Those that are more relevant to this study are:

- All thought is fundamentally mediated by power relations that are socially and historically constituted.
- Facts can never be isolated from the domain of values or removed from some form of ideological inscription.
- The relationship between concept and object and between signifier and signified is never stable or fixed.
- The relationship between concept and object and between signifier and signified is often mediated by the social relations of capitalism and consumption.
- That certain groups in any society are privileged over other groups.
- Oppression is more forcefully reproduced when the oppressed accept their social status as natural, necessary, or inevitable.
- There are many inter-related aspects of oppression (gender, class, race, socioeconomic status, etc.).

Guba and Lincoln (1994) describe critical theory in terms of its ontology, epistemology, and methodology. From the first perspective, reality is shaped by "a congeries of social, political, cultural, economic, ethnic, and gender factors" (p. 110). In terms of epistemology, there is an inter-relation between the investigator and the object of investigation. Second, research findings are mediated through the researcher's values. Finally, the third perspective proposes a dialectical dialogue between the researcher and the others in which the oppressed reach consciousness of their oppression and act against it.

The term critical theory originally referred to the intellectual movement originated in the Frankfurt School (Morris, 1999). These scholars promoted a critical examination of the status quo and the development of a new moral and social order in which economic, social and cultural inequities against the oppressed were eliminated and a social emancipation be reached (Kanpol, 1999). It was in the 1960s and 1970s that critical theory regained popularity among civil rights, gay, lesbian, environmental, feminist, and other intellectuals (Kincheloe and McLaren, 1994).

The role of critical theory in education is to question and act to upset unequal relations between people in the school (Kanpol, 1999). Kanpol suggests that schools are a place of inherent and implicit contradictions. Critical theorists and critical pedagogists argue that "alternatives to an educational system that on the one hand preaches equal opportunity through values such as hard work, self-discipline, and motivation and on the other hand supports inequity within social, cultural, and economic relations, must be realized and changed … this change will bring the education system closer to the democratic ideals that the United States and the Constitution were founded on" (Kanpol, 1999, p. 29).

According to Scheurich (2001), critical theory is an excellent avenue by which to examine culturally relevant pedagogy. His argument is as follows:

> A critical theorist believes that schools are steeped in deficit thinking, or the idea that minority students are somehow less because they may not think, act, and learn in ways that white society has deemed appropriate. Critical theorists would agree that schools have a system of inequity built into them and work to delegitimize that practice. Certain cultures are validated because they are recognized and used in schools. Minority children often do not possess this cultural capital and are therefore behind even before they enter school. (p. 3c)

Theoretical Framework

The theoretical framework that informed this study comes from the idea of culturally relevant teaching (Ladson-Billings, 1994, 1995). This is not a new theory in educational research. Other researchers have studied the effects of home and community cultures in teaching and learning. Although Mohatt & Erickson (1981) called it cultural congruent teaching, Au & Jordan (1981) called it culturally appropriate teaching, Cazden & Leggett (1981) called it culturally responsive teaching, and Jordan (1985) called it culturally compatible teaching, the theory of culturally relevant teaching is broader in perspective, "moving beyond language to include other aspects of student and school culture" (Ladson-Billings, 1994, p.17). Culturally relevant teaching is defined by Ladson-Billings (1994):

> Culturally relevant teaching is a pedagogy that empowers students intellectually, socially, emotionally, and politically by using cultural referents to impart knowledge, skills, and attitudes … culturally relevant teaching uses school culture in order to maintain it and to transcend the negative effects of the dominant

> culture. The negative effects are brought about, for example, by not seeing one's history, culture or background represented in the textbook or curriculum or by seeing that history, culture, or background distorted. (p. 17-18)

A complementary definition of culturally relevant pedagogy was restated a year later (Ladson-Bilings, 1995):

> [Culturally relevant pedagogy] is a theoretical model [framework] that not only addresses student achievement but also helps students to accept and affirm their cultural identity while developing critical perspectives that challenge inequities that schools (and other institutions) perpetuate. (p. 469)

Culturally relevant teaching must meet three criteria: (a) ability to develop students academically, (b) a willingness to promote cultural competence, and (c) the development of a sociopolitical consciousness (Ladson-Billings, 1995). It is designed to "problematize teaching and encourage teachers to ask about the nature of the student-teacher relationship, the curriculum, schooling, and society" (Ladson-Billings, 1995, p. 483).

Although the theory of culturally relevant teaching was created with African - American students in minds, I believe that it can be used in a Puerto Rican setting. There are several reasons for my belief: (a) there are parallelisms between dominant and dominated cultures in both United States and Puerto Rico. In the case of the United States, the White culture is thought to be implicitly dominant, and the African American culture is considered implicitly dominated. In the case of Puerto Rico, an "American" culture guides to some extent the teaching and learning of Puerto Rican students, who have their own and distinct culture, (b) culturally relevant teaching can also be perceived not in the narrow context of African Americans and White Americans, but in a broader context of two different cultures, without the basic premises of the theory being threatened with falseness, and (c) most of the population in Puerto Rico share a common ethnic ancestry with African Americans in the United States, and undoubtedly, some cultural similarities. For the case of Puerto Rican high school physics teachers, it is desirable for them to teach physics content that is culturally relevant to their students, that fosters their cultural identity, and that provide them with knowledge and practices to operate successfully in their society (Osborne, 1996).

Rationale

In the past few decades, educational researchers have perceived a decline in the quality of science education in many developing world countries (Gray, 1999). Although a variety of reasons produce this unfortunate perception, one of those reasons might be that developing countries rely excessively on other countries to create their own educational philosophy and curriculum. As a consequence, a textbook-orientated, theory-based, transmission-focused, highly decontextualized curriculum emerges, which badly emulates what happens in the developed world (Gray, 1999). It is very important for developing countries to develop educational policies, philosophies and curricula "that are authentic, contextually relevant, and affordable in their own particular country" (p. 262) (Gray, 1999).

In the case of Puerto Rico, the influence of a foreign culture in many aspects of the Puerto Rican life, including education, is evident. For example, the science textbooks at different grade levels are translations of American textbooks produced by publishing companies in a generic, decontextualized way to be sold in as many countries as possible. Keep in mind that the primary concern of the publisher is "to earn their producers a living" (p. 86)(Apple, 1986). Given the fact that 75% of the time elementary and secondary students are in classrooms and 90% of their time on homework is spent with text materials (Apple, 1986), educators and policy makers must make sure the classroom materials are the best suited for Puerto Rican students. This area of research, in the United States in general, and Puerto Rico in particular, is especially fertile, since "very little critical attention has been paid to the ideological, political, and economic sources of [textbook] production, distribution, and reception” (p. 86)(Apple, 1986).

Research on the contextual and cultural relevance of the textbooks used in Puerto Rican schools has not been performed, but when done it might also provide evidence that these components, now somewhat missing in the physics classroom, might increase student achievement in physics, might promote a more positive perception of physics among students, and might even promote enrollment in high school physics courses. This might produce more educated and scientifically literate citizens in general, and should strengthen the science foundation for those students who plan to go to college.

Another reason for studying the contextual and cultural relevance of the textbooks used in Puerto Rican schools is in terms of the high school physics teachers. This and future research in this area might provide evidence in favor of supplementary teaching resources that consider the culture and context of the students in presenting physics concepts. It is expected that teaching physics with attention to these factors will be less difficult and more enjoyable for teacher and students alike. Teachers might also combine experiences and knowledge to become active participants in the creation of these supplementary materials.

Research Questions

The following study was guided by the following research questions:

1. To what extent do Puerto Rican high school physics teachers modify the physics curriculum to make it more contextual and culturally relevant to the student population they attend?
2. To what extent do Puerto Rican high school physics teachers modify their teaching methodology to make it more contextual and culturally relevant to the student population they attend?
3. What factors determine if Puerto Rican high school physics teachers modify the physics curriculum to make it more contextual and culturally relevant to the student population they attend?
4. What factors determine if Puerto Rican high school physics teachers modify their teaching methodology to make it more contextual and culturally relevant to the student population they attend?

Summary of First Chapter

In this introductory chapter, the reader was familiarized with the purpose and the research questions of this study. These were informed by an overview of the problem of curriculum importation, with particular emphasis to Puerto Rico and its postcolonial situation. Also, the myth that science textbooks originating from the United States must be of a high quality was challenged. The purpose and research questions were also shaped by Critical Theory as a theoretical model and Culturally Relevant Pedagogy as a theoretical framework, and evidenced in the rationale section.

The next chapter provides the reader with an in-depth review of the associated literature. The topics that were thoroughly reviewed included (a) secondary education in Puerto Rico, (b) physics education in Puerto Rico, (c) contextual teaching and learning, and (d) multicultural education.

CHAPTER 2

LITERATURE REVIEW

Overview

In this chapter, a summary of the historical aspects of education in Puerto Rico in general, and secondary education in particular, contextual teaching and learning, and multicultural education are presented, with emphasis on the introduction of educational influences external to the Puerto Rican culture, first under Spain and then under the United States. Given the strength of these external influences in all aspects, education included, it is not surprising to find that textbooks in general, and science textbooks in particular, are still the main curricular component of Puerto Rican education.

Secondary Education in Puerto Rico

Vision

What is the reason for that external educational influence? According to several authors (e.g. Solis, 1994; Eliza-Colon, 1989), it is the political relationship between Puerto Rico and the United States that discourages efforts to make the public school system more in-phase with the Puerto Rican culture and reality. For example, Jose Solis argues that "even though schooling in Puerto Rico has expanded over colonialism, the contribution that such expansion has made to Puerto Rico's own development remains limited by this relationship [with the United States]" (Solis, 1994, p. 145). He continued his argument suggesting that the limitation of that political relationship has truncated the development of a Puerto Rican education system, since "the history of public education reform policies and their language has been a major source of the contributions to a sustained colonial relationship" (Solis, 1994, p. 151). Earlier, Eliza-Colon (1989) similarly concluded that the role of the public school in sustaining the colonial mentality, that economic survival depends on the preservation of the political link between Puerto Rico and the United States:

> As a fundamental part of a political structure, the public school system serves the goals of that structure. Therefore, public instruction cannot remain neutral or isolated from the political ideals that are its reason of being … In principle, the public school is politically oriented. In practice, it is a political act directed at conforming the citizens of the structures and values of the political state. (p. 2)

This vision of the Puerto Rican as hopeless without the help of the United States, according to Eliza-Colon, is not challenged at school, but encouraged by a school system which serves the interests of the United States. She continues her argument by saying, "through a colonized curriculum, the schools do not reflect the efforts of the Puerto Rican who have really struggled to make the island an independent and self-sufficient nation" (p. 118).

History

According to Lopez Yustos (1991), at the beginning of the 19th century, secondary education in Puerto Rico was almost nonexistent. Some general courses in Latin grammar, one of the seven liberal arts of the trivium and quadrivium were taught by Catholic priests in San Juan. Although those courses were primarily intended for those students who were preparing to become priests, interested students with no religious inclinations did have access to them.

During the course of that century, modest efforts promoted by social and religious organizations tried to promote education on the island. In 1814, the "Sociedad Economica de Amigos del Pais" [Economic Society of the Country's Friends] , a non-profit organization started offering some courses in mathematics and drawing for a very limited number of students (near 40 students). Later, in 1832, courses in physics and chemistry became available. In 1823 the Catholic Church opened the "Seminario Conciliar" [Councilary Seminar], a seminary open to candidates for priesthood and laymen. Between 1843 and 1858 the courses offered by the "Sociedad Economica de Amigos del Pais" (physics, chemistry, mathematics, drawing) were included with the courses offered by the "Seminario Conciliar" (Latin, theology, philosophy, and moral), creating a group of courses equivalent to those of the secondary schools in Spain. For political reasons, the non-religious courses offered by the "Seminario Conciliar" were cancelled about 1882.

In 1882 the "Instituto Provincial de Segunda Enseñanza" [Province Institute of Secondary Education], an institution of secondary education academically equivalent to those in Spain, was opened by the Spanish government. It was the only educational institution authorized to offer the degree of baccalaureate. A number of private secondary institutions were also created in some of the relatively big cities (Ponce, Mayaguez, Caguas, Humacao, Guayama, Arecibo), but they must have been associated with the "Instituto Provincial de Segunda Enseñanza" for their students to receive the degree. Notice that, because of the political status of the island, the recently implemented educational system tried to mirror similar institutions in Spain, instead of the creation of a Puerto Rican educational system. In addition, because of the lack of an adequate number of educated Puerto Ricans, most of the secondary school teachers were Spanish.

Despite the effort to promote education and literacy in Puerto Rico, when the United States took possession of the island in 1898, they found only 529 primary schools and a population of 940,000 people. The literacy rate was a mere 20%. A dissertation conducted by Negron de Montilla (1990) about the influence of the presence of the United States in the public education of Puerto Rico at the beginning of the 20th century concluded that the "Americanization" of Puerto Ricans via public instruction started very early in the century:

> Sobre la base de los datos presentados en este estudio, puede llegarse a la conclusion de que: primero, el sistema de instruccion publica jugo un importante papel en el proceso de americanizacion de Puerto Rico; segundo, las escuelas sirvieron a los propositos de americanizacion; tercero, los Comisionados de Educacion cubiertos en este estudio utilizaron el sistema de instruccion publica en sus intentos de americanizar a Puerto Rico. (p. 273).
>
> (Based on the data presented in this study, it can be concluded that (a) the public education system played an important role in the Americanization process of Puerto Rico, (b) school served an Americanization purpose, and (c) the Education Commissioners used the public education system in their attempts to Americanize Puerto Rico. Translation by author).

This "Americanization" process may be considered one of the reasons why the educational system in Puerto Rico is still very open to use, copy and adapt curriculum and instructional materials that originates in the United States, including the translation of science textbooks from the United States for the use of Puerto Rican students.

Negron de Montilla (1990) also summarizes the first three decades of public education in Puerto Rico by presenting the main contributions of the Education Commissioners to the development of public instruction in the island. Interestingly enough, all the Commissioners seem to have had something in common: "Americanization, expansion of the school system, and the teaching of English" (Osuna, 1949).

After United States troops took control of Puerto Rico on October 18, 1898, General John Eaton, former United States Education Commissioner, was put in charge of developing an educational system for Puerto Rico. After examining the school laws, texts, and methods of instruction established by the Spanish government, Eaton created a "Codigo de Leyes Escolares" [School Law Code] to substitute for the old educational system. Although this Code provided positive aspects to the education of Puerto Rico, it clashed with great criticism from some sectors, which argued that the Code "was not adapted to the local conditions", but "was based on the Massachusetts school system", and "not applicable to the Puerto Rican situation." (Negron de Montilla, 1990, p. 25).

In 1899, General Clark (who succeeded General Eaton as Puerto Rico Education Commissioner) acknowledged the opposition of the people to the new educational system (Negron de Montilla, 1990):

> Existe una oposicion a las escuelas americanas … esta oposicion se produce por varias razones. En primer lugar, los principales educadores de la Isla han hecho

> sus estudios en escuelas de España o Francia. Estan familiarizados con los sistemas usados en dichos paises, pero no lo estan con el sistema americano. (p. 28).
>
> (There is an opposition to American schools … there are several reasons for this opposition. First, the main educators of the Island had made their studies in France or Spain. They are familiar with the educational systems used in these countries, but they are not familiar with the American system. Translation by author).

This statement is important because it is an admission that there was some kind of educational system running in Puerto Rico prior to the Hispanic-American War of 1898, and that the educational system imported from the United States was foreign to the people of Puerto Rico.

On May 1, 1900 the Foraker Act (Rafucci de Garcia, 1981) was implemented in Puerto Rico, giving the island a civil government, but keeping its control in the United States. Among other things, the Foraker Act formalized the position of an Education Commissioner and described its roles and responsibilities. The President of the United States selected Dr. Martin Grove Brumbaugh as the first Education Commissioner of the civil government. He prepared the new School Law, known as "Acta para el establecimiento de un sistema de escuelas publicas en Puerto Rico" [Act for the establishment of a public school system in Puerto Rico] and was implemented after July 1 of the following year. Although the new School Law was approved by the government, it confronted opposition. Newspaper articles criticized the Law, considering it as despotic, centralized, and inept.

Although Dr. Brumbaugh focused his effort on the development of elementary schools, he also provided funding for students to continue their secondary education in the United States, promoted the creation of libraries and the construction of school buildings (which were named after American figures, such as Franklin, Adams, Lincoln, Grant, Longfellow, just to mention a few), imported teachers from the United States "graduated from first class universities, colleges and normal schools" (Negron de Montilla, 1990) to teach primary school, and helped create the "Escuela Normal Insular" [Insular normal school] , a normal school which later became the University of Puerto Rico. Under Dr. Brumbaugh's administration the distribution of the Teachers Manual written for the Public Schools of Puerto Rico, was promoted. This document, written with the purpose of helping teachers make changes in the schools so that they were "in equality of conditions to the public schools in the States of the Union" is described by Negron de Montilla (1990):

> La publicacion presentaba una relacion de la filosofia educativa, la literatura y el sistema de organizacion de escuelas, predominante "actualmente" en los Estados Unidos. El compendio incluia capitulos del plan educacional, educacion primaria, educacion secundaria, preparacion para profesores, educacion industrial, jardines del infancia, y administracion escolar. (p. 58)
>
> (The publication presented the relationship between educational philosophy, literature, and the school organization system that were working "actually" in the United States. The compendium included chapters about the educational plan, primary and secondary education, teacher preparation, vocational education, kindergarten, and school administration. Translation by author).

Dr Brumbaugh also helped institutionalize the teaching of English and procedures to create American patriotism in Puerto Rican students. All schools celebrated American holidays, such as Washington's birthday and the Day of the Flag. Schools also had a flag from the United States; raising the flag was a signal that classes started. Students must salute the flag before starting the class day. They also sang “patriotic songs”, such as “America”, “Hail, Columbia!”, and “Star-Spangled Banner.” At the end of Dr. Brumbaugh's period as Education Commissioner on November 15, 1901, there were 733 schools with 31,172 students enrolled, about 10% of the total estimated school age population of 322,393.

Dr. Samuel McCune Lindsay succeeded Dr. Brumbaugh. Dr Lindsay, who worked in that position until October 1, 1904, generally followed Dr. Brumbaugh's educational policies with respect to Americanization and the teaching of English, and confronted some of the same problems, such as finding qualified teachers. The new Education Commissioner develop a novel project, in which Puerto Rican teachers received scholarships to take summer classes at Cornell University and Harvard, while conserving the original project of sending students to continue secondary education in United States. He also transformed the Normal School into the University of Puerto Rico on March 12, 1903, established agricultural and industrial schools, and four secondary schools, and created an annual "voluntary" English examination that became an unnamed "requirement" to find better opportunities in teaching positions. To promote English language in Puerto Rican schools, Dr. Lindsay stressed the use of textbooks from the United States in the schools (Puerto Rico Department of Education, 1903):

> Estamos intentando introducir libros de texto en idioma ingles tan rapidamente como sea posible, y de hecho la intencion del Departamento es que las clases se desarrollen totalmente en el idioma ingles tan pronto como los alumnos y los profesores esten lo suficientemente entrenados en el uso del idioma ingles para hacer de este el idioma oficial escolar, como lo es ya en la vida publica, y se esta convirtiendo rapidamente en la lengua predominante en el mundo de los negocios. (p. 21)
>
> (We are trying to introduce textbooks in English as fast as possible; it is the intention of the Department that classes are taught in English as soon as students and teachers are prepared enough in using English to make this language the school official one, in the same way it is in public life, and it will be in the world of business, Translation by author).

This is probably one of the first explicit quotations about introducing textbooks from the United States in Puerto Rican schools. There is no mention of even a bit of thought about the adequacy or practicality of using foreign textbooks in student of cultures different from the colonizing one.

Dr. Lindsay kept the tradition of celebrating U. S. holidays in Puerto Rican schools established by his predecessor, including Washington's Day, Arbor Day, Day of the Flag, and Memorial Day. For Memorial Day, the Department of Education created an "educational pamphlet" describing the merits of that celebration. In sharp contrast, no special program was prepared for the celebration of Columbus Day. The intention of the Department of Education to promote assimilation to the culture from the United States was very obvious. At the end of Dr. Lindsay's period as Education Commissioner in

1904, there were 1,113 schools with 41,811 students enrolled, about 16% of the total estimated school age population of 259,696.

Commissioner Lindsay was succeeded by Roland F. Falkner on October 2, 1904. At the beginning of his term his main agenda was to improve the quality of the schools, instead of their quantity, and to try to modify the educational system to fulfill the needs of Puerto Rico. However, he put in place what was called Falkner's Linguistic Policy: eliminating the teaching of English as a subject and substituting it with teaching of almost all subjects in English. This policy was followed between 1905 and 1916. To strengthen the English fluency of Puerto Rican teachers, Commissioner Falkner created economic rewards for teachers based on an annual English test, and strongly suggested the use of the English language in conversations with teachers and superintendents who came from the United States. As expected, the new Linguistic Policy faced strong resistance of a sector of the Puerto Rican society, arguing that learning is almost impossible when the medium is not understood (Muñiz-Souffront, 1950):

> Se enseñaba el ingles desde el primer grado siguiendo el plan que en 1905 estableciera el comisionado Falkner. Violando asi los principios mas elementales de la pedagogia, el trabajo escolar era una tarea dificil, monotona y desagradable tanto para los niños cuyo unico medio de expresion era el español y en cuyo ambiente tampoco se hablaba otro idioma, como para el maestro cuyo dominio del ingles resultaba limitado en extremo para hacer de la labor docente una tarea eficaz. (p. 11)
>
> (English was taught since first grade following the 1905 plan by Commissioner Falkner. Violating in this way the most elementary principles of pedagogy,

> school work was a hard, unpleasant, and boring for the kids, whose only means of expression was Spanish at school and home, and for the teacher, whose proficiency in English was too limited for effective teaching. Translation by author).

Commissioner Falkner maintained the celebration of American holidays and the scholarships for student to study secondary education in the United States.

A positive complement to this financial aid was the willingness of some individuals to privately fund the secondary studies of some students. At the end of his term, on August 1, 1907, there were 65,436 students enrolled in public schools, under the tutelage of 1175 teachers. This was an increase of 57% compared to the school enrollment in 1904.

Commissioner Edwing G. Dexter took Falkner's position on August 9, 1907. Under his administration, the number of school districts was increased from 19 to 66, one school district per city or town. The purpose of this change was to reduce the number of schools per district so that they could be supervised more often. He also increased the economic resources devoted to study-abroad scholarships, and maintained the celebration of U. S. holidays.

It was Commissioner Dexter who directly related the approval of the teachers English test with employment security, arguing that not taking the English test might be enough reason for employment suspension. He also ordered the graduation tests (junior high and high school) to be taken in English, and introduced voluntary military education in public schools. At the end of Commissioner Dexter's term, on July 18, 1912, there were 160,657 students enrolled in public schools. This was an increase of 146%

compared to the school enrollment in 1907. He was replaced by Commissioner Edward M. Bainter.

Commissioner Bainter followed the general guidelines set by his predecessors, although, because of a political turmoil in Puerto Rico at that time, he had disagreements with the government with respect to educational laws, the use of English in schools, the classification and assessment of teachers. He left office on May 15, 1915.

Commissioner Paul G. Miller succeeded Commissioner Bainter on August 26, 1915. Due to a reduction in the education budget, Commissioner Miller focused on strengthening available schools, instead of creating new ones. This was particularly true in rural schools, where literacy levels were about 30%. He suggested that teachers live close to the schools, that they gain the confidence of community members, and that they visit the student's homes. He also modified somewhat the Falkner's Linguistic Policy so that teachers were able to teach mathematics in Spanish in the first four grades. This change was far from what most Puerto Rican wanted: all classes in Spanish and English as a second language.

In terms of teacher preparation, Commissioner Miller created a professional reading class for teachers, in which they read and discussed books related to education that were brought from the United States. The books selected were Thorndike's "Principles of Teaching", Strayer's "A Brief Course in the Teaching Process", Earheart's "Types of Teaching", and Bagley's "Classroom Management".

During Commissioner Miller's incumbency two important events took place: First, the Jones Act of 1917, which gave U. S. citizenship to the people of Puerto Rico, was approved. A brief description of the Jones Act is provided by the Hispanic Division of the Library of Congress (1999):

> On March 2, 1917, President Woodrow Wilson signed the Jones-Shafroth Act. This law gave Puerto Ricans U.S. citizenship. The Jones Act separated the Executive, Judicial, and Legislative branches of Puerto Rican government, provided civil rights to the individual, and created a locally elected bicameral legislature. The two houses were a Senate consisting of 19 members and a 39-member House of Representatives. However, the Governor and the President of the United States had the power to veto any law passed by the legislature. Also, the United States Congress had the power to stop any action taken by the legislature in Puerto Rico. The U.S. maintained control over fiscal and economic matters and exercised authority over mail services, immigration, defense and other basic governmental matters. (p. 1)

This Act was later introduced by the Commissioner of Education as part of the public school syllabus of the course on civics.

Second, United States entered in World War I. The Commissioner took advantage of the situation to promote American patriotism in native students. This strategy was not totally effective. There were confrontations between high school and university students who believed in independence and Commissioner Miller. The Commissioner left his position on August 30, 1921.

Juan B. Huyke took the job as Education Commissioner on October 3, 1921. He was the first Puerto Rican to fill this important position. Unfortunately, he was not thinking about modifying the educational system to fit it to the situation in Puerto Rico.

He was an "asimilista" [assimilationist], a person who believed that English should be the language of instruction in the island, thus, assimilating Puerto Ricans to the colonizing culture. As a consequence his educational policies with respect to the use of English in the schools, teacher knowledge of English, use of textbooks brought from the United States, etc., did not differ much from other Commissioners from the United States.

Commissioner Huyke, following some ideas of the early American progressive education movement of the 1920's, created student clubs in which students talked in English at all times, and carried a small pin of the American flag on their chest, promoted the exchange of correspondence between Puerto Rican and American students, and established English as the official language of teacher meetings and textbooks. Commissioner Huyke even suggested that future teachers with different political ideas from his, would not be recruited as teachers (Huyke, cited by Negron de Montilla, 1990):

> Ya les he expuesto a ustedes mis ideas sobre la patria. Si ustedes opinan lo mismo que yo, mejor que mejor; pero si no es asi, les recomiendo que estudien otra cosa, leyes, farmacia, etc. Soy Comisionado de Educacion y Rector de la Universidad. Como Rector no puedo anular el diploma que la Universidad concede; pero como Comisionado les aseguro que no contratare a ningun maestro cuyas ideas no sean las mismas que las del Departamento. (p. 211)
>
> (I have exposed you to my ideas about the country. If you have the same opinion that I have, that's good. If you do not, then I will recommend you to study something else, law, pharmacy, etc. I am Commissioner of Education and Chancellor of the University. As Chancellor, I cannot cancel the diploma the

> University awards; but as Commissioner of Education I can assure you that I will not hire any teacher whose ideas are different from those of the Department. Translation by author).

This poignant quotation shows the repression of any aspect of the Puerto Rican nationality from the government in general and the Department of Education in particular. As I stated before, the transformation of Puerto Rican into “Americans” was one of the main goals of the Department of Education in the first decades of the 20th century.

During 1925, Columbia University made a comprehensive research study about the public educational system in Puerto Rico, from first grade to the university level. The purpose of the research was to "shed light about the quality of teaching, the content of the program of study, the effectiveness of teacher and school supervision, and the complex problems related to the linguistic policy" of the Department of Education (Negron de Montilla, 1990, p. 222). One of the researchers' main findings was that the first six grades should focus on subjects other than English, and that English should not be the language of instruction until the seventh grade. Although some of the suggestions made by Columbia University were followed, Commissioner Huyke kept in place the use of English in the schools.

The Commissioner also maintained the celebration of American holidays. For example, he ordered that one whole week be dedicated to study of the life of Theodore Roosevelt. He also ordered that books written by him, which promoted assimilationist ideas, were to be introduced into the school curriculum. This caused negative reactions from teachers and other individuals. Commissioner Huyke even suggested to teachers not to participate in the meetings of the Teachers Association, an organization that was very critical of his job as Education Commissioner. Juan B. Huyke left his position as Commissioner on January 13, 1930. During this time there were 233,209 students enrolled in school.

Commissioner Jose Padin succeeded Commissioner Huyke on January 14, 1930. Interestingly enough, Jose Padin was one of the students who participated in the government scholarships for studying abroad under Commissioner Brumbaugh. According to Lopez Yustos (1991), the administration of Commissioner Padin focused on the linguistic problem in schools and in his belief that both the Puerto Rican and the American culture could co-exist harmoniously.

After a careful examination of the school system, Commissioner Padin concluded that students were learning neither good Spanish, nor good English, and this had a negative impact on the learning of all other school subjects. In a drastic change of educational policy, compared to previous Commissioners, he decided that all subjects be taught in Spanish at the elementary school (grades 1 through 8) and that English was to be taught as a second language. This decision was a consequence of Commissioner Padin's philosophical vision of the educational system; a vision in which the Puerto Rican culture will prevail by adapting some things about the U. S. culture, but keeping a Puerto Rican identity (Padin, 1935):

> Es preferible para Puerto Rico acomodarse a la situacion conservando cuanto sea bueno de su herencia cultural y adoptando ideales americanos de pensamiento y accion que enriqueceran su vida sin ocasionar conflictos. (p. 8-9)

(It is better for Puerto Rico to accommodate to the situation, keeping what is good of our cultural heritage, but adopting the American thought and action ideals that will enrich us without creating conflict. Translation by author).

During Commissioner Padin's administration the development of vocational and domestic programs increased in Puerto Rico. He also modified the school curriculum by creating courses in integrated sciences and social sciences.

Dr. Jose M. Gallardo replaced Commissioner Padin for the school year 1937-1938. This commissioner was the first one in receiving direct instruction from the President of the United States (Franklin D. Roosevelt) with respect to the use of English in the public schools. President Roosevelt argued that hundreds of thousands of Puerto Ricans knew no English despite many years of American control over the island, and despite the fact that Puerto Ricans were American citizens (Lopez Yustos, 1991). However, making the suggested changes to the educational system without raising political criticism from the local government was almost impossible. Finally, Commissioner Gallardo decided to restructure the educational system into a 6-3-3 format so that Spanish became the language of instruction in the first six grades (with English as a subject), and English became the language of instruction in the higher grades (7-12) with Spanish as a subject. As a result, almost all textbooks in junior high and high school were American textbooks.

Commissioner Mariano Villaronga succeeded Dr. Gallardo in 1948. Because of the establishment of the Commonwealth status in Puerto Rico in the 1950's, Commissioner Villaronga was the last Education Commissioner appointed by the president of the United States. He was not confirmed by the United States Congress, but the local government of the island appointed him to the new position of Secretary of Education. In 1949 Secretary Villaronga declared Spanish as the language of instruction in all the schools, with English taught as a subject in all grades. By taking this step, Secretary Villaronga started the development of a somewhat more Puerto Rican educational system (Lopez Yustos, 1991):

> Aunque el uso del ingles como medio de instruccion venia decayendo desde que Gallardo dejo la direccion del Departamento, la orden de Mariano Villaronga resolvio definitivamente la cuestion. Las escuelas enseñaron en español en todos los grados, se abandono la contratacion de maestros de los Estados Unidos, se tradujeron y se produjeron mas libros de texto en español y se tomaron todas las medidas para hacer la escuela publica realmente puertorriqueña. (p. 142)
>
> (Even though the use of English in school was diminishing since Gallardo left the Department of Education in 1948, the order of Mariano Villaronga solved this issue definitively. Schools taught in Spanish in all grades, contracting teachers from the United states was stopped, textbooks in Spanish were both translated and produced, and all measures were taken to transform into Puerto Rican the public education system. Translation by author)

Notice that Lopez Yustos talks about production and translation of textbooks in Spanish. Implicitly in the statement is the fact that the majority of the texts translated came from the United States. As a consequence it is questionable the paradox of developing a "truly Puerto Rican public school" given the presence and use of foreign textbooks in the classrooms.

Secretary Villaronga put in place an aggressive expansion of the educational system in the island, since the newly adapted Constitution of the Commonwealth provided obligatory primary schooling for all children between 6 and 12 years old. In a report to Governor Muñoz, Villaronga stated that in 1956, 91% of all the children between 6 and 12 years are enrolled in elementary school, 75% of all children between 13 and 15 are enrolled in junior high school, and that 41% of all children between 16 and 18 years were enrolled in high school (Villaronga, 1956). Also, in 1956, teacher instruction became departmentalized. In the departmentalized format, one teacher taught the courses of the same discipline (science, English, social studies, etc) in all grades. In the original system a teacher taught all the disciplines in a single grade.

Efrain Sanchez Hidalgo replaced Secretary Villaronga in the summer of 1957. He was in the position for less than two years.

In 1960 the Governor of the Island appointed Candido Oliveras as Secretary of Education, a person described by Lopez Yustos as one of limited educational background (two bachelor degrees and some advanced courses), but an administrator of great caliber. His administration focused not on expansion of the educational system, but on improving its quality. Some of the major aspects of his educational reform were: reducing school drop-out rates, reducing alternate scheduling, creating exemplary schools where new methods of instruction were developed for later use in all the system, establishing kindergarten, providing special attention to students with special needs (gifted and retarded), creating standardized tests in several school subjects, producing educational programs via the government television station, and strengthening community education and auxiliary services.

Candido Oliveras was succeeded by Angel Quintero Alfaro, who worked under Candido Oliveras' administration as Sub-secretary of Education. In this way, the continuity of the educational reforms implemented by Secretary Oliveras were assured. He also implemented some of his own reforms, such as revising the curriculum, exchanging teachers between Puerto Rico and the United States, and creating vocational and industrial educational centers.

In 1969 Ramon Mellado was appointed as Secretary of Education by the recently elected Governor Ferre, who belonged to the pro-statehood party. This created a politically tense situation in the Department of Education because most of the administrative personnel were members of the pro-commonwealth party and, by law, could not be replaced. Instead of internal opposition, he developed his educational agenda, including: returning to a "back-to-the-basics" philosophy, reducing alternate scheduling, creating a new salary scale for teachers, and emphasizing the teaching of English and introducing bilingual teachers in the schools. This last point is reflective of the political thought of the government.

After 1970, political and economic events produced instability in the educational system. In terms of political events, the administration changed several times:

- Before 1968: pro-commonwealth administration
- 1968-1972: pro-statehood administration
- 1972-1976: pro-commonwealth administration
- 1976-1984: pro-statehood administration
- 1984-1992: pro-commonwealth administration

- 1992-2000: pro-statehood administration
- 2000 to present: pro-commonwealth administration

As a consequence, new administrations ignored the good things prior administrations implemented, and shifted their educational priorities based on their political ideas. This had a serious and detrimental consequence in the development of better educational programs. Political, economical, and social events, both in Puerto Rico and the United States are still the major contributors to the sometimes inarticulate educational programs in the Island.

Throughout this section a summary of the creation, evolution and actual state of the Puerto Rican educational system was presented. I went into great detail in the foreign influences of both Spain and the United States into our educational system, the explicit efforts of the American power to promote the Americanization of the Puerto Rican by means of education, and the Commonwealth struggle to create an educational identity that was not purely American, but more of an amalgamate of American and Puerto Rican educational viewpoints. In the next section I will focus on physics education in the secondary school in Puerto Rico, in both a historical and analytical way.

Physics education in Puerto Rico in the 20th century

Unfortunately, there is just sketchy information about physics education in Puerto Rico, especially being available outside of the Island. Based on the information that is available, I created a brief summary of some historical and analytical aspects of physics education in the public schools of the Island. A document of special importance in this section is the dissertation by Court, which explored how physics teachers reacted to the introduction of Harvard Physics Project, a recognized American introductory physics curriculum.

It was Dr. Rufo Manuel Fernandez, a priest from Galicia, Spain, who first taught physical sciences in Puerto Rico (Lopez Yustos, 1991) in 1832. He was also the first one in teaching science with the laboratory equipment of the times, which included electric and pneumatic apparatus, batteries, Leiden jars, Volta's battery, and a compression pump. According to one of his disciples (Alonso, 1967), Dr. Fernandez studied physics and chemistry in Spain, becoming a lecturer of logic, metaphysics, chemistry, and physics at the University of Galicia. He later moved to Puerto Rico, where he offered a course in physical science to those interested. Before leaving the island in 1841, Dr. Fernandez donated all his scientific equipment to the "Sociedad Economica de Amigos del País" [Economic Society of the Country's Friends], who used it to keep alive the physical science courses until 1882, when the non-religious courses were canceled.

When the "Instituto Provincial de Segunda Enseñanza" [Province Institute of Secondary Education]" opened in 1882, a course in physics and chemistry was established. The textbook used was "Curso de Fisica experimental y aplicada para la enseñanza secundaria", written by Bartolome Feliu y Perez. The class met daily for 90 minutes. This course was offered until near the end of the century, when Puerto Rico ceased to be a colony of Spain and became a colony of the United States.

In the previous section it was described how most aspects of the American educational system were introduced in Puerto Rico during the first decades of the 20^{th} century. This was also the case for secondary science. Although there were not many secondary schools available (basic literacy was the main goal of the Department of

Education), those who were active had a course in chemistry and a course in physics. A document from 1925 called "Course of Study for Physics and Chemistry" can be used as an example of the intended curriculum in these disciplines and the influence of the American educational system in the Puerto Rican science curriculum.

The preface of the document clearly stated that "the following courses have been adapted from the courses outlined by the College Entrance Examination Board of New York". Also in this preface an acknowledgement of two teachers who provide assistance in the "preparation and revision of the courses" is presented. The textbook assigned to the physics course was *Practical Physics*, by Millikan & Gale.

The purpose of the course of study in physics was to provide "equally suitable" instruction for students either preparing for college or not going beyond high school. The document also described the principal instructional methods the physics teacher should use: (a) lectures to "illustrate the facts and phenomena of physics in their quantitative aspects and in their practical applications", (b) recitations, to emphasize the general principles outlined in the syllabus students "apply these principles intelligently to the solution of simple and practical problems", and (c) individual laboratory work, to "supplement the pupil's fund of concrete knowledge and to cultivate his power of accurate observation and clearness of thought and expression" (Department of Education, 1925).

The list of topics followed very much that of an American standard introductory physics course at the beginning of the century: metric system; linear, square and cubic measures; states of matter; fluids, pressure and buoyancy; gas laws; Newton's laws; power and conservation of energy; kinematics; gravitation; heat and temperature;

thermodynamics; magnetism; static and current electricity; sound; and light. A list of 11 experiments in mechanics, 8 experiments on heat, 11 experiments on magnetism and electricity, 4 experiments on sound, and 7 experiments on light was included. A laboratory notebook was required to collect all the data and prepare written reports.

It is evident that the educational administrators were transposing the American educational system in the Puerto Rican setting, even though most of the secondary schools in existence did not have the equipment to perform some of the "required" experiments. There is no evidence of an attempt to modify the physics curriculum based on the needs of the average Puerto Rican student. Unfortunately, this is a trend that was to continue, with no major modifications, in the rest of the century. Today, the high school physics textbook is a translation of the American version of *Physics: Principles and Problems* (Zitzewitz and Murphy, 1990).

How do we evaluate if the curriculum imported from the United States was effective for Puerto Rican students? There is very little information about that, although some surveys of the state of science education in the Island had been performed in the fifties and sixties. King (1959) reported on some aspects of secondary education in Puerto Rico, including science education. He found, among other things, that science teachers were not capable to "readjust and vivify the school curriculum" (p. 19). Court (1972) included a quotation by Barnard (1959) in which he stated that "sixty-three percent of the high school science students said that the content was not adapted to their abilities". Moreover, "forty-three percent said that the science courses did not take their own needs into consideration". (p. 11).

In reporting his own research, Court (1972) discovered that most physics teachers taught PSSC Physics, which is a translated American curriculum. He presented the teacher's perception about the recently implemented Harvard Project Physics curriculum in Puerto Rico:

> Several of the teachers emphasized that a straight word-for-word translation of the materials should not be employed in the adaptation process, but rather a cultural translation. Too often, they maintained, materials had been translated word-for-word with the result that the Spanish was sometimes meaningless. The languages are not carbon copies of one another, with a mere difference in symbolism, and any effective translation requires a person who is not only fluently bilingual in every aspect of the language but also "fluently bicultural". It must also be emphasized that Puerto Rican Spanish, in both its general and idiomatic usages, is a unique form of Spanish and as such should be reflected in any translation designed for the Puerto Rican School system. (p. 48-49)

This statement is a clear support to the argument that a simple translation of science materials is not enough to make them understandable to students who were not the clientele of the original version of the science curriculum.

A thorough knowledge of the Puerto Rican culture is essential to create culturally relevant Puerto Rican science curricula. In the particular realm of science textbooks, Court (1972) also found the same pattern of literal translation and little meaningfulness:

> Books, in the senior high school, eseemed (sic) subject to the same problems as in the junior high school. They were, however, generally straight translations of United States textbooks and were bought through a commercial publishing

> company rather than being published by the Puerto Rican Department of Public Instruction. The teachers reported that these books were not adapted to the Puerto Rican schools or to the Puerto Rican students, and that students, therefore, tended to become disinterested very quickly. (p. 64)

Court pointed out one of the consequences of a decontextualized science textbook: students get disengaged and bored. As a high school physics student myself, I remembered that I often said to myself that it would be really nice if I can see some practical, everyday applications of those physics concepts. Now I understand the reason why I never saw the relevance of those physics concepts until much later, when I became a physics teacher myself. At that point in time, after observing the struggle my students had understanding physics, I started feeling the obligation to teach them in a meaningful way.

In his concluding remarks, Court (1972) provided the following recommendation for increasing the effectiveness of physics teaching in Puerto Rico:

> The books that are used in the Puerto Rican Public School System should, where possible, be produced in Puerto Rico by Puerto Rican teachers and supervisors. The present study has shown that direct translations of American textbooks are often not relevant to Puerto Rican students and, sometimes, do not even make sense. Also any translation, if it is to do done (sic) must be carried out by someone who is "fluently bicultural" as well as fluently bilingual. (p. 79)

Contextual Teaching and Learning

In this section, an exploration of the concept of contextual learning and its foundation in the educational literature will be presented. Since any information that is acquired exists in some context (Neperud, 1995; Balsam, 1985), this concept is very relevant in this study. It is clear that students can learn better if the topics covered are embedded in a familiar context that can help students in making the transition between the unknown and the familiar. In the particular case of this research, an underlying premise is that American textbooks that are translated into other languages such as Spanish, may not provide a familiar contextual framework that Puerto Rican students may take advantage of in their own learning.

Formal education is an institution that was created in a social, cultural, political and economic context. Given the fact that our educational artifacts, especially the language we use to communicate in our classrooms, are resources of the culture, researchers are coming to understand that learning is continually shaped by its sociocultural context (Alexander and Murphy, 1999). Both teachers and students also bring contextual factors to education, in the form of a set of prior experiences, beliefs and values about instruction, demographic factors, as well as accumulated knowledge in relation to the curriculum (Fordham, 1983).

Since the term context has in the past been fraught with loose and varied interpretations (Rosnow and Georgoudi, 1986), a few definitions of context and contextualization are in order. For example, Gage and Berlinger (1992) define contextualization as an ability "to understand an item or an event in relation to the context in which it occurs." (p. 173). According to Shrum and Glisan (1994), we teach in context when we present real situations that encompasses many aspects, like the physical setting, the purpose of the lesson, the participants, and the social norms. Rosnow and Georgoudi (1986) defined contextualism in the following way:

> In short, the idea is that … knowledge is made concrete and is framed by relevant factors, relations, and conditions (the setting or context) within which, or among which, human acts and events unfold. Contextualism underscores the idea that human activity does not develop in a social vacuum, but rather it is rigorously situated with a sociohistorical and cultural context of meanings and relationships. Like a message that makes sense only in terms of the total context of time, space, culture, and the local tacit rules of conduct. (p. 4)

Cole and Griffin (1987) defined context as:

> [Context is] the events preceding, occurring with, and following the cognitive task; context so conceived includes all factors that might influence the quality of time spent on the task, ranging from the arrangement of a lesson in the curriculum, to the relation of the classroom to the school a s a whole, and to the relation of the school to the community of which is part. (p. 6-7)

These researchers argued that contextual learning works by modifying the cognitive task itself by using "familiar scripts", making available otherwise unused cognitive resources that help students in dealing with a difficult problem or with new material. They also maintained that reorganization of lesson format to attend specifically to linguistic and cultural variations can promote educational excellence (Cole and Griffin, 1987). These researchers suggest that research is needed on the context-rich methods of instruction including those that involve culturally valued and pleasurable content. This statements supports the argument that a textbook that is culturally tailored to Puerto Rican students might improve the students interest in this topic and, hopefully, academic achievement in physics.

The Contextual Teaching and Learning Project web site (College of Education, University of Georgia, 2000) also summarized the basic concept of contextual teaching and learning and its relationship to the goals of education:

> These goals [of education] will be achieved through contextual teaching and learning by embedding lessons within meaningful contexts. We believe this will result in deeper foundational knowledge. Also, learners will have a richer understanding of the problem and the ways to solve the problem. They will be able to independently use their knowledge to solve new and unfamiliar problems. They will take more responsibility for their own learning as they gain experience and knowledge (p. 1)

In the same web site, the basic characteristics of contextual teaching and learning were pointed out (College of Education, University of Georgia, 2000):

- Students are actively engaged
- Students view learning as relevant
- Learning is related to "real world" and/or simulated issues and meaningful problems
- Appreciating students' diverse life contexts and prior experiences are fundamental to learning
- Students are encouraged to become active participants in the improvement of society
- Learning occurs in multiple settings and contexts

- Knowledge is interdisciplinary and extends beyond the boundaries of conventional classrooms
- Learning in multiple contexts allows students to identify and solve problems in new contexts (transfer)

Other researchers argued that contextual learning is more than a specific tailored curriculum. Sternberg, in his Triarchic Theory of Intelligence, propose that there are three kinds of intelligence: (a) componential intelligence, or the ability to reason abstractly, process information, and determine the kind and sequence of operations required for a task or problem, (b) experiential intelligence, or the capacity to deal with novel tasks or new ideas, and to combine unrelated facts, and (c) contextual intelligence, or the ability to adapt, select, or shape one's environment to optimize one's opportunities (McCown, Driscoll, and Roop, 1996). This last type of intelligence is dependent on the characteristics of the environment in which a person lives. For example a student can be a very good car mechanic but not understand the underlying physical principles that make a motor work. That student will not have good grades if the physics content is decontextualized, but he will probably understand much better the physics behind a car if he selects that object as a reference in his learning, thus having a greater opportunity in demonstrating competence in the physics topics related to cars.

The effects of contextualized and decontextualized curricula has been documented in the educational literature. An example of a decontextualized curriculum is provided by the research of Erickson and Mohatt (1982). They explored classroom discourse in an American curriculum with Native-American students. The researchers discovered that Native-American students behaved in a particular way based on their perception of how they should behave in that setting by adopting the observer role that they know to be appropriate. They also believed that it was not acceptable to single out a student for praise or censure on a public occasion. American teachers perceived their classroom behavior as passive and silent. Of course the teachers were expecting active participation and classroom involvement.

On the other hand, Tharp (1982) provided a nice example of how a carefully contextualized curriculum can be successful. This researcher report the results of an elementary reading curriculum, the Kamehameha Early Education Program, that was specially designed taking into consideration the distinct cultural characteristics of students of Polynesian and Hawaiian ancestry. His conclusion was that the effectiveness of the innovative and culturally relevant reading curriculum suggests that cultural compatibility in instruction can help minorities in their academic learning.

A researcher must be careful with the use of words to denote specific concepts. Context and context relevance, as perceived in this document, is not necessarily the same as context relevance theory from special education. Sailor, Goetz, Anderson, Hunt, and Gee (1988) use the term contextual relevance theory that predicts generalization and maintenance of newly learned skills by students with extensive and severe disabilities. Although some aspects of this theory can be useful in this study (the utility of the new skill, the social context in which the skill is acquired, the practicality of the skill for the student, and the adaptation of the new skill to different situations), this particular conception of contextualism might not be totally useful.

Contextual learning as an area of research is still full of interesting and challenging questions. Alexander and Murphy (1999) argued that many in cognitive psychology have only recently reawakened to the force of contextual and situational factors and its effects on learning and development. Fordham (1983) pointed out that "the study of the context in which learning and teaching occur has not previously held an important place in much classroom-learning research" (p. 7). It is pertinent then, to keep doing research in this area, especially in a Puerto Rican setting where the textbooks used are translations of American textbooks and, as a result, are probably providing decontextualized physics learning experiences that students may not be able to understand.

Multicultural Education

Given the fact that we are considering educational issues in the context of the American and Puerto Rican cultures, it is necessary to evaluate the literature on multicultural education. Multicultural education has been defined by several researchers. For example, Banks and McGee Banks (1995) provided this definition of multicultural education: "Multicultural education is a field of study and an emerging discipline whose major aim is to create equal educational opportunities for students from diverse racial, ethnic, social-class and cultural groups". (p. xi). Banks (1993) expands this idea by conceptualizing multicultural education as a process, not a monolithic field of study that stays too much theoretical and too little practical.

Gay (1995), while presenting several definitions of multicultural education provided by other researchers, summarizes the main point that a definition of multicultural education should have. She argues that multicultural education is "a concept, a framework, a way of thinking, a philosophical viewpoint, a value orientation, and a set of criteria for making decisions that best serve the educational needs of culturally diverse student populations". (p. 28). She also perceived multicultural education as a reform movement whose purpose is to promote the critical assessment of all the components that constitute the educational system and modify them in such a way that provide equal educational opportunities to all the members of our pluralistic society. She also perceived multicultural education as a self-standing and rigorous field of study with an adequate and ever increasing scholarship.

According to Gay (1995), Nieto (1992) presents what she considers the most eclectic and comprehensive definition of multicultural education. Nieto (1992) defined multicultural education in the following way:

> [Multicultural education is] a process of comprehensive school reform and basic education for all students. It challenges and rejects racism and other forms of discrimination in school and society and accepts and affirm the pluralism … that students, their communities, and teachers represent … because it uses critical pedagogy as its underlying philosophy and focuses on knowledge, reflection and action (praxis) as the basis for social change, multicultural education furthers the democratic principles of social justice (p. 208).

Grant (1994) argued that multicultural education is both a philosophical concept and an educational process. As a philosophy, multicultural education builds in the ideals of freedom, justice, equality, equity, and human dignity that are the backbone of the American society. As an educational process, multicultural education takes place in schools and other educational institutions and “informs all academic disciplines and other aspects of the curriculum” (p. 4) by providing knowledge about the history, culture, and contributions of diverse groups to our society. This researcher also suggested that the school staff must be multi-racial and multiculturally literate, and that some staff must be fluent in more than one language.

Multicultural education comes from a critical theory perspective. As such, multiculturalists argued that people of color, women, the disabled, and the poor are oppressed by racism, sexism, and classism, and that a multicultural education will "empower students so that they may have the courage, knowledge and wisdom to control their life circumstances and transform society (Grant, 1994, p. 6).

Multicultural education is a complex and multidimensional concept. Banks (1993) summarized its five main dimensions (p. 25-27):

- Content integration deals with the extent to which teachers use examples, data, and information from a variety of cultures and groups to illustrate the key concepts, principles, generalizations, and theories in their subject area or discipline.
- Knowledge construction encompasses the procedures by which social, behavioral, and natural scientists create knowledge in their disciplines; a multicultural focus include discussion of the ways in which the implicit cultural assumptions, frames of reference, perspectives, and biases within a discipline influence the construction of knowledge.
- Prejudice reduction focuses on the characteristics of children's racial attitudes and on strategies that can be used to help students develop more positive racial and ethnic attitudes.

- Equity pedagogy invites teachers to use techniques and teaching methods that facilitate the academic achievement of students from diverse racial and ethnic groups and from all social classes.
- An empowering school culture and social structure requires the restructuring of the culture and organization of the school so that students from diverse racial, ethnic, and social-class groups will experience educational equality and a sense of empowerment by conceptualizing the school as a unit of change and by making structural changes within the school environment.

In addition, Nieto (1994) argues that the internalization of a multicultural education perspective has several levels of interaction toward people from a different background:

- Tolerance, or to endure differences, but not necessarily embrace them.
- Acceptance, or to acknowledge differences; their importance is not denied or belittled.
- Respect, or to admire and have a high esteem for diversity; differences are used as the basis for much of what can go on in a school.
- Affirmation, solidarity, and critique; the differences that students and their families represent are embraced and accepted as legitimate vehicles for learning; conflict is not avoided, but accepted as an inevitable part of learning.

Multicultural education has expanded at an accelerated rate since the movement took its contemporary form in the late 1960's and 1970's. It included, among other themes, issues related to history, curriculum, systemic initiatives, research, cognition, philosophy, epistemology, culture, teaching, assessment, and language. Multicultural education is being implemented widely in various educational setting, from preschool to higher education, although it is not free from challenges and criticism (Banks, 1993).

Summary of Second Chapter

In the previous chapter the literature associated with the history of secondary education in Puerto Rico during the last century was explored. It was not hard to notice the inter-relation between education and government policy/ideology. This is not surprising, given Puerto Rico's centralized public education structure and the closeness between political parties and status options.

Also, a summary of the limited information available of the origins of physics education in Puerto Rico was offered. An important piece in this summary is Court's (1972) study on the importation of the Harvard Project Physics curriculum in local schools and how its implementation was negatively influenced by cultural and linguistic limitations.

Finally, the literature associated with contextual teaching and learning and multicultural education was reviewed. The next chapter will provide the reader with details associated with the methodology of this study.

CHAPTER 3

METHODOLOGY

Overview

In this chapter, a detailed explanation of the methodology of this study will be presented, including a description of the population of interest, sample section, procedures for collecting the research data, and a brief explanation of the statistical analysis that will be performed.

Sample

Of the more than 120 physics teachers contacted during the eight-week period of data collection in Puerto Rico, ninety-two public high school physics teachers from the east and south of Puerto Rico participated in this study by returning the research instruments in person or by mail. These teachers were contacted by visiting their schools during the eight-week period of data collection in Puerto Rico. The participants were not randomly selected, making this a convenience sample. This, however, should not present any significant issue in terms of the assumptions underlying the statistical analysis that are performed. Given the limited geographical area of Puerto Rico (3427 sq. mi., or roughly twice the area of Delaware), ninety-two high school physics teacher comprise about one third of the total population of interest, which makes this sample more than representative.

The sampling strategy consisted in visiting as many public high schools as possible in a five-week period. On the first visit, physics teachers were identified and contacted. Also, teachers received a brief explanation of the purpose and procedures of the study, and a questionnaire was provided if they decided to participate on the study. Schools were visited a second time to gather completed questionnaires or leave a self-addressed stamped envelope for teachers to send their completed questionnaires to the researcher’s work address. During the last three weeks of data collections, 21 teachers were visited a third time for them to be interviewed. The criteria for selecting which teachers to interview were both their responses to the research instruments and their geographical location.

Variables

To collect the research data, mostly quantitative instruments were used, though interview and short answer questions complement this data. The variables on which this study focuses, along with a description of the instruments created to collect these data, are next given.

The quantitative portion of this study has three dependent variables and eleven independent variables. However, the use of the terminology "independent" and "dependent" variables is not the same as in an experimental research, because there is no manipulation of independent variables. Given the fact that I am exploring "already existing conditions" that are occurring at this very moment in Puerto Rican high schools, this type of research is usually referred to as ex post facto or causal-comparative research

(Best & Kahn, 1989). These researchers explained the importance of ex post facto research design in education:

> Ex post facto and causal-comparative research is widely and appropriately used, particularly in the behavioral sciences. In education, because it is impossible, impracticable, or unthinkable to manipulate such variables as aptitude, intelligence, personality traits, cultural deprivation, teacher competence, and some variables that might present an unacceptable threat to human beings, this method will continue to be used. (p. 104)

The dependent variables in this study are (a) the degree to which the Puerto Rican high school physics teachers modify the physics content presentation to make it more contextual and culturally relevant to the student population they serve, (b) the degree to which the Puerto Rican high school physics teachers modify their teaching methodologies to make them more contextual and culturally relevant to the student population they serve, and (c) the perceived degree of confidence in their physics knowledge. In this study there are eleven independent variables, which are:

- Gender
- Years of teaching experience
- Years of experience as a physics teacher
- Academic preparation in physics
- School size
- Zone of school
- Number of students per physics class
- Perceived freedom to change the physics curriculum

- Perceived freedom to change their teaching methodology
- Perceived quality of the physics textbook
- Political beliefs

The independent variables were chosen based on several criteria. One group of these variables can be called demographic variables and provide general information about the participants, which might or might not be related to the dependent variables of interest. Examples of demographic variables are the participant's gender, age, and years of general teaching experience.

A second group of variables were specifically selected based on my experience, preparation and knowledge of the Puerto Rican education and culture. They were considered important and with a strong potential for a significant relationship with the dependent variables. Examples of these variables are the teachers' years of experience teaching physics, academic preparation in physics, number of students per physics class, perceived freedom to change the physics curriculum and their teaching methodologies, perceived quality of the physics textbook, and the teachers' political/ideological beliefs.

A third group of variables were included to support the validity of the study by producing non-significant results purposefully. Examples of these variables were school size and school zone. Based on the centralized procedures the Puerto Rico Department of Education use to place teachers, no difference was expected between teachers in urban, suburban, or rural areas, or from teachers from small, medium-sized, or large schools. Statistically significant results in these variables might have placed the validity and reliability of the instruments in question.

Hypotheses

By using a hypothesis-testing notation, the null hypotheses of this study is:

- There will be no significant difference in the (a) degree to which the high school physics teachers modify the physics curriculum, (b) degree to which the high school physics teachers modify the teaching methodologies, and (c) perceived degree of confidence of the teachers' physics knowledge among teachers with different gender.
- There will be no significant difference in the (a) degree to which the high school physics teachers modify the physics curriculum, (b) degree to which the high school physics teachers modify the teaching methodologies, and (c) perceived degree of confidence of the teachers' physics knowledge among teachers with different years of teaching experience.
- There will be no significant difference in the (a) degree to which the high school physics teachers modify the physics curriculum, (b) degree to which the high school physics teachers modify the teaching methodologies, and (c) perceived degree of confidence of the teachers' physics knowledge among teachers with different years of physics teaching experience.
- There will be no significant difference in the (a) degree to which the high school physics teachers modify the physics curriculum, (b) degree to which the high school physics teachers modify the teaching methodologies, and (c) perceived degree of confidence of the teachers' physics knowledge among teachers with different academic preparation in physics.
- There will be no significant difference in the (a) degree to which the high school physics teachers modify the physics curriculum, (b) degree to which the high school

physics teachers modify the teaching methodologies, and (c) perceived degree of confidence of the teachers' physics knowledge among teachers from schools with different total student enrollment.

- There will be no significant difference in the (a) degree to which the high school physics teachers modify the physics curriculum, (b) degree to which the high school physics teachers modify the teaching methodologies, and (c) perceived degree of confidence of the teachers' physics knowledge among teachers from different school zones.
- There will be no significant difference in the (a) degree to which the high school physics teachers modify the physics curriculum, (b) degree to which the high school physics teachers modify the teaching methodologies, and (c) perceived degree of confidence of the teachers' physics knowledge among teachers with different number of students per class.
- There will be no significant difference in the (a) degree to which the high school physics teachers modify the physics curriculum, (b) degree to which the high school physics teachers modify the teaching methodologies, and (c) perceived degree of confidence of the teachers' physics knowledge among teachers with different perceived freedom to change the physics curriculum.
- There will be no significant difference in the (a) degree to which the high school physics teachers modify the physics curriculum, (b) degree to which the high school physics teachers modify the teaching methodologies, and (c) perceived degree of confidence of the teachers' physics knowledge among teachers with different perceived freedom to change their teaching methodology.

- There will be no significant difference in the (a) degree to which the high school physics teachers modify the physics curriculum, (b) degree to which the high school physics teachers modify the teaching methodologies, and (c) perceived degree of confidence of the teachers' physics knowledge among teachers with different quality perceptions of the textbook.
- There will be no significant difference in the (a) degree to which the high school physics teachers modify the physics curriculum, (b) degree to which the high school physics teachers modify the teaching methodologies, and (c) perceived degree of confidence of the teachers' physics knowledge among teachers with different political beliefs.

Instruments

In order to gather the experimental data, three quantitative instruments and two qualitative data-gathering options (structured interview protocol and short answer questions) were developed by the researcher. The first quantitative instrument was the Textbook Relevance Degree of Change Instrument (TRI).

This instrument was created to measure one of the dependent variables. It uses a Likert-type numerical scale (between 1 and 5) and an additional N/A option. The TRI is composed of 20 topics usually covered in a typical high school physics course (for example: motion, forces, momentum, gas laws, sound, light, etc.). The role of the teacher is to evaluate his/her degree of modification of those topics to make them more contextual and culturally relevant to their students.

In this instrument's scale, selecting "1" implied that the teacher did not make any modification in the way they present physics concepts discussed in the textbook to account for the characteristics and experiences of Puerto Rican students. On the other hand, selecting "5" implied that the teacher used examples with common materials and familiar situations, applied the physics concepts to problems of local relevance, included components of the Puerto Rican culture in the explanations, and connected the physics concepts with Puerto Rican realities. Intermediate numbers are assumed to represent a linear transition between the two extremes. The N/A option will be selected only if the teacher does not teach that particular topic in his/her class.

In addition, a section is provided for teachers to evaluate their degree of confidence of the different physics topics presented, which is the second dependent variable. This variable was also measured on a 1 to 5 scale, in which selecting "1" implies that the teacher is completely unsure (total lack of confidence) about his physics knowledge, "2" implies that the teachers is partially unsure (partial lack of confidence) about his physics knowledge, "3" implies that the teacher is undecided about his confidence in his physics knowledge, "4" implies that the teacher is partially sure/confident of his physics knowledge, and"5" implies that the teacher is completely sure/confident of his physics knowledge.

The second quantitative instrument was called the Teaching Methodology Degree of Change Instrument (TMI), created to measure the third dependent variable. It also uses a Likert-type numerical scale (between 1 and 5) and an additional N/A option. The TMI is composed of 19 common teaching techniques used by teachers in a typical high school course (for example: lecture, demonstration, laboratory, group projects, etc.). The role of the teachers is to evaluate his/her degree of modification of those teaching techniques to make them more contextual and culturally relevant to the needs, experiences, and particularities of their students.

In this instrument's scale, selecting "1" implied that the teacher did not make any modification in their teaching methodologies to account for the characteristics and experiences of Puerto Rican students. On the other hand, selecting "5" implied that the teacher adapted his teaching methods to include problems and situations of local relevance, used materials and equipment readily available in the community, and included components of the Puerto Rican culture. Intermediate numbers are assumed to represent a linear transition between the two extremes. The N/A option will be selected only if the teacher does not use a particular teaching technique in his/her class.

The third quantitative instrument was called the High School Physics Teacher's Demographics Survey (DS). It was created to gather information about the independent variables in a fast and efficient way.

The first qualitative data-gathering option was the Textbook Relevance Degree of Change Questionnaire (TRQ). This instrument included six questions in which teachers must provide short written answers, and are ask the following questions:

- Do you think that physics concepts can be taught in contextual, culturally relevant ways for Puerto Rican students? Why or why not?
- Do you think that teaching physics concepts in a contextual, culturally relevant way can improve Puerto Rican students' academic achievement in physics? Why or why not?

- Do you think that the textbook you are using is appropriate to the context and cultural background of Puerto Rican students?
- How do you incorporate modifications in the physics curriculum to make it contextual to your students? Please provide a few examples.
- How do you incorporate modifications in the physics curriculum to make it more culturally relevant to your students? Please provide a few examples.
- How do you modify your teaching strategies and techniques to help your students learn the physics content better?

The second qualitative data-gathering option was a structured interview for a selected group of teachers (21 participants). The following questions were asked:

- What do you do to contextualize your teaching? What examples from the students' everyday life do you use?
- Do you think that physics concepts and our Puerto Rican culture can be combined?
- What is your opinion about the physics textbook that you are currently using? What would you do to improve the textbook?
- What do you think is the students' opinion of the physics textbook they use?
- Do you think that a teacher who has a pro-statehood ideology will be less critical of the physics textbook actually used because it was made in the United States?
- Do you think that teachers who believe in commonwealth and independence will include more aspects of the Puerto Rican culture in their physics class?

The questions in the structured interview and the short answer questionnaire provided a complementary qualitative description about how those changes made, and if the changes are substantial and well thought-out, or cosmetic.

Role of the Pilot Study

Before the final version of the research instruments was ready, a pilot study was conducted. The purpose of the pilot study was to determine whether the instructions and items of the quantitative instruments were easily understood and accurate in terms of the variables of interest. In the pilot study, the TRI, TMI, and DS instruments were given to seven high school physics teachers, located mostly in the northwest region of Puerto Rico. Their answerers were received by mail and analyzed.

In general, the seven physics teachers who participated in the pilot study understood most of the instruments items. Only the format of the item associated with the teachers' political beliefs, originally a straight line in which teachers locate themselves between two ideological extremes (statehood and independence), proved to be confusing to some teachers. As a consequence, the format of this item was modified. The responses to the rest of the items did not show any confusion, suggesting that the participants understood what was asked of them.

Although the pilot study produced some quantitative data, the extremely low sample size prevented me from doing any relevant statistical analysis. In addition, with a sample size of seven, some categories had only one participant. Overall, the mean for the teachers' perceived confidence in their physics knowledge turned out to be high, around 4.0, which is consistent to subsequent data analysis. Also, the mean for change in teaching methodology to make it more contextual and culturally relevant was higher than the mean for the change in physics content presentation (3.75 and 3.45 respectively), which is also consistent with subsequent data analysis.

Despite the fact that the number of participants was very small compared to the expected sample size before data collection (about 80 teachers), the mean results were roughly comparable to the data analysis of the 92 participants.

Data Analysis

In this study, both quantitative and qualitative techniques were used. Quantitative techniques are based on the collection and analysis of numerical data, while qualitative techniques are based on the collection and analysis of non-numerical data, such as interview transcripts. Research suggests that these techniques, commonly called mixed-methods research are complementary rather than contradictory (Onwuegbuzie, 2000; Reichardt and Rallis, 1994; Brannen, 1992; Wang, 1992). For example, Gay and Airasian (1996) argued that these approaches "represent complementary components of the scientific and disciplined inquiry approach; qualitative research involve primarily inductive reasoning while quantitative approaches involve primarily deductive reasoning" (p. 10). Goodwin and Goodwin (1996) also agreed with the combination of quantitative and qualitative research:

> We sense no inherent incompatibility between quantitative and qualitative approaches to the generation of knowledge … the two major types of research, while different, have unique strengths and limitations that can render their combined use both logical and wise.(p. 157)

I believe that both approaches provide a more complete answer to the research questions.

One of the main purposes of quantitative research is to quantify variance and to separate it into different portions, which usually correspond to the independent variables of the study (Wiersma, 2000). In this case, one-way analysis of variance is used as the main statistical technique. Two-way multivariate analysis of variance was also used on two pre-selected independent variables.

Analysis of variance is an inferential statistical procedure used to detect significant differences in means for two or more populations or groups of people with different characteristics. It tests the null hypothesis that different groups' means (for a given dependent variable) are equal. The data available provided thirty one-way tests between the independent and dependent variables, and three two-way tests between two specific independent variables and the dependent variables. The significance level was determined to be at 0.05, providing a balance between being too lax or too strict in the acceptance or rejection of significant differences between the variables.

In addition to numerical data, other data was also gathered through short answer questions printed in a questionnaire and a structured interview. Both formats were used because, although more participants (92 of them, compared to 21 interviewed) answered the short answer questions, it has some disadvantages. Non-responses, incomplete responses, respondents who did not answer the original question, poorly worded or ambiguous responses are just some examples of those disadvantages. On the other hand, interviews guarantee responses that are more detailed, and provide for elaboration and clarification (Wiersma, 2000).

For the qualitative data analysis of the short answer questions, the participant's responses were assigned a code number to preserve confidentiality and transcribed in Spanish into a single word-processing document to maintain an accurate record of each participants' responses. Then, the data was classified according to questions. All the answers to the same questions were placed on a single file, providing me the opportunity to study, compare and contrast all the responses to the same question. After reading the participants' responses, I noticed some common responses and some opposing viewpoints, which created both descriptive and interpretative categories and patterns that are presented in the analysis section. For some questions, the variety of responses created a large number of categories, but the strength of some categories provided the rationale to explore those in more detail. Representative quotes that supported the emerging categories were carefully translated from Spanish into English.

The analysis of the interview data was similar. Each audiotape received a code number to preserve the participant's confidentiality and was transcribed in Spanish into a single word-processing document for each participant. The data was subsequently rearranged and classified according to each of the structured interview questions. All the answers to the same questions were placed on a single file, providing me the opportunity to study, compare and contrast all the responses to the same question. This process revealed both common responses and contradicting perspectives, which created the categories and patterns that are presented in the corresponding analysis section. As in the case of the analysis of short answer questions, the diversity of answers created a large number of categories, but these were collapsed into those that were more meaningful and informative. Representative quotes that supported the emerging categories were carefully translated from Spanish into English.

Power Considerations

On an experimental setting, we establish null hypothesis that are accepted or rejected depending on a variety of factors. Because of measurement error, the researcher is never 100% sure that the decision made corresponds to what happens in reality. According to Hinkle, Wiersma and Jurs (1994), when we decide to reject or not reject the null hypothesis, there are four possible scenarios:

- A true null hypothesis is rejected.
- A true null hypothesis is accepted.
- A false null hypothesis is rejected.
- A false null hypothesis is accepted.

Let’s start by mentioning the wrong decisions. If a true null hypothesis is rejected, the researcher made a Type I error. Type I error can also be thought as the odds of saying that there is a relationship between independent and dependent variables when in fact there is not. If a false null hypothesis is accepted, the researcher made a Type II error. Type II error can also be thought as the odds of saying that there is no relationship between independent and dependent variables when in fact there is a relationship (Hinkle, Wiersma and Jurs, 1994; Trochim, 1999).

The goal of the researcher must be to minimize both types of error, that is, to maximize the research level of confidence and power. By increasing the power of a statistical test, we are increasing its sensibility, or capacity to find even relatively small differences that are significant (Diekhoff, 1996). Cohen and Cohen (1983) argued that the researcher must take into consideration power issues in his study.

For this study, all possible efforts were made to maximizing its expected power within the limitation of the researcher. Diekhoff (1996) identified four main factors (choice of level of significance, choice of sample size, size of the effect of interest, and error variance in the population). Of those, I focused on the first two: choice of level of significance and choice of sample size.

When researchers adopt a liberal level of significance, they are making it easier for the statistical test to find significant differences, even if they are not that large. By increasing level of significance, we can increase the sensitivity of the test (power). Due to the nature of this study and the limitations of quantitative educational research, choosing a conservative significance level, like 0.01 or 0.001, is not recommended. Also, choosing a liberal significance level, like 0.1 or 0.2, is not a good option because of the number of univariate and multivariate tests performed and the risk of chance capitalization. As a way to both increase power and acknowledge the limitations of my study, a significance level of 0.05 was selected, although this was considered flexible at times.

A difference of a given amount is more likely to be found significant if the researchers have a large sample size. A large sample size also reduces the sample variance. As a consequence, statistical tests are more able to recognize two variances as different. By increasing the sample size, we can increase the sensitivity of the test (power). During my visit to Puerto Rico I contacted as many teachers as possible to gather the largest possible sample size. At the end of data collection, the sample size consisted of 92 teachers, or about 1/3 of the total population of public high school physics teachers in Puerto Rico. Such a large proportion of participants out of the total population is an excellent indication that the study will be sensitive enough to make population generalizations.

Reliability and Validity Considerations

The concepts of reliability and validity are two of the underlying building blocks in educational research. As researchers, we must take into consideration to what extent the results of a study could be replicated and whether we have enough empirical evidence to support the conclusions of a study.

Since there is a great variety of textbooks on educational measurement and test construction available, many sources for definitions of reliability and validity are available. For simplicity purposes, only the definitions by Colosi, (1997), Thorndike (1997), Walsh and Betz (1985), Sax (1980), and Cook and Campbell (1979) will be presented. These authors were selected mainly because they represent, in my opinion, the typical definitions of reliability and validity.

Colosi (1997) defines reliability as “the consistency of your measurement, or the degree to which an instrument measures the same way each time it is used under the same condition with the same subjects. In short, it is the repeatability of your measurement. A measure is considered reliable if a person's score on the same test given twice is similar. It is important to remember that reliability is not measured, it is estimated.” Thorndike (1997) defines reliability simply as “the accuracy and precision of a measurement procedure” (p. 96). Also, Walsh and Betz (1985) presented their definition of reliability as “the extent to which we are measuring some attribute in a systematic and therefore repeatable way” (p. 47). Finally, Sax (1980) defined reliability as “ the extent to which measurements can be depended on to provide consistent, unambiguous information. Measurements are reliable if they reflect “true” rather than chance aspects of the trait or ability measured” (p. 255-256).

In this study, reliability was achieved by combining several strategies. The three data gathering procedures (questionnaire, interviews, short answer questions) were designed to be consistent with one another by being guided by the research questions. In addition, the use of multiple methods of data collection provided some triangulation to the study, especially for the qualitative data. Another strategy to ensure reliability was to be as uniform as possible in the data collection and analysis process. This is evidenced in the way the short answer and interview chapter were presented and discussed.

The design of instruments specifically for the collection of data on independent and dependent variables in this study, which is unique in many aspects, and the use of instruments and questions in Spanish to collect data are also supportive of reliability. The last strategy the researcher used to ensure reliability was to provided a detailed description of the research design, subjects, and instruments so that other researchers have enough information to replicate this study if they so desire.

Cook and Campbell (1979) defined validity as the strength of our conclusions, inferences or propositions. More formally, it can be defined as the best available approximation to the truth or falsity of a given inference, proposition or conclusion (Cook and Campbell, 1979). In short, were we right? (Colosi, 1997). Thorndike (1997) defined validity as “the degree to which the test scores provide information that is relevant to the inferences that are to be made from them” (p. 96). Also, Walsh and Betz (1985) presented their definition of validity as “the extent to which the test we are using actually measures the characteristic or dimension we intend to measure" (p. 56). Finally, validity is defined by Sax (1980) as "the extent to which measurements are useful in making decisions relevant to a given purpose".

To ensure internal validity (the extent to which results can be interpreted accurately) and external validity (the extent to which results can be generalized), several strategies were followed. First, I used the same instruments and questions for all the participants. These instruments were piloted prior to formal data collection to make sure items were clear and precise, and questions were simply worded and focused. A few items were modified after the pilot stage to ensure item accuracy.

Second, some of the statistical tests were specifically designed to support the validity of the study. Based on my knowledge of Puerto Rico and its education system, I hypothesized that some of the variables selected (like the school's geographical location or the school size) would not gave significant results, and they did not.

Third, although random selection of subject was not possible due to time constraints, efforts were made to compensate for this. For example, the sampling procedure covered an extensive geographical area (39 out of 78 municipalities, including four of the largest municipalities). Also, the use of a large sample proportion (about 1:4) is a factor that contributes to the validity of the conclusions. Finally, to prevent dishonesty in the data collected, the participants were informed that their confidentiality would not be compromised by the use of a numerical code in questionnaires and transcripts.

Summary of Third Chapter

In the previous chapter the researcher described the study's sample, introduced the independent and dependent variables, and used hypothesis notation to establish the null hypothesis under consideration. In addition, a thorough report of the quantitative and qualitative data-gathering instruments was presented, along with the statistical techniques used to analyze the quantitative data collected and a description of the qualitative data was analyzed. Finally, power, reliability, and validity were considered.

In the next chapter, the findings for the quantitative component of the study will be presented, discussed, and analyzed.

CHAPTER 4

STATISTICAL ANALYSIS

Overview

In the following section, the statistical results, including detailed descriptive information of the independent and dependent variables, univariate tests between the independent and dependent variables, and a multivariate test combining two previously selected independent variables, are presented and discussed. Data from the independent variables was collected through a written instrument in which teachers responded a number of categorical items. The independent variables included:

- Gender
- Years of experience as teachers (general)
- Years of experience as physics teachers
- Academic preparation in physics
- School geographical location
- School size
- Number of students per class
- Perceived freedom to change the physics curriculum
- Perceived freedom to change the teaching methodology
- Perceived quality of physics textbook used
- Political status preference

Data for the dependent variables was gathered through Likert-type instruments in which teachers responded on a 1 to 5 scale. For the variable “average change in the physics content presentation”, one extreme of the scale represented the option of no modifications to the physics content presentation to include context and cultural relevance and the opposite extreme represented the option of making modifications to this content to include the Puerto Rican culture and context in twenty selected physics topics. For the variable “average change in teaching methodology” one extreme of the scale represented the option of no change in the teaching methodologies to enhance contextual and cultural relevance and the opposite extreme represented the option of making modifications to these methodologies to include the Puerto Rican culture and context in nineteen commonly used teaching methodologies. For the variable “average degree of confidence teachers have of their own physics knowledge”, one extreme of the scale represented total lack of confidence in their subject matter knowledge and the opposite extreme represented absolute confidence in their subject knowledge for twenty selected physics topics.

Thirty univariate test between the independent and dependent variables were performed using analysis of variance. Analysis of variance (ANOVA) was used to test hypotheses about the equality or difference of two or more means. A confidence level of 0.05 was selected because it provides a good balance between being too conservative and thus failing to detect a significant relationship, and being too liberal and detecting false positives that might not be replicated in further research.

Finally, the results from a multivariate test between “years of experience as physics teacher” and “academic preparation in physics”, variables selected *a priori*, was reported and discussed. After each section, a discussion of the findings follows, in which the most important of them will be summarized. Also, statements that might explain particular findings and additional context will be provided. At the end of all section, a summary highlighting the main statistical findings will be included.

Findings: Descriptive Data for Independent Variables

First, for the “gender” variable, it was found that there were 44 (47.8%) females and 48 (52.2%) male participants, for a total of 92 participants.

For the “age” variable, it was found that there were 2 (2.2%) participants between 21-25 years old, 7 (7.6%) participants between 26-30 years old, 12 (13%) participants between 31-35 years old, 14 (15.2%) participants between 36-40 years old, 24 (26.1%) participants between 41-45 years old, 18 (19.6%) participants between 46-50 years old, 13 (14.1%) participants between 51-55 years old, no participants between 56-60 years old, and 2 (2.2%) participants with more than 61 years old. The mean age is approximately 42 years old.

For the variable “years of experience as teacher”, it was found that there were 11 (12%) participants with 1 - 5 years of experience, 14 (15.2%) participants with 6 -10 years of experience, 18 (19.6) participants with 11 -15 years of experience, 12 (13%) participants with 16 - 20 years of experience, 23 (25%) participants with 21 - 25 years of experience, 8 (8.7%) participants with 26 - 30 years of experience, and 6 (6.5%) participants with more than 30 years of experience as teachers. The average number of years of experience for the sample is approximately 17 years.

For the variable “years of experience as physics teacher”, it was found that there were 42 (45.7%) participants with 1 – 5 years of experience, 22 (23.9%) participants with 6 – 10 years, and 9 (9.8%) participants with 11 – 15 years of experience, 11 (12%) participants with 16 – 20 years, 6 (6.5%) participants with 21 – 25 years, and one participant (1.1%) each with 25 – 30 and 30+ years of experience as physics teachers. The average years of experience as physics teachers is approximately 9 years.

For the variable “academic preparation in physics”, operationally defined as the number of physics semester courses, it was found that there were 24 (26.1%) participants with 0 – 2 semesters of physics, 29 (31.5%) participants with 3 – 5 semesters, 15 (16.3%) participants with 6 – 8 semesters, 8 (8.7%) participants with 9 – 11 semesters, 3 (3.3%) participants with 12 – 14 and 15 – 17 semesters of physics each, and 9 (9.8%) participants with more than 18 semesters in this subject area. The average number of semesters of physics for this sample is approximately 6 semesters.

School type: There were 84 participants from public school and 7 from private school. This disproportion was caused by logistical difficulties for interviewing teachers in private schools. As a consequence, this variable will not be considered for statistical analysis.

School zone: There were 61 (66.3%) participants from urban schools, 9 (9.8%) from suburban, and 18 (19.6%) for rural schools.

School size: There were 7 (7.6%) participants from relatively small schools, 36 (39.1%) from medium-sized schools, and 47 (51.1%) from relatively large schools. Although the definition of school size was left for the teacher to decide based on his own situation (for example, a teacher might consider his school as medium-sized compared to near high schools despite the fact that might have the same number of students as another school classified as small sized), in general terms, A small Puerto Rican high school might have between 230 and 600 students (median is approximately 440 students) a medium-sized school might have between 600 and 830 students (median is approximately 710 students), and a large high school might have between 830 and 1300 students (median is approximately 940 students).

For the variable “number of students per class”, it was found that there were 2 (2.2%) participants who had between 1 – 10 students, per physics class, 12 (13%) participants who had between 11 – 20 students, 49 (53.3%) participants who had between 21 and 30 students, and 29 (31.5%) participants who had more than 30 students per physics class. The average number of students per physics class is approximately 25 students.

For the variable “perceived freedom to change the physics curriculum” it was found that there were 12 (13%) participants who perceived that they have no freedom at all to change the curriculum, 57 (62%) participants who perceived that they have some freedom, and 20 (21.7%) participants who perceived that they have absolute freedom to change the physics curriculum.

For the variable “perceived freedom to change the teaching methodology” it was found that there were 5 (5.4%) participants who perceived that they have no freedom at all to change their teaching methodology, 52 (56.5%) participants who perceived that they have some freedom, and 30 (32.6%) participants who perceived that they have absolute freedom to change their teaching methodology.

For the variable “quality of text’ it was found that there were 7 (7.6%) participants who evaluate the textbook as excellent, 47 (51.1%) participants as good, 31 (33.7%) participants as average, 4 (4.3%) participants as deficient, and one (1.1%) participant as poor.

For the variable “political status preference’ it was found that there were 21 (22.8%) participants who have pro-statehood ideological beliefs, 27 (29.3%) participants who have pro-commonwealth ideological beliefs, 8 (8.7%) participants who have pro-associated republic ideological beliefs, and 16 (17.4%) who have pro-independence political beliefs. However, 20 (21.7%) participants leave this item blank, answered something else, or provided multiple answers.

Discussion: Descriptive Data for Independent Variables

The variable “age” provides evidence, in addition to what the educational literature presents, of a potential future science teacher shortage. Looking at the data, very few young science and physics teachers are entering the profession (approximately 10%), compared to those who should be leaving within the next decade (approximately 34%). This is already a cause for concern in Puerto Rican education circles, where some reform in science teacher education is being considered.

The variable “years of experience” looks mostly the way it should be expected, with less numbers of people in the extremes of the distribution (approximately 27% of novice teachers and 15% of very experienced teachers), and the plurality of people concentrated in the center of the distribution (approximately 42%). This contrasts significantly with the variable “years of experience as physics teachers”. This variable is distributed in an odd way, with about 70% of the people in the novice extreme, 28% of the people in the center of the distribution, and only 2% of the people in the other extreme. This suggests that most of the actual teachers who teach physics did not start in this subject area. From the data, a reason for this discrepancy cannot be ascertained. However, based on my discussions with the teachers, I can speculate a number of possible scenarios that fit the data at hand. The most probable one is that experienced science teachers (usually in biology) are, voluntarily or involuntarily, chosen to teach one or two sections of physics to compensate for increased enrollment. The increased enrollment can be explained by a change of educational policy in the mid 1990's. When I studied my senior year in school, about 1987, only two sciences were requisite. Students tended to choose biology and chemistry because they are perceived as easier than physics. Only students who wanted to go to college, or those who were interested in the class, took physics in our senior year. At some point in the 1990's, the Puerto Rico Department of Education decided to increase the science requirement from two to three classes. Now, students take biology, chemistry and either physics or environmental sciences. When the environmental sciences get full, students are automatically enrolled in physics. The number of physics sections offered increased from one (when I studied) to three (in the same school I studied) or up to five, six or maybe more in some large schools.

A second scenario might be that some science teachers started as such, but then later, through professional development or advanced degrees, received physics certification and are teaching physics now. Several teachers mentioned participating in an alternative physics certification program provided by the University of Puerto Rico at

Mayaguez and Cayey. Some of the teachers, however, did not finish it, but just by taking some physics courses makes them prepared enough to teach high school physics. These two possibilities are complemented with the recruitment of new teachers who may not be prepared in physics, but are placed in some or all physics classes. An overarching theme from these scenarios is that there is a shortage of more qualified teachers, coupled with the belief that science teachers can teach any science.

The fact that about 26% of the teachers have 2 semesters of physics or less is very disturbing, and provides additional evidence that a number of teachers who are teaching physics do not have enough physics courses to be certified in this area. To create a context for interpreting these numbers, I think a brief discussion about physics teacher certification in PR is in order. Given the fact that the University of Puerto Rico tailored its science teaching curriculum for the Department of Education certification, it is easier to analyze the University's course offerings. Besides, certification is much more than a set of physics courses, involving specific general education courses, pre-service experiences and student teaching. I selected the University of Puerto Rico because it is one of the very few (other than the Catholic University in Ponce) which has both physics and physics teaching options.

According to the University of Puerto Rico at Rio Piedras undergraduate course catalog, for teachers to be certified in secondary education with a general science emphasis, they must take General Physics I and II, and either Physical Sciences I and II, or Life Sciences I and II, which means a minimum of two semesters of physics and a maximum of four, if the teachers take Physical Sciences. This does not take into consideration elective courses that might or might not be in physics. For teachers to be certified in secondary education with a physics emphasis, they must take eight semester hours of General Physics plus laboratory, three semester hours of calculus-based College Physics, three semester hours of Modern Physics, and either Physical Sciences I and II, or Life Sciences I and II (six semester hours each), which means a minimum of fourteen semester hours of physics and a maximum of twenty semester hours, if the teachers took Physical Sciences. Again, this does not take into consideration elective courses that might or might not be in physics. For example, in my undergraduate studies as a physics education major, I took Physical Sciences I and II (six semester hours), plus six semesters hours of physics in addition to those required, including three semester hours of Mathematical Methods in Physics and one additional three semester hour course of calculus-based College Physics. For teachers to receive a Bachelor of Science in Physics, they must take approximately 46 semester hours of physics, plus electives that might or might not be in physics. With more time, future researchers might ask physics teacher to provide transcripts and evidence of professional development courses in physics to explore this topic further.

For the variable “number of students per class”, the fact that almost one in three of the teachers interviewed have more than 30 students per class might affect student performance and quality teaching. It is well known that lower class sizes help students learn content better (see for example, Rice 1999, Ziegler, 1997, Bennett, 1987).

It is interesting that, for the variable “perceived freedom to change the physics curriculum” there were people in all three categories, despite the fact that the physics curriculum is prescribed by the Puerto Rico Department of Education. It seems like the administration has one way to look at the curriculum, but the participants have very different perspectives. For example, some teachers covered only the first chapters from the text; others reported covering most chapters (those provided in the questionnaire), while other teachers picked and chose among the chapters. Also, there might be variation in the depth of coverage per chapter (conceptual, mathematical, skimming), but that information could not be gathered by the instruments. On the other hand, the Puerto Rico Department of Education has no specific guidelines regarding teaching methodologies, which is reflected by the fact that approximately 94% of the teachers reported having some or all freedom in deciding the way to present physics content to their students.

For the variable “textbook quality”, it is interesting that approximately 60% the participants considered the textbook excellent or good, but the short answer and interview data suggested otherwise. These data will be discussed later in this report.

For the variable “status preference” it was a bit unexpected to see that the distribution of teachers across the different status options is not consistent with results from both the general elections and status plebiscites. Table 1 summarizes this information.

In this table, the second column includes the percentage of teachers who reported believing in the three status options. Since not all teachers answered this questions, the percentages do not add up to 100%. The numbers in parenthesis are normalized percentages for the teachers who did respond. The third and fourth columns report the mean percentages obtained by each party on five general elections and two status plebiscites. It is more accurate to compare the normalized percentages (with parenthesis on column two) with the mean percentages on the last two columns.

Table 1: Comparison Between Survey Data and Local Elections and Plebiscites.

Status option/ Political party	Survey data/ (adjusted)	Mean for general elections results between 1980 - 2000	Mean for 1993 and 1998 status plebiscites
PNP/statehood	22.8% / (32.8%)	47.9%	46.4%
PPD/commonwealth	29.3% / (42.2%)	46.9%	49.5%
PIP/independence	17.4% / (25.0%)	4.8%	3.5%

These discrepancies might suggest that teachers take into consideration other factors than their beliefs when voting in an election or plebiscite. For example, it is well known in Puerto Rico that people who believe in independence do not necessarily vote for the pro-independence party for various reasons, including historical disagreements between people associated with the party and other independentistas, and the perception that they might be wasting their vote by voting for a party with no chance to win an election.

In addition, approximately 9% of the participants reported believing in the associated republic status. The alternative “associated republic” is defined as a sovereign nation in full free association with the United States, by means of a bilateral compact, which can only be amended by mutual agreement. The “associated republic” must be sovereign, self-governed, and clearly outside the Territorial Clause, with full authority and responsibility for its internal and external affairs; it can enter into treaties with other nations, have their own diplomatic and consular corps, and belong to the United Nations and other international organizations (Perusse, 1987). Summarizing, the descriptive values for the independent variables, by themselves, are interesting and sometimes surprising. In addition they provide insight and context to the overall findings section.

Findings: Descriptive Data for Dependent Variables

In the conception of the study, the most important dependent variable was the average change in the physics content presentation. This variable was calculated by averaging the reported change in twenty physics topics portrayed in the textbook. The following is a more detailed analysis of the reported changes. This variable was measured on a 1 to 5 scale. In this scale, selecting “1” implied that the teacher did not make any modification in the way they present the physics concepts discussed in the textbook to account for the characteristics and experiences of Puerto Rican students. On the other hand, selecting “5” implied that the teacher used examples with common materials and familiar situations, applied the physics concepts to problems of local relevance, included components of the Puerto Rican culture in the explanations, and connected the physics concepts with Puerto Rican realities. Intermediate numbers are assumed to represent a linear transition between the two extremes. Table 2 summarizes the basic descriptive data for the twenty physics topics selected:

Table 2: Mean, Standard Deviation, Skewness, and Kurtosis for the Change in Physics Content Presentation.

Topic	N	Mean	SD	Skewness	Kurtosis
Forces	90	3.79	1.34	-0.965	-0.292
Work, Energy, Simple Machines	84	3.70	1.41	-0.767	-0.703
Motion in a Straight Line	92	3.68	1.43	-0.833	-0.629

Graphical Analysis of Motion	90	3.67	1.37	-0.783	-0.563
Current electric	75	3.61	1.35	-0.699	-0.680
Thermal Energy	71	3.61	1.34	-0.640	-0.799
Series and Parallel Circuits	75	3.60	1.41	-0.666	-0.872
Vectors	84	3.58	1.43	-0.637	-0.925
States of Matter	70	3.51	1.41	-0.571	-0.943
Magnetic Fields	72	3.49	1.34	-0.526	-0.818
Sound	72	3.49	1.35	-0.426	-0.971
Static electricity	72	3.46	1.33	-0.534	-0.816
Energy and its Conservation	83	3.43	1.47	-0.484	-1.145
Motion in Two Dimensions	76	3.43	1.37	-0.482	-0.979
Mirrors and Lenses	63	3.40	1.39	-0.380	-1.112
Momentum and its Conservation	80	3.39	1.41	-0.446	-1.019
Light	69	3.33	1.52	-0.383	-1.307
Mathematical Relationships	92	3.32	1.55	-0.418	-1.344
Reflection and Refraction	66	3.32	1.46	-0.364	-1.195
Gas Laws	66	3.30	1.25	-0.408	-0.890

Table 3 summarizes the participant’s response frequency per scale component per topic.

Table 3: Distribution of the Number and Percentage of Participants across Scale Response Categories for the Change in Physics Content Presentation.

Topic	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)
Forces	90	10	8	8	29	35
		11.1%	8.9%	8.9%	32.2%	38.9%
Work, Energy, Simple Machines	84	11	6	15	17	35
		13.1%	7.1%	17.9%	20.2%	41.7%
Motion in a Straight Line	92	14	5	13	24	36
		15.2%	5.4%	14.1%	26.1%	39.1%
Graphical Analysis of Motion	90	12	5	17	23	33
		13.3%	5.6%	18.9%	25.6%	36.7%
Current electric	75	9	7	13	21	25
		12.0%	9.3%	17.3%	28.0%	33.3%
Thermal Energy	71	7	10	10	21	23
		9.9%	14.1%	14.1%	29.6%	32.4%
Series and Parallel Circuits	75	10	8	11	19	27
		13.3%	10.7%	14.7%	25.3%	36.0%
Vectors	84	12	8	14	19	31
		14.3%	9.5%	16.7%	22.6%	36.9%
States of Matter	70	10	7	13	17	23
		14.3%	10.0%	18.6%	24.3%	32.9%
Magnetic Fields	72	9	7	17	18	21
		12.5%	9.7%	23.6%	25.0%	29.2%

Sound	72	8	9	18	14	23
		11.1%	12.5%	25.0%	19.4%	31.9%
Static electricity	72	9	8	15	21	19
		12.5%	11.1%	20.8%	29.2%	26.4%
Energy and its Conservation	83	14	9	14	19	27
		16.9 %	10.8%	16.9%	22.9%	32.5%
Motion in Two Dimensions	76	10	10	14	21	21
		13.2%	13.2%	18.4%	27.6%	27.6%
Mirrors and Lenses	63	8	10	12	15	18
		12.7%	15.9%	19.0%	23.8%	28.6%
Momentum and its Conservation	80	13	7	19	18	23
		16.3%	8.8%	23.8%	22.5%	28.8%
Light	69	14	7	12	14	22
		20.3%	10.1%	17.4%	20.3%	31.9%
Mathematical Relationships	92	21	8	12	23	28
		22.8%	8.7%	13.0%	25.0%	30.4%
Reflection and Refraction	66	12	7	14	14	19
		18.2%	10.6%	21.2%	21.2%	28.8%
Gas Laws	66	7	12	12	24	11
		10.6%	18.2%	18.2%	36.4%	16.7%

Based on these data, it can be said that Puerto Rican physics teachers make a number of changes in the way they present these topics to make them more contextual and culturally relevant to their students. The topics that are presented in the most contextual and culturally relevant way are forces (mean = 3.79), work, energy and simple machines (mean = 3.70), motion in straight line (mean = 3.68) and graphical analysis of motion (mean = 3.67). Note that these topics are usually taught on the first semester of the academic year. The topics that are presented in the least contextual and culturally relevant way, relatively speaking, are light (mean = 3.33), reflection and refraction (mean = 3.32), mathematical relationships (mean = 3.32) and gas laws (mean = 3.30). Although these differences were noted, teachers tended to indicate that they change most topics in relatively similar ways.

Interestingly, although all these topics were part of the physics textbook used, not all topics were covered by all teachers. For example, 100% of the teachers covered motion in a straight line and mathematical relationships, and 90% of the teachers also covered forces, graphical analysis of motion, work, energy and simple machines, vectors and conservation of energy. By contrast, 76% of the teachers covered the topic of matter, 75% of the teachers covered light, and only 72% of the teachers covered gas laws, reflection, and refraction.

Another dependent variable for this study was the average change in teaching methodology. This variable was calculated by averaging the reported change in nineteen common teaching methodologies. This variable was also measured in a 1 to 5 scale. In this scale, selecting “1” implied that the teacher did not make any modification in their teaching methodologies to account for the characteristics and experiences of Puerto Rican students. On the other hand, selecting “5” implied that the teacher adapted his teaching methods to include problems and situations of local relevance, used materials and equipment readily available in the community, and included components of the Puerto Rican culture. Intermediate numbers are assumed to represent a linear transition between the two extremes. Table 4 summarizes the descriptive data for the nineteen teaching methods selected.

Table 4: Mean, Standard Deviation, Skewness, and Kurtosis for the Change in Teaching Methodology.

Teaching method	N	Mean	SD	Skewness	Kurtosis
Discussion	88	4.27	1.15	-1.756	2.313
Drill & Practice	91	4.24	1.34	-1.577	1.015
Collaborative learning	87	4.23	1.06	-1.424	1.436
Demonstration	92	4.07	1.22	-1.313	0.810
Homework	92	4.05	1.27	-1.124	0.081
Questioning	89	4.04	1.24	-1.287	0.656
Laboratory	87	3.92	1.35	-0.957	-0.336
Group projects	83	3.87	1.26	-0.763	-0.500
Individual projects	83	3.87	1.29	-0.840	-0.410
Brainstorming	78	3.85	1.19	-0.799	-0.237
Lecture	82	3.80	1.17	-0.889	0.041
Inquiry-based teaching	75	3.75	1.33	-0.695	-0.843
Audiovisual aids, use of	84	3.73	1.31	-0.690	-0.666
Case study	69	3.62	1.16	-0.653	-0.171
Tutorials	77	3.55	1.24	-0.425	-0.847
Creative writing	65	3.52	1.34	-0.355	-1.133

Debate	64	3.25	1.37	-0.240	-1.143
Role play	65	3.20	1.49	-0.238	-1.378
Guest speaker	60	2.80	1.49	0.165	0.309

Table 5 summarizes the participant's response frequency per scale component per topic.

Table 5: Distribution of the Number and Percentage of Participants across Scale Response Categories for the Change in Teaching Methodology.

Teaching method	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)
Discussion	88	6	2	7	20	53
		6.8%	2.3%	8.0%	22.7%	60.2%
Drill & Practice	91	9	4	7	7	64
		9.9%	4.4%	7.7%	7.7%	70.3%
Collaborative learning	87	3	4	11	21	48
		3.4%	4.6%	12.6%	24.1%	55.2%
Demonstration	92	7	4	11	24	46
		7.6%	4.3%	12.0%	26.1%	50.0%
Homework	92	6	7	14	14	51
		6.5%	7.6%	15.2%	15.2%	55.4%
Questioning	89	7	5	9	24	44
		7.9%	5.6%	10.1%	27.0%	49.4%
Laboratory	87	8	6	16	12	45
		9.2%	6.9%	18.4%	13.8%	51.7%

Group projects	83	5	7	20	13	38
		6.0%	8.4%	24.1%	15.7%	45.8%
Individual projects	83	6	7	17	15	38
		7.2%	8.4%	20.5%	18.1%	45.8%
Brainstorming	78	4	7	16	21	30
		5.1%	9.0%	20.5%	26.9%	38.5%
Lecture	82	5	7	14	29	27
		6.1%	8.5%	17.1%	35.4%	32.9%
Inquiry-based teaching	75	5	13	8	19	30
		6.7%	17.3%	10.7%	25.3%	40.0%
Audiovisual aids, use of	84	7	9	17	18	33
		8.3%	10.7%	20.2%	21.4%	39.6%
Case study	69	5	5	19	22	18
		7.2%	7.2%	27.5%	31.9%	26.1%
Tutorials	77	5	12	18	20	22
		6.5%	15.6%	23.4%	26.0%	28.6%
Creative writing	65	5	12	14	12	22
		7.7%	18.5%	21.5%	18.5%	33.8%
Debate	64	9	11	14	15	15
		14.1%	17.2%	21.9%	23.4%	23.4%
Role play	65	13	10	10	15	17
		20.0%	15.4%	15.4%	23.1%	26.2%

Guest speaker	60	18	7	16	7	12
		30.0%	11.7%	26.7%	11.7%	20.0%

Based on these data, we can say that Puerto Rican physics teachers also make a number of changes in the teaching methodologies they use to make their class more contextual and culturally relevant. The teaching methodologies that are modified the most are discussion (mean = 4.27), drill and practice (mean = 4.24) and collaborative learning (mean = 4.23). The topics that are modified the least, relatively speaking, are debate (mean = 3.25), role play (mean = 3.20) and the use of a guest speaker (mean = 2.80). These changes were more dramatic with most teaching methods compared to the changes in physics content presentation (More than half of the scale values for the teaching methodologies are higher than the highest scale value for the change in content presentation, which is forces).

Again, not all teaching methodologies are used by all teachers. For example, 100% of the teachers reported using demonstrations and homework assignments, and 90% of the teachers reported using discussion, drill and practice, collaborative learning, questioning, laboratories, lecture, audiovisuals and projects. By contrast, 71% of the teachers used creative writing and drama, 70% used debates, and only 65% of the teachers invited a guest speaker to their class.

The third dependent variable of this study is the average degree of confidence teachers has of their own physics knowledge. This average is created by combining the teachers' report of their degree of confidence in their physics knowledge for the 20 topics selected from the book, and commonly covered in class.

This variable is measured on a 1 to 5 scale, in which selecting "1" implies that the teacher is completely unsure (total lack of confidence) about his physics knowledge, "2" implies that the teachers is partially unsure (partial lack of confidence) about his physics knowledge, "3" implies that the teacher is undecided about his confidence in his physics knowledge, "4" implies that the teacher is partially sure/confident of his physics knowledge, and"5" implies that the teacher is completely sure/confident of his physics knowledge. Table 6 summarizes the descriptive data for the twenty physics topics selected.

Table 6: Mean, Standard Deviation, Skewness, and Kurtosis for the Teachers' Subject Knowledge Confidence.

Topic	N	Mean	SD	Skewness	Kurtosis
Motion in a Straight Line	88	4.85	0.36	-2.020	2.129
Mathematical Relationships	88	4.84	0.37	-1.897	1.634
Forces	88	4.81	0.40	-1.581	0.512
Graphical Analysis of Motion	87	4.76	0.48	-1.850	2.694
States of Matter	80	4.70	0.70	-3.128	11.654
Energy and its Conservation	85	4.67	0.70	-2.908	10.572
Work, Energy, Simple Machines	85	4.67	0.70	-2.908	10.572
Thermal Energy	80	4.49	0.81	-2.002	4.730
Vectors	87	4.46	0.79	-1.751	3.864
Gas Laws	77	4.45	0.84	-1.727	3.285

Motion in Two Dimensions	84	4.45	0.80	-1.883	4.496
Momentum and its Conservation	85	4.41	0.85	-1.628	2.828
Sound	80	4.35	0.93	-1.733	3.196
Light	81	4.32	0.89	-1.661	3.394
Current electric	84	4.24	0.98	-1.293	1.405
Static electricity	83	4.22	0.96	-1.291	1.556
Series and Parallel Circuits	85	4.21	0.94	-1.321	1.841
Reflection and Refraction	78	4.12	0.94	-1.200	1.674
Magnetic Fields	84	4.07	0.99	-1.058	0.849
Mirrors and Lenses	79	3.97	1.01	-0.861	0.371

Table 7 summarizes the participant’s response frequency per scale component per topic.

Table 7: Distribution of the Number and Percentage of Participants across Scale Response Categories for the Teachers’ Subject Knowledge Confidence.

Topic	N	1 (%)	2 (%)	3 (%)	4 (%)	5 (%)
Motion in a Straight Line	88	0	0	0	13	75
					14.8%	85.2%
Mathematical Relationships	88	0	0	0	14	74
					15.9%	84.1%
Forces	88	0	0	0	17	71
					19.3%	80.7%
Graphical Analysis of Motion	87	0	0	2	17	68

				2.3%	19.5%	78.2%
States of Matter	80	1	1	2	13	63
		1.3%	1.3%	2.5%	16.3%	78.8%
Energy and its Conservation	85	1	1	2	17	64
		1.2%	1.2%	2.4%	20.0%	75.3%
Work, Energy, Simple Machines	85	1	1	2	17	64
		1.2%	1.2%	2.4%	20.0%	75.3%
Thermal Energy	80	1	2	4	23	50
		1.3%	2.5%	5.0%	28.8%	62.5%
Vectors	87	1	1	7	26	52
		1.1%	1.1%	8.0%	29.9%	59.8%
Gas Laws	77	1	1	8	19	48
		1.3%	1.3%	10.4%	24.7%	62.3%
Motion in Two Dimensions	84	1	2	4	28	49
		1.2%	2.4%	4.8%	33.3%	58.3%
Momentum and its Conservation	85	1	2	8	24	50
		1.2%	2.4%	9.4%	28.2%	58.8%
Sound	80	2	2	7	24	45
		2.5%	2.5%	8.8%	30.0%	56.3%
Light	81	2	1	8	28	42
		2.5%	1.2%	9.9%	34.6%	51.9%
Current electric	84	2	2	14	22	44

		2.4%	2.4%	16.7%	26.2%	52.4%
Static electricity	83	2	2	13	25	41
		2.4%	2.4%	15.7%	30.1%	49.4%
Series and Parallel Circuits	85	2	2	12	29	40
		2.4%	2.4%	14.1%	34.1%	47.1%
Reflection and Refraction	78	2	2	12	31	31
		2.6%	2.6%	15.4%	39.7%	39.7%
Magnetic Fields	84	2	4	14	30	34
		2.4%	4.8%	16.7%	35.7%	40.5%
Mirrors and Lenses	79	2	4	17	27	29
		2.5%	5.1%	21.5%	34.2%	36.7%

Based on these data, we can see that Puerto Rican teachers are very confident of their physics knowledge. The topics in which teachers are more confident about their knowledge are motion in a straight line (mean = 4.85), mathematical relationships (mean = 4.84), forces (mean = 4.81), and graphical analysis of motion (mean = 4.76). All of these topics are covered in first semester. Without assessing significance, the topics in which teachers are relatively less confident of their knowledge are static electricity (mean = 4.22), circuits (mean = 4.21), reflection and refraction (mean = 4.12), magnetism (mean = 4.07), and mirrors/lenses (mean = 3.97). All of these topics are covered in the second semester.

From the 1668 pooled responses, 61.99% of the total responses indicated complete security/confidence in the teachers' physics knowledge, 26.62% indicated partial security/confidence in their physics knowledge, 8.15% of the total responses indicated indecision or neutrality about their physics knowledge, 1.80% indicated partial lack of confidence in their physics knowledge, and 1.44% of the total responses indicated total lack of confidence in their physics knowledge.

Discussion: Descriptive Data for Dependent Variables

For the variable "average change in the physics content presentation" the descriptive data gathered make sense to me as a former physics teacher. The topics with the larger mean, that is, those that are made more contextual and culturally relevant, are usually easier to teach, are taught more frequently, and are generally more familiar to students. I think teachers take advantage of their familiarity to make contextual and culturally relevant changes. In addition, evidence from short answer and interview data support the contextualization and culturally relevance of those uppermost topics. The converse is true also, for the topics with the lowest mean, that is, those that are made contextually and culturally relevant less frequently, are generally not taught as frequently (except for mathematical relationships, but there is an explanation for that), and might not be familiar to students. In addition, studying light, reflection, refraction, and gas laws requires special equipment that the teacher might not have. The topic "mathematical relationships" is taught very frequently as a prelude to physics, but it is nothing more than a quick review of simple math concepts, and it is not suitable for contextualization or culturally relevance. In any case, all topics had means larger than three, which suggest appreciable changes.

Interestingly, a correlation between the number of teachers who responded to a given topic and the overall topic means reported was noted, that is, the more participants provided answers per topic, the large the mean was. The correlation between those values is approximately 0.53. Using regression analysis, it was determined that this relationship was significant (F = 7.095, p = 0.016). Although teachers make significant changes to some topics, it is possible that other topics are not covered or covered with fewer changes to make them more contextual and culturally relevant. I personally gave instructions to the teachers about leaving blank those topics they did not cover, so it is assumed that participants who provided answers in the instruments did so understanding the instructions provided. To explore this further, new descriptive data were obtained only for teachers who gave answers to all topics (n = 38). For that case, sample size will not be a factor. Table 8 summarizes this information:

Table 8: Mean for the Change in Physics Content Presentation, Adjusted for the Number of Respondents.

Topic	Unadjusted mean	Mean adjusted for sample size
Forces	3.79	3.92
Work, Energy, Simple Machines	3.70	3.82
Motion in a Straight Line	3.68	3.58
Graphical Analysis of Motion	3.67	3.84
Current electric	3.61	3.50
Thermal Energy	3.61	3.58

Series and Parallel Circuits	3.60	3.37
Vectors	3.58	3.50
States of Matter	3.51	3.61
Magnetic Fields	3.49	3.39
Sound	3.49	3.53
Static electricity	3.46	3.45
Energy and its Conservation	3.43	3.42
Motion in Two Dimensions	3.43	3.58
Mirrors and Lenses	3.40	3.50
Momentum and its Conservation	3.39	3.66
Light	3.33	3.50
Mathematical Relationships	3.32	3.37
Reflection and Refraction	3.32	3.32
Gas Laws	3.30	3.29

In general the ranking of topics was similar in the extremes. Gas laws, reflection and refraction, and mathematical relationships still have the lowest means. Forces, and work, energy and simple machines still have the highest means. Topics near the center of the distribution switched places, but most means stayed relatively close. However, there were topics whose ranking varied considerably (circuits, conservation of momentum) but that difference was not statistically significant ($p = 0.44$ and $p = 0.33$ respectively). All this suggests that the relationship between sample size and mean is present, but that other variables might also influence the topic ranking.

Another explanation for the relationship might be an item order effect. In educational measurement, some researchers suggest that the position of an item on an instrument, also known as context effect, can affect the item's parameters, like mean, standard deviation, etc. (Linn, 1989). To prevent context effects, it is suggested that several forms of the instrument be developed, in which items change position randomly (Terry, Schurr and Henriksen, 1983). Since this was not done with this instrument, it is possible that context effects might have caused the odd relationship between sample size and means. As a counterpoint, not all researchers believe that context effects are strong enough to invalidate the assumption of item parameter invariance (Leary and Dorans, 1985).

The frequency table for the participant's answers also shows an interesting pattern. In almost all topics, teachers systematically selected scale “one” more frequently than scale “two” and then increased their answers for the scale “three”, “four” and “five”. This might suggest two basic groups of people: those that do not make any changes to the content presentation to make it contextual and culturally relevant, and a larger group who do make notable changes. This is supported by both the short answer and interview data.

For the variable “average change in teaching methodology”, the range of mean values is much broader than the previous variable (from 2.80 to 4.27), which suggests more variability in their likelihood of changing their methods. However, the sequencing of teaching methodologies also makes sense to me. For example, discussion, collaboratively learning, demonstrations, homework or questioning all are suitable for contextualization and cultural relevancy. Also, drill and practice is suitable for the inclusion of culture and context. This is so because many teachers perceived the textbooks problems as inadequate and created their own exercises and problems. On the other hand, there is very little a teacher can do to change a guest speaker's conference or the facts needed for debate.

As with the previous variable, there is a correlation between sample size per topic and its mean. In this case, the correlation is much stronger, approximately 0.91. Using regression analysis, it was determined that the relationship was significant ($F = 52.241$, $p = 000$). I personally gave instructions to the teachers about leaving blank those methodologies they did not use, so it is assumed that participants who provided answers in the instrument did so understanding the instructions provided. To eliminate sample size as a variable, new descriptive data were calculated only for participants who gave answers for all topics. Table 9 summarizes this information.

Table 9: Mean for the Change in Teaching Methodology, Adjusted for the Number of Respondents.

Teaching methodology	Unadjusted mean	Mean adjusted for sample size
Discussion	4.27	4.56
Drill & Practice	4.24	4.46
Collaborative learning	4.23	4.46
Demonstration	4.07	4.38
Homework	4.05	4.13
Questioning	4.04	4.28
Laboratory	3.92	4.21
Group projects	3.87	4.03
Individual projects	3.87	3.92

Brainstorming	3.85	4.15
Lecture	3.80	4.26
Inquiry-based teaching	3.75	3.92
Audiovisual aids, use of	3.73	3.97
Case study	3.62	3.74
Tutorials	3.55	3.64
Creative writing	3.52	3.74
Debate	3.25	3.41
Role play	3.20	3.44
Guest speaker	2.80	3.00

Notice that the rankings at the extremes are very similar when we adjust for sample size. The mean differences are not significant, except for the topic “lecture”, which increased significantly when adjusted for missing data ($p = 0.0314$). This suggests that, although there is a relationship between sample size and mean values, there might be other unknown variables involved.

The frequency pattern for the reported teaching methodologies means are less consistent than those of the previous variable. The majority of the frequency patterns are either similar to the previous variable (high-low-high-high-high) or ascending. However, there is an odd “w” pattern (high-low-high-low-high) and an “inverted normal” pattern (high-low-low-high-high). Especially noticeable is the frequency pattern for “drill and practice” (problem solving), which is essentially flat in the first four scales and jumps suddenly to 70% for scale answer “five”, which provide additional evidence that most teachers create their own exercises and problems because those available in the textbook might not be adequate.

For the variable “teachers’ degree of confidence in their physics knowledge”, the overall results are impressive. The reported mean for nineteen out of twenty topics is “4” or more, which suggest that teachers are confident of their physics knowledge. This contrasts with the fact that approximately 58% of the teachers have five or less semesters of physics. It is possible that teachers are very confident of the physics content they have to teach or the physics content presented in the textbook, maybe because of experience as physics teachers (although almost half of them have five years of experience or less) or the relative facility of the physics content they have to teach.

Since it is known that sometimes teachers tend to teach more frequently (and with more quality) the material they master the best, I decided to check for a relationship between mean degree of confidence and mean change in physics content presentation. A significant relationship might suggest that teachers made contextual and culturally relevant changes in content presentation to those topics they are more confident about. Using regression analysis, it was determined that there is no such relationship in the population of interest ($F = 3.504$, $p = 0.078$).

Again, there is a relationship between sample size and the mean degree of confidence. The correlation is 0.563. Using regression analysis, it was determined that the relationship was significant ($F = 8.357$, $p = 0.010$). Possible explanations are discussed elsewhere, but the fact that it happened on three independent scales tend to suggest that item order effect might be the cause because there was only one form for the research instruments. The following table (Table 10) include mean adjusted for sample size (n = 59).

Table 10: Mean for the Teachers' Subject Knowledge Confidence, Adjusted for the Number of Respondents.

Topic	Unadjusted mean	Mean adjusted for sample size
Motion in a Straight Line	4.85	4.86
Mathematical Relationships	4.84	4.83
Forces	4.81	4.83
Graphical Analysis of Motion	4.76	4.76
States of Matter	4.70	4.69
Energy and its Conservation	4.67	4.68
Work, Energy, Simple Machines	4.67	4.69
Thermal Energy	4.49	4.46
Vectors	4.46	4.53
Gas Laws	4.45	4.49
Motion in Two Dimensions	4.45	4.42
Momentum and its Conservation	4.41	4.49
Sound	4.35	4.34
Light	4.32	4.25
Current electric	4.24	4.17
Static electricity	4.22	4.29
Series and Parallel Circuits	4.21	4.17

Reflection and Refraction	4.12	4.10
Magnetic Fields	4.07	4.05
Mirrors and Lenses	3.97	3.98

Notice that the topic ranking is very similar, possibly because of a larger sample, compared to the other two dependent variables. None of the differences in means are significant.

The frequency pattern for the teachers' responses is consistent across topics. Very few people selected scale values of "1" or "2". Even the topic that teachers perceived themselves as less confident, mirrors and lenses, only six participants selected either "1" or "2" on the corresponding Likert scale.

In summary, the descriptive data for the dependent variables suggest that Puerto Rican high school physics teachers do make noticeable changes in the presentation of physics content and in the teaching methodologies they use to promote contextual learning and cultural relevance. In addition, teachers perceived themselves as remarkably confident of their physics knowledge or, at least, the physics knowledge they need to teach general physics to high school students. Future research might study whether the teachers' perception matches reality.

It is theorized that an item order effect or other similar effect might have caused a relationship between sample size and the dependent variables. This relationship was statistically significant, but it might not be consequential because the difference between unadjusted means and means adjusted for sample size are, in almost all cases, not significant. Furthermore, the relative position (ranking) of the topics and teaching methodologies remained comparable. As suggested in the literature, a replication of this research should include multiple forms with items in different order.

Findings: Univariate Statistical Tests for Change in Physics Content Presentation

For the following univariate tests, the statistical technique used was simple analysis of variance (ANOVA) to detect mean difference for the groups compared, with a confidence level of 0.05. In addition, the Levene test was performed to examine the assumption of homogeneity of variance. ANOVA works well even when this assumption is violated, except in the case where there are unequal numbers of subjects in the various groups. Since this is the case, a significant result for this test will automatically discard that particular test. All the statistical analyses were accomplished using SPSS (Statistical Package for the Social Sciences), version 9.0.

This section will be organized by dependent variable, starting with the variable "teachers' average change in physics content presentation", followed by "average change in teaching methodology", and "perceived degree of confidence in the participants physics subject knowledge". For each variable, significant tests will be presented first, followed by tests that showed a non-significant trend, non-significant/non-trend tests, and finishing with tests that were discarded because of assumption violation, especially heteroscedasticity.

Test 1 (S): Average Change in Physics Content Presentation as a Function of Teacher's Years of Experience Teaching Physics.

Based on a sample size of 90 participants, the statistical analysis showed that there is not a statistically significant difference in the average change in physics content presentation across all categories (F = 2.410, p = 0.055). However, since the obtained p value is so close to the confidence level selected, plus the fact that 0.05 is nothing more than an arbitrary cutoff point, for discussion purposes this test will be considered significant. More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. Table 11 summarizes the descriptive data for this test.

Table 11: Sample Size, Mean Change in Physics Content Presentation and Standard Deviations for the "Years of Experience as Physics Teacher" Category.

Yrs. exp. as physics teacher	Sample size	Arithmetic mean	Standard deviation
0 – 5 years	42	3.1558	1.1772
6 – 10 years	22	3.7798	1.0949
11 – 15 years	9	3.5981	0.9047
16 – 20 years	11	3.6631	0.7068
21 – 25 years	6	4.3022	0.7526
26 – 30 years	1	na	na
More than 30 years	1	na	na

<u>Test 2 (S): Average Change in Physics Content Presentation as a Function of the Average Number of Students Physics Teachers Have in their Groups.</u>

Based on a sample size of 90 participants, the statistical analysis showed an overall significant relationship between the average change in physics content presentation and the number of students per class section (F = 3.565, p = 0.033). This result suggest that the larger the number of students in a classroom, the less change the teachers made in their content presentation (use of examples with common materials and familiar situations, application of physics concepts to problems of local relevance, inclusion of components of the Puerto Rican culture in their explanations, connection of the physics concepts with Puerto Rican realities). Interestingly, the post-hoc pair-wise comparison failed to identify any two means that are statistically different. Table 12 summarizes the descriptive data for this test.

Table 12: Sample Size, Mean Change in Physics Content Presentation and Standard Deviations for the Number of Students Physics Teachers Have in their Groups.

Students per group	Sample size	Arithmetic mean	Standard deviation
0 – 10 students	2	na	na
11 – 20 students	12	3.8398	0.8697
21 – 30 students	49	3.6354	0.1939
31 – 40 students	29	3.0403	1.1335

<u>Test 3 (S): Average Change in Physics Content Presentation as a Function of the Perceived Freedom of the Teacher to Modify their Teaching Methodology.</u>

Based on a sample size of 87 participants, the statistical analysis showed that there is not a statistically significant difference in the average change in physics content presentation across all categories ($F = 3.073$, $p = 0.052$). However, since the obtained p value is so close to the confidence level selected, plus the fact that 0.05 is nothing more than an arbitrary cutoff point, for discussion purposes this test will be considered significant. More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. Table 13 summarizes the descriptive data for this test.

Table 13: Sample Size, Mean Change in Physics Content Presentation and Standard Deviations for the Perceived Freedom of the Teacher to Modify their Teaching Methodology.

Perceived freedom	Sample size	Arithmetic mean	Standard deviation
No freedom	5	2.2922	1.0769
Some freedom	52	3.4905	1.1279
Absolute freedom	30	3.5755	1.0121

<u>Test 4 (T): Average Change in Physics Content Presentation as a Function of the Number of Semesters of Physics Courses Teachers Have.</u>

Based on a sample size of 91 participants, the statistical analysis showed that there is not a statistically significant difference in the average change in physics content presentation across all categories ($F = 1.172$, $p = 0.329$). However, the accuracy of this result might be questioned because the test for homogeneity of variance was significant ($L = 2.536$, $p = 0.026$), in other words, the assumption of homogeneity of variance is not met. This test should be discarded. Table 14 summarizes the descriptive data for this test.

Table 14: Sample Size, Mean Change in Physics Content Presentation and Standard Deviations for the Number of Semesters of Physics Courses Teachers Have.

No. semesters of physics	Sample size	Arithmetic mean	Standard deviation
0 – 2 semesters	24	3.1153	1.1735
3 – 5 semesters	29	3.4432	1.2235

6 – 8 semesters	15	3.9743	0.8757
9 – 11 semesters	8	3.4580	0.6285
12 – 14 semesters	3	4.2013	0.1947
15 – 17 semesters	3	3.5893	0.7034
18 + semesters	9	3.4403	1.2980

However, in order to increase statistical power, the seven original categories were collapsed in to four new categories: 0 – 2 semesters, 3 – 5 semesters, 6 – 11 semesters, and 12 or more semesters of physics.

When the new statistical analysis was performed, it found that the data were homoscedastic, but no significant relationship between the variables of interest ($F = 1.616$, $p = 0.192$) was determined, although an ascending trend was noted (more prepared teachers make more changes to the physics content presentation to make it contextual and culturally relevant compared to less prepared teachers). Table 15, with the new collapsed categories, summarizes this information.

Table 15: Sample Size, Mean Change in Physics Content Presentation and Standard Deviations for the Number of Semesters of Physics Courses Teachers Have (Collapsed Data).

No. semesters of physics	Sample size	Arithmetic mean	Standard deviation
0 – 2 semesters	24	3.1153	1.1735
3 – 5 semesters	29	3.4432	1.2235
6 – 11 semesters	23	3.7947	1.0640
12 + semesters	15	3.6223	1.1062

In general, the new statistical test suggest that physics teachers do make changes to their physics content presentation, regardless of their academic preparation, although there is a trend for teachers with more physics courses to make more changes compared to teachers who are less academically prepared in physics.

Test 5 (NSNT): Average Change in Physics Content Presentation as a Function of Teacher's Gender.

Based on a sample size of 92 participants (48 males and 44 females), the statistical analysis showed that the average change in physics content presentation for males was 3.6418 with a standard deviation of 1.0940. For females, the average change in physics content presentation was 3.3108 with a standard deviation of 1.0993. The difference in means between males and females was not significant ($F = 2.091$, $p = 0.152$).

Test 6 (NSNT): Average Change in Physics Content Presentation as a Function of Teacher's Years of Experience.

Based on a sample size of 92 participants, the statistical analysis showed that there is not a statistically significant difference in the average change in physics content presentation across all categories ($F = 0.323$, $p = 0.923$). More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. Table 16 summarizes the descriptive data for this test.

Table 16: Sample Size, Mean Change in Physics Content Presentation and Standard Deviations for the "Years of Experience" Category.

Years of experience	Sample size	Arithmetic mean	Standard deviation
0 – 5 years	11	3.3001	0.9570
6 – 10 years	14	3.5459	1.2126
11 – 15 years	18	3.4717	1.2028
16 – 20 years	12	3.7385	0.9595
21 – 25 years	26	3.3020	1.0936
26 – 30 years	8	3.7184	1.4532
More than 30 years	6	3.5823	0.9137

Test 7 (NSNT): Average Change in Physics Content Presentation as a Function of School Geographical Location.

Based on a sample size of 88 participants, the statistical analysis showed that there is not a statistically significant difference in the average change in physics content presentation across all categories ($F = 0.582$, $p = 0.561$). More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. Table 17 summarizes the descriptive data for this test.

Table 17: Sample Size, Mean Change in Physics Content Presentation and Standard Deviations for the School Geographical Location.

School location	Sample size	Arithmetic mean	Standard deviation
Urban	61	3.5464	1.1093
Suburban	9	3.6435	1.0988
Rural	18	3.2521	1.0916

Test 8 (NSNT): Average Change in Physics Content Presentation as a Function of the Perceived Freedom of the Teacher to Modify the Course Content.

Based on a sample size of 89 participants, the statistical analysis showed that there is not a statistically significant difference in the average change in physics content presentation across all categories (F = 1.940, p = 0.150). More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. Table 18 summarizes the descriptive data for this test.

Table 18: Sample Size, Mean Change in Physics Content Presentation and Standard Deviations for the Perceived Freedom of the Teacher to Modify the Course Content.

Perceived freedom	Sample size	Arithmetic mean	Standard deviation
No freedom	12	2.9516	1.2103
Some freedom	57	3.6334	1.0157
Absolute freedom	20	3.4133	1.2941

Test 9 (NSNT): Average Change in Physics Content Presentation as a Function of Text Quality.

Based on a sample size of 89 participants, the statistical analysis showed that there is not a statistically significant difference in the average change in physics content presentation across all categories (F = 1.069, p = 0.367). More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. Table 19 summarizes the descriptive data for this test.

Table 19: Sample Size, Mean Change in Physics Content Presentation and Standard Deviations for Text Quality.

Text quality	Sample size	Arithmetic mean	Standard deviation
Excellent	7	3.5346	1.2822
Good	47	3.2807	1.1669
Average	31	3.6097	0.9932
Deficient/poor	4/1	4.0286	0.5859

<u>Test 10 (D): Average Change in Physics Content Presentation as a Function of the Teacher's Ideological Beliefs.</u>

Based on a sample size of 92 participants, the statistical analysis showed that there is not a statistically significant difference in the average change in physics content presentation across all categories ($F = 0.680$, $p = 0.608$). More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. For this variable, the test for homogeneity of variance was significant ($L = 5.095$, $p = 0.001$). As a consequence, the test was discarded. Table 20 summarizes the descriptive data for this test.

Table 20: Sample Size, Mean Change in Physics Content Presentation and Standard Deviations for the Teacher's Ideological Beliefs.

Ideological beliefs	Sample size	Arithmetic mean	Standard deviation
Pro-statehood	21	3.5864	0.8757

Pro-commonwealth	27	3.2153	1.4327
Pro assoc. republic	8	3.6439	0.7930
Pro-independence	16	3.7314	0.8013
Other/blank/multiple	20	3.4751	1.1388

Discussion: Univariate Statistical Tests for Change in Physics Content Presentation

The first test showed that, although there is not a significant relationship at the 0.05 level between the mean change in physics content presentation and the participants' years of experience as physics teachers, there is a relationship at the 0.10 level. Since the p value for this test is so close to 0.05, I think it is worth mentioning, especially the appreciable difference in reported mean between novice teachers (approximately 3.16 for teachers with less than five years of experience) and veteran teachers (approximately 4.30 for teachers with 21 – 25 years of experience).

This difference between novice and veteran teachers might suggest that teachers learn to make their physics content presentation more contextual and culturally relevant from experience teaching physics classes, since the reported means started low at the novice level and keep increasing from the third category on. I do not have a good reason to explain why the reported mean for the 6 – 10 years of experience category is different from the overall trend.

To increase the statistical power of the test, the last three categories were collapsed into one new category (21 or more years of experience) and a new analysis of variance was performed. It failed to detect significant differences at the 0.05 level ($F = 2.639$, $p = 0.054$), but since the new p value is almost identical to the value obtained from the original test, the argument presented above is still valid. Since the obtained p value is so close to 0.05, and this confidence level is arbitrary, for discussion purposes this test will be considered significant. In general, these tests suggest that physics teachers do make changes to their physics content presentation, regardless of years of experience teaching physics, although there is a trend for veteran teachers to make more changes compared to novice teachers.

The second test showed a significant relationship between the number of students physics teachers have in their class sections and the mean change they make to the physics content presentation to make it more contextually and culturally relevant, even after collapsing the first two categories into a single one to increase the statistical power of the test ($F = 3.898$, $p = 0.024$). This significant result suggests that the more students physics teachers have in their classes, another factor or factors associated with this increase affect the teachers' inclusion of context and culture in the physics class. As a consequence, less time is spent using examples with common materials and familiar situations, applying physics concepts to problems of local relevance, including components of the Puerto Rican culture in class, and connecting the physics concepts with Puerto Rican realities. In all cases, the mean change reported is more than three, which is indicative that even teachers with a large number of students per class are able to make some changes to their physics content presentation along more relevant lines.

The third test revealed that there is not a significant relationship, at the 0.05 confidence level, between whether teachers believed they have freedom to select and modify their teaching methodology and the reported mean changes in their physics content presentation to make it contextually and culturally relevant. However, there is a significant relationship at the 0.1 confidence level. In fact, the p value from the test is so close to 0.05 that it might be considered significant for discussion purposes. The reported mean for those teachers who think they have no say on their teaching methodologies (approximately 2.29) is very low compared to the reported mean for teachers who think they have some or all freedom in choosing and modifying their teaching methodologies (3.49 and 3.58 respectively). This is also consistent with the beliefs versus actions framework in the physics classroom.

My experience is that the Puerto Rico Department of Education has no specific guidelines suggesting a group of teaching methodologies over others. Teachers, as education professionals, are left to judge and decide on the teaching methodologies that they want to use. However, I understand why some teachers think they have no freedom to modify their teaching methodologies. For one, public schools tend to be traditional, focusing on content coverage by lecturing, discussion and other teacher-directed means. In addition, it is easier, more objective and evidentiable (for legal purposes) to assess students on content knowledge by testing what was given by the teacher. Teachers might feel that they must (as opposed to "should") follow teacher-directed means of instruction.

The fourth test, which explored a relationship between the participants' academic preparation in physics and the mean change in physics content presentation to make it more contextual and culturally relevant, was originally discarded. After collapsing some of the categories to have more subjects per category, the test was still not-significant. However, examining the reported means do indicate a trend for more changes in physics content presentation as the teachers become more knowledgeable of the subject. This finding is evident, because teachers who do not have a good preparation in physics might not know what topics could be modified to make them relevant to the local students, what would be the best way to make effective changes, or why these changes are necessary for students learning of the subject.

The fifth test showed that male teachers tend to report making more changes in the physics content to make it more contextually and culturally relevant compared to female teachers, although this difference is not significant based on the sample from which data was gathered. Since the reported mean for both males and females is more than 3.00, this confirms that teachers, regardless of gender, make noticeable changes in the presentation of physics content.

The sixth test showed that there is not a significant relationship between the years of experience as teachers of the sample and the changes they make to make the presentation of physics content more contextually and culturally relevant. In fact, the means obtained have an unusual zigzag pattern.

From the seven original categories, two of them have less than 10 subjects. In order to increase the statistical power of the test, the categories were collapsed into three new categories: 0 – 10 years of experience, 11 – 20 years of experience, and 21 or more years of experience. Statistical analysis of the new categories failed to detect a significant difference in the reported means ($F = 0.162$, $p = 0.851$).

The seventh test, which explored a relationship between the participant’s school geographical location (urban, suburban, and rural) and the average change in physics content presentation to make it contextually and culturally relevant failed to detect a statistical difference for the means reported. Results such as these were expected because of the way science teachers' job placement works in Puerto Rico, and the small geographical area of the island.

The eighth test, which tried to detect a relationship between whether the participants believed they have freedom to modify the course content in general, and the reported mean change in physics content presentation to make it more contextual and culturally relevant, found no such relationship. Interestingly, there is a obvious difference between the mean changes reported by teachers who think they have no freedom to change the course content (approximately 2.95) compared to those teachers who think they have some or all freedom to do so (approximately 3.63 and 3.41, respectively). This result is very consistent, in terms of beliefs versus actions in the physics classrooms. At the same time, it is contradictory because, theoretically, teachers who think they have no freedom to change the course content, should have a reported mean change close to one or two, rather than the center of the distribution.

On the other hand, the curriculum of the high school physics course is determined by the Puerto Rico Department of Education and is the same for all schools. How can approximately one in five teachers report having absolute freedom to change the course content? Is it because they are following their professional judgement rather than the directions from the Department of Education? Is it because there may be school administration-related differences? Only more research can answer these interesting questions.

The ninth test exploring a relationship between the participants' evaluation of the textbook quality and the average change in physics content presentation to make it contextually and culturally relevant failed to detect a significant relationship.

The tenth test showed that there is not a significant relationship between the participant's ideological beliefs and the reported mean change in physics content presentation to make it contextual and culturally relevant. Since the Levene test determined that the data were heteroscedastic, it was determined that collapsing some categories might increase the statistical power of the test. However, the selection of the method used for collapsing the categories is both intricate and sensitive because of the nature of the option ”associated republic”. Groups of people consider that militants of the “associated republic” option are people who support the commonwealth status, but with more autonomous powers delegated from the United States. This description suggests collapsing the “pro-commonwealth” and “associated republic” options into a single category, named Model One, which might be called “pro-autonomy”.

On the other hand, people who believe in the “associated republic option” can also be considered as moderate “pro-independents” who are less radical about their ideas, recognizing that some type of relationship between the United States and Puerto Rico might be beneficial to both countries. This second description suggests collapsing the “associated republic” and “pro-independence” option into a single category, named Model Two. Since this matter is still unresolved, both models were statistically tested, and none found statistical relationships between the variables under scrutiny ($n = 72$, $F = 0.913$, $p = 0.406$ for Model One; $n = 72$, $F = 1.381$, $p = 0.258$ for Model Two). The category “other/blank/multiple” was also not considered on the modified models.

In the modified models, the Levene test for homogeneity of variance was significant ($L = 5.760$, $p = 0.005$ for Model One; $L = 10.9$, $p = 0.000$ for Model Two). As a consequence of this, and an unequal sample size (21, 35, and 16 participants reported believing in statehood, associated republic/commonwealth, and independence for Model One; 21, 27, and 34 participants reported believing in statehood, commonwealth, and associated republic/independence for Model Two), these tests were reported, but discarded.

Findings: Univariate Statistical Tests for Change in Teaching Methodology

The following section presents findings associated with the dependent variable "teachers' average change in teaching methodology". For each variable, significant tests will be presented first, followed by tests that showed a non-significant trend, non-significant/non-trend tests, and finishing with tests that were discarded because of assumption violation, especially heteroscedasticity.

Test 11 (S): Average Change in Teaching Methodology as a Function of Teacher's Gender.

Based on a sample size of 92 (48 males and 44 females), the statistical analysis found that the average change in teaching methodology for males was 3.99 with a standard deviation of 0.7812. For females, the average change in teaching methodology was 3.48 with a standard deviation of 0.9678. The difference in means between males and females was significant ($F = 7.802$, $p = 0.006$), which suggests that male physics teachers make more adaptations to their teaching methods to include problems and situations of local relevance, use more materials and equipment readily available in the community, and include more components of the Puerto Rican culture, compared to female physics teachers.

Test 12 (S): Average Change in Teaching Methodology as a Function of the Number of Semesters of Physics Courses Teachers Have.

Based on a sample size of 91 participants, the statistical analysis found no statistically significant difference in the perceived degree of confidence in the teacher's physics knowledge across all categories (F = 1.658, p = 0.142). Table 21 summarizes the descriptive data for this test.

Table 21: Sample Size, Average Change in Teaching Methodology, and Standard Deviations for the Number of Semesters of Physics Courses Teachers Have.

No. semesters of physics	Sample size	Arithmetic mean	Standard deviation
0 – 2 semesters	24	3.2827	1.0796
3 – 5 semesters	29	3.9137	0.7668
6 – 8 semesters	15	3.9887	0.8425
9 – 11 semesters	8	3.9206	0.5713
12 – 14 semesters	3	4.0773	0.4595
15 – 17 semesters	3	4.0413	0.6683
18 + semesters	9	3.5967	1.1037

However, new statistical analysis with fewer categories found a significant relationship between these variables (F = 3.050, p = 0.033), which suggest that teachers who have taken more physics courses make more changes to their teaching methodologies compared to teachers who are less academically prepared in this subject area. Table 22 summarizes these new results.

Table 22: Sample Size, Average Change in Teaching Methodology, and Standard Deviations for the Number of Semesters of Physics Courses Teachers Have (Collapsed Data).

No. semesters of physics	Sample size	Arithmetic mean	Standard deviation
0 – 2 semesters	24	3.2827	1.0796
3 – 5 semesters	29	3.9137	0.7668
6 – 11 semesters	23	3.9650	0.8425
12 + semesters	15	3.7817	0.5713

Test 13 (T): Average Change in Teaching Methodology as a Function of Text Quality.

Based on a sample size of 89 participants, the statistical analysis found no statistically significant difference in the average change in teaching methodology across all categories ($F = 0.959$, $p = 0.416$). More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. Table 23 summarizes the descriptive data for this test.

Table 23: Sample Size, Mean Change in Teaching Methodology and Standard Deviations for Text Quality.

Text quality	Sample size	Arithmetic mean	Standard deviation
Excellent	7	3.5360	1.0403
Good	47	3.6089	0.9574

Average	31	3.9090	0.8284
Deficient/poor	4/1	4.0218	0.6444

Test 14 (NSNT): Average Change in Teaching Methodology as a Function of Teacher's Years of Experience.

Based on a sample size of 92 participants, the statistical analysis found no statistically significant difference in the average change in teaching methodology across all categories (F = 0.882, p = 0.512). More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. Table 24 summarizes the descriptive data for this test.

Table 24: Sample Size, Mean Change in Teaching Methodology, and Standard Deviations for the "Years of Experience" Category.

Years of experience	Sample size	Arithmetic mean	Standard deviation
0 – 5 years	11	3.3344	1.0493
6 – 10 years	14	4.0518	0.7853
11 – 15 years	18	3.9132	0.7109
16 – 20 years	12	3.5878	1.1000
21 – 25 years	23	3.6822	0.9189
26 – 30 years	8	3.9165	0.9245
More than 30 years	6	3.6235	1.0060

Test 15 (NSNT): Average Change in Teaching Methodology as a Function of Teacher's Years of Experience as a Physics Teacher.

Based on a sample size of 92 participants, the statistical analysis found no statistically significant difference in the average change in teaching methodology across all categories (F = 1.622, p = 0.176). More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. Table 25 summarizes the descriptive data for this test.

Table 25: Sample Size, Mean Change in Teaching Methodology, and Standard Deviations for the "Years of Experience as Physics Teacher" Category.

Years of experience	Sample size	Arithmetic mean	Standard deviation
0 – 5 years	42	3.5716	1.0101
6 – 10 years	22	4.0461	0.8796
11 – 15 years	9	3.5651	0.6782
16 – 20 years	11	3.8718	0.5586
21 – 25 years	6	4.2228	0.5115
26 – 30 years	1	na	na
More than 30 years	1	na	na

Test 16 (NSNT): Average Change in Teaching Methodology as a Function of School Geographical Location.

Based on a sample size of 88 participants, the statistical analysis found no statistically significant difference in the perceived degree of confidence in the teacher's physics knowledge across all categories (F = 0.008, p = 0.992). More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. Table 26 summarizes the descriptive data for this test.

Table 26: Sample Size, Average Change in Teaching Methodology, and Standard Deviations for School Geographical Location.

School location	Sample size	Arithmetic mean	Standard deviation
Urban	61	3.7705	0.9747
Suburban	9	3.7567	0.9400
Rural	18	3.7394	0.6828

Test 17 (NSNT): Average Change in Teaching Methodology as a Function of the Perceived Freedom of the Teacher to Modify the Course Content.

Based on a sample size of 89 participants, the statistical analysis found no statistically significant difference in the average change in physics content presentation across all categories ($F = 0.480$, $p = 0.621$). More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. Table 27 summarizes the descriptive data from this test.

Table 27: Sample Size, Average Change in Teaching Methodology and Standard Deviations for the Perceived Freedom of the Teacher to Modify the Course Content.

Perceived freedom	Sample size	Arithmetic mean	Standard deviation
No freedom	12	3.7120	1.0493
Some freedom	57	3.8152	0.7704
Absolute freedom	20	3.5848	1.1899s

Test 18 (NSNT): Average Change in Teaching Methodology as a Function of the Teacher's Ideological Beliefs.

Based on a sample size of 92 participants, the statistical analysis found no statistically significant difference in the average change in teaching methodology across all categories (F = 0.334, p = 0.854). More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. Table 28 summarizes the descriptive data from this test.

Table 28: Sample Size, Mean Change in Teaching Methodology and Standard Deviations for the Teacher's Ideological Beliefs.

Ideological beliefs	Sample size	Arithmetic mean	Standard deviation
Pro-statehood	21	3.6127	0.7992
Pro-commonwealth	27	3.7749	1.0740
Pro assoc. republic	8	4.0465	0.4954
Pro-independence	16	3.7154	0.7820
Other/blank/multiple	20	3.7526	1.0300

Test 19 (D): Average Change in Teaching Methodology as a Function of the Number of Students that Physics Teachers Have in their Groups.

Based on a sample size of 90 participants, the statistical analysis found an overall significant relationship between the average change in teaching methodology and the number of students per group teachers have (F = 3.641, p = 0.030). In particular, the post-hoc pair-wise comparisons identified a significant difference between the mean for the 21 – 30 students and the 31 – 40 students categories.

However, although the results are significant, this dependent variable does not satisfy the test for homogeneity of variance (L = 4.153, p = 0.019). This test was discarded. Table 29 summarizes the descriptive data for this test.

Table 29: Sample Size, Average Change in Teaching Methodology, and Standard Deviations for the Number of Students Physics Teachers Have in their Groups.

No. students per group	Sample size	Arithmetic mean	Standard deviation
0 – 10 students	2	na	na
11 – 20 students	12	3.8708	0.4847
21 – 30 students	49	3.9329	0.7893
31 – 40 students	29	3.3798	1.1442

Test 20 (D): Average Change in Teaching Methodology as a Function of the Perceived Freedom of the Teacher to Modify their Teaching Methodology.

Based on a sample size of 87 participants, the statistical analysis found an overall statistically significant difference in the average change in teaching methodology across all categories (F = 3.724, p = 0.028). However, the post-hoc pair-wise comparison failed to identify any two means that are statistically different. Despite a significant result, the test for homogeneity of variance was significant (L = 9.628, p = 0.000). Since the assumption of homogeneity of variance is not met, this test was discarded. Table 30 summarizes the descriptive data for this test.

Table 30: Sample Size, Average Change in Teaching Methodology and Standard Deviations for the Perceived Freedom of the Teacher to Modify their Teaching Methodology.

Perceived freedom	Sample size	Arithmetic mean	Standard deviation
No freedom	5	2.9094	1.8206
Some freedom	52	3.9159	0.7040
Absolute freedom	30	3.5641	0.9996

Discussion: Univariate Statistical Tests for Change in Teaching Methodology

The eleventh test demonstrated that males modify their teaching methodology to make them contextually and culturally relevant significantly more than females. Since the academic preparation for becoming a science teacher might be similar for both genders, I theorize that factors related to their classroom experience are responsible for this difference, but there are no data to support this or any particular explanation for the significant result. Unfortunately, the data gathered do not provide any clues about this assertion; only future research might explore this topic more deeply.

The twelfth test originally revealed that there was not a statistical relationship between the teachers' mean changes to their teaching methodologies to make them more contextual and culturally relevant and their academic preparation in physics. This finding is paradoxical in a sense, because one might think that subject content preparation and pedagogical preparation are two independent realms. Evidence of this is the fact that in Puerto Rico science teachers take their content area courses from the academic departments and their secondary or science pedagogy courses from the College of

Education. I think that these last three tests do suggest that teachers must know their physics content in order for them to recognize a need to change. Teachers who are not well prepared in physics might tend to follow the text more closely and focus on covering the content without taking into consideration the local students' needs, experiences and interests.

The thirteenth test exploring a relationship between the participants' evaluation of the textbook quality and the three dependent variables failed to detect significant relationships among them. However, the examination of the reported means do indicate a tendency toward increasing changes in teaching methodologies to make them contextual and culturally relevant as the evaluation moved from excellent, to good, to average, to deficient/poor in the textbook quality independent variable. This might imply that physics teachers are more flexible in their conceptions about teaching methodologies and how they can be changed, compared to changes in content material. Subsequent studies might tackle this interesting tendency in more detail.

The fourteenth test demonstrated that there is not a significant relationship between changes teacher make to their teaching methodologies in order to accommodate more contextual and cultural relevance and the participants' teaching experience. A new statistical analysis was made with collapsed categories (0 – 10 years of experience, 11 – 20 years of experience, and 21 or more years of experience, and it also failed to disclose statistical differences between the reported means ($F = 0.037$, $p = 0.963$). However, since all means are above three, we can claim that physics teachers, regardless of their teaching experience, do report making noticeable changes to their teaching methodologies.

The fifteenth test demonstrated that there is not a significant relationship between the teachers' years of experience teaching physics and the mean change in teaching methodologies to make them more contextually and culturally relevant, even after collapsing the last three categories into one ($F = 1.633$, $p = 0.188$). The sixteenth tests, which explored a relationship between the participant's school geographical location (urban, suburban, and rural) and the average change in teaching methodologies failed to detect a statistical difference. The seventeenth test showed that there is not a statistical relationship between whether the participants believed they have freedom to modify the course content in general, and the reported mean changes in teaching methodologies to make them contextual and culturally relevant.

The eighteenth test found no relationship between the teachers' ideological beliefs and the reported mean change to teaching methodologies to make them contextual and culturally relevant, even after performing the statistical analysis of the two new models ($n = 72$, $F = 0.432$, $p = 0.651$ for the first Model; $n = 72$, $F = 0.349$, $p = 0.707$ for the second Model). As the reader might recall, Model one collapsed the categories "pro-commonwealth" and "associated republic" into a single category; the second Model collapsed the categories "pro-independence" and "associated republic" into a single category. Overall, it is quite surprising, that the teachers' ideological beliefs have no significant effect in their change to their teaching methodologies to make them contextual and culturally relevant, that is, they all make noticeable changes, regardless of their political affiliation.

The nineteenth test, which explored a relationship between the number of students teachers have in their physics classroom and the mean change to their teaching methodologies to make them more contextually and culturally relevant, was significant even after collapsing the first two categories into a single one ($F = 3.704$, $p = 0.028$). However, the Levene test for homogeneity of variance determined that the data was heteroscedastic. Since heteroscedasticity plus an unequal sample size (14 for the 1 – 20 category, 49 for 21 – 30 category, and 29 for the 31 – 40 category) makes this test inaccurate, it was reported but discarded.

The twentieth test found a statistical relationship between whether teachers believed they have freedom to select and modify their teaching methodologies, and the reported mean changes in teaching methodologies to make them contextual and culturally relevant. Since these two variables are conceptually very close to each other, the significant result was promising, however, the Levene test for homogeneity of variance determined that the data was heteroscedastic. Since heteroscedasticity plus an unequal sample size (5 for the “no freedom” category, 52 for the “some freedom category” and 30 for the “absolute freedom” category) makes this test inaccurate, it was reported but discarded.

Findings: Univariate Statistical Tests for Teachers’ Subject Knowledge Confidence

The following section presented the findings associated with the dependent variable “teachers’ perceived confidence in their physics knowledge”. For each variable, significant tests will be presented first, followed by tests that showed a non-significant trend, non-significant/non-trend tests, and finishing with tests that were discarded because of assumption violation, especially heteroscedasticity.

Test 21 (S): Perceived Degree of Confidence in the Teacher's Physics Knowledge as a Function of the Number of Semesters of Physics Courses Teachers Have.

Given n = 89 participants, the statistical analysis revealed that there is not a statistically significant difference in the perceived degree of confidence in the teacher's physics knowledge across all categories (F = 1.669, p = 0.139). Table 31 summarizes the descriptive data for this test.

Table 31: Sample Size, Mean Change in Perceived Degree of Confidence in Physics Knowledge, and Standard Deviations for the Number of Semesters of Physics Courses Teachers Have.

No. semesters of physics	Sample size	Arithmetic mean	Standard deviation
0 – 2 semesters	23	4.2406	0.6515
3 – 5 semesters	29	4.4057	0.5556
6 – 8 semesters	14	4.6064	0.4269
9 – 11 semesters	8	4.7285	0.1990
12 – 14 semesters	3	4.5500	0.1500
15 – 17 semesters	3	4.4920	0.5258
18 + semesters	9	4.7306	0.4082

However, since some categories have few subjects compared to others, the original seven categories were collapsed into four categories to increase the power of the test and the statistical analysis was performed again. Table 32 summarizes the new descriptive information.

Table 32: Sample Size, Mean Change in Perceived Degree of Confidence in Physics Knowledge, and Standard Deviations for the Number of Semesters of Physics Courses Teachers Have (Collapsed Data).

No. semesters of physics	Sample size	Arithmetic mean	Standard deviation
0 – 2 semesters	23	4.2406	0.6515
3 – 5 semesters	29	4.4057	0.5556
6 – 11 semesters	22	4.6508	0.3601
12 + semesters	15	4.6467	0.3868

The new analysis showed a statistical difference between the reported means ($F = 3.126$, $p = 0.030$), which state the obvious fact that teachers with less academic preparation in physics have less confidence in their physics knowledge compared to teachers with more physics courses.

Test 22 (T): Perceived Degree of Confidence in the Teacher's Physics Knowledge as a Function of School Geographical Location.

Given n = 86 participants, the statistical analysis revealed that there is not a statistically significant difference in the perceived degree of confidence in the teacher's physics knowledge across all categories ($F = 0.876$, $p = 0.420$). More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. Table 33 summarizes the descriptive data for this test.

Table 33: Sample Size, Mean Change in Perceived Degree of Confidence in Physics Knowledge, and Standard Deviations for the School Geographical Location.

School location	Sample size	Arithmetic mean	Standard deviation
Urban	59	4.5236	0.4662
Suburban	9	4.3940	0.4877
Rural	18	4.3426	0.7604

Test 23 (T): Perceived Degree of Confidence in the Teacher's Physics Knowledge as a Function of the Perceived Freedom of the Teacher to Modify their Teaching Methodology.

Given n = 85 participants, the statistical analysis revealed that there is not a statistically significant difference in the average change in physics content presentation across all categories (F = 0.251, p = 0.779). More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. For this variable, the test for homogeneity of variance was not significant. Table 34 summarizes the descriptive data for this test.

Table 34: Sample Size, Perceived Degree of Confidence in the Teacher's Physics Knowledge and Standard Deviations for the Perceived Freedom of the Teacher to Modify their Teaching Methodology.

Perceived freedom	Sample size	Arithmetic mean	Standard deviation
No freedom	4	4.3010	0.7442
Some freedom	52	4.4871	0.5039
Absolute freedom	29	4.5090	0.6054

Test 24 (NSNT): Perceived Degree of Confidence in the Teacher's Physics Knowledge as a Function of Teacher's Gender.

Given n = 90 (48 males and 42 females), the statistical analysis revealed that the perceived degree of confidence of physics knowledge for males was 4.3825 with a standard deviation of 0.6301. For females, the perceived degree of confidence of physics knowledge was 4.5704 with a standard deviation of 0.3872. The difference in means between males and females was also not significant (F = 2.806, p = 0.097).

Test 25 (NSNT): Perceived Degree of Confidence in the Teacher's Physics Knowledge as a Function of Teacher's Years of Experience.

Given n = 90 participants, the statistical analysis revealed that there is not a statistically significant difference in the perceived degree of confidence in the teacher's physics knowledge across all categories (F = 1.317, p = 0.259). More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. Table 35 summarizes the descriptive data for this test.

Table 35: Sample Size, Mean Change in Perceived Degree of Confidence in Physics Knowledge, and Standard Deviations for the "Years of Experience" Category.

Years of experience	Sample size	Arithmetic mean	Standard deviation
0 – 5 years	11	4.3684	0.3234
6 – 10 years	14	4.4669	0.5697
11 – 15 years	18	4.3404	0.6872
16 – 20 years	12	4.7500	0.4095
21 – 25 years	22	4.5497	0.4262

26 – 30 years	7	4.5337	0.3609
More than 30 years	6	4.1285	0.8533

Test 26 (NSNT): Perceived Degree of Confidence in the Teacher's Physics Knowledge as a Function of Teacher's Years of Experience as a Physics Teacher.

Given n = 90 participants, the statistical analysis revealed that there is not a statistically significant difference in the perceived degree of confidence in the teacher's physics knowledge across all categories (F = 1.611, p = 0.179). More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. Table 36 summarizes the descriptive data for this test.

Table 36: Sample Size, Mean Change in Perceived Degree of Confidence in Physics Knowledge, and Standard Deviations for the "Years of Experience as Physics Teacher" Category.

Years of exp phys. teacher	Sample size	Arithmetic mean	Standard deviation
0 – 5 years	42	4.3436	0.5694
6 – 10 years	21	4.5277	0.4226
11 – 15 years	9	4.4866	0.8036
16 – 20 years	10	4.8038	0.2507
21 – 25 years	6	4.4728	0.4222
26 – 30 years	1	na	na
More than 30 years	1	na	na

Test 27 (NSNT): Perceived Degree of Confidence in the Teacher's Physics Knowledge as a Function of the Number of Students Physics Teachers Have in their Groups.

Given n = 89 participants, the statistical analysis revealed that there is not a statistically significant difference in the perceived degree of confidence in the teacher's physics knowledge across all categories (F = 0.331, p = 0.719). More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. For this variable, the test for homogeneity of variance was not significant. Table 37 summarizes the descriptive data for this test.

Table 37: Sample Size, Mean Change in Perceived Degree of Confidence in Physics Knowledge, and Standard Deviations for the Number of Students Physics Teachers Have in their Groups.

No. students per group	Sample size	Arithmetic mean	Standard deviation
0 – 10 students	2	na	na
11 – 20 students	12	4.3879	0.4502
21 – 30 students	49	4.4472	0.5293
31 – 40 students	29	4.5267	0.5915

Test 28 (D): Perceived Degree of Confidence in the Teacher's Physics Knowledge as a Function of the Perceived Freedom of the Teacher to Modify the Course Content.

Given n = 87 participants, the statistical analysis revealed that there is an overall statistically significant difference in the perceived degree of confidence in the teacher's physics knowledge across the categories (F = 4.803, p = 0.011). In particular, the post-hoc pair-wise comparison identified two significant differences between individual means. The first significant difference is between the mean of those who perceived that they have no freedom to modify the presentation of the physics concepts and those who perceived that they have some freedom to modify the presentation of the physics concepts. The second significant difference is between the mean of those who perceived that they have no freedom to modify the presentation of the physics concepts and those who perceived that they have absolute freedom to modify the presentation of the physics concepts.

However, although the results are significant, this dependent variable does not satisfy the test for homogeneity of variance (L = 11.397, p = 0.000). This test was discarded. Table 38 summarizes the descriptive data for this test.

Table 38: Sample Size, Perceived Degree of Confidence in the Teacher's Physics Knowledge and Standard Deviations for the Perceived Freedom of the Teacher to Modify the Course Content.

Perceived freedom	Sample size	Arithmetic mean	Standard deviation
No freedom	11	4.0227	1.0051
Some freedom	57	4.5369	0.4166
Absolute freedom	19	4.5518	0.3905

<u>Test 29 (D): Perceived Degree of Confidence in the Teacher's Physics Knowledge as a Function of Text Quality.</u>

Given n = 87 participants, the statistical analysis revealed that there is not a statistically significant difference in the average change in physics content presentation across all categories (F = 2.533, p = 0.062). More detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. For this variable, the test for homogeneity of variance was significant (L = 3.295, p = 0.024). This test was discarded. Table 39 summarizes the descriptive data for this test.

Table 39: Sample Size, Perceived Degree of Confidence in the Teacher’s Physics Knowledge and Standard Deviations for Text Quality.

Text quality	Sample size	Arithmetic mean	Standard deviation
Excellent	7	4.4727	0.4412
Good	45	4.5998	0.3782
Average	31	4.3294	0.6223
Deficient/poor	4/1	4.0878	1.0159

<u>Test 30 (D): Perceived Degree of Confidence in the Teacher’s Physics Knowledge as a Function of the Teacher’s Ideological Beliefs.</u>

Given n = 90 participants, the statistical analysis revealed that there is a statistically significant difference in the perceived degree of confidence in the teacher’s physics knowledge across all categories (F = 2.582, p = 0.043). However, more detailed analyses, especially pair-wise comparisons among the means for the different categories, failed to identify any two means that are statistically different. Despite a significant result, the test for homogeneity of variance was significant (L = 2.775, p = 0.032). This test was discarded. Table 40 summarizes the descriptive data for this test.

Table 40: Sample Size, Perceived Degree of Confidence in the Teacher's Physics Knowledge and Standard Deviations for the Teacher's Ideological Beliefs.

Ideological beliefs	Sample size	Arithmetic mean	Standard deviation
Pro-statehood	21	4.3393	0.7240
Pro-commonwealth	25	4.5860	0.3614
Pro assoc. republic	8	4.6189	0.3587
Pro-independence	16	4.1793	0.6528
Other/blank/multiple	20	4.6360	0.3173

Discussion: Univariate Statistical Tests for Teachers' Subject Knowledge Confidence

The twenty-first test originally showed that there was not a statistical relationship between the participants' perceived degree of confidence in their physics knowledge and their academic preparation in physics, however a new statistical test with fewer categories detected a significant result between the relationship of academic preparation in physics and perceived degree of confidence in this subject. The fact that this obvious result was found provides evidence that the confidence scale is measuring what it was intended to measure. This might be considered a barometer test for this instrument.

The twenty-second test, which explored a relationship between the participant's school geographical location (urban, suburban, and rural) and the perceived degree of confidence in their physics subject knowledge failed to detect a statistical difference. This result suggests that all physics teachers, regardless of whether the schools are located near the city or in rural areas, perceived themselves as confident in their physics subject knowledge. Results like these were expected because of the way science teachers' job placement in Puerto Rico, and the small geographical area of the island.

It should be noted that although the test was not significant, examining the reported means do indicate a trend toward less confidence in the participants' physics knowledge as you move from urban to suburban to rural. Future research might examine whether these trends might be worth of examining or not.

The twenty-third test demonstrated that there is not a statistical relationship between whether teachers believed they have freedom to select and modify their teaching methodology, and their perceived degree of confidence in their physics knowledge. This result suggests that their confidence of their knowledge is independent of their beliefs about whether they can select and change their teaching methodologies. However, there is a trend toward more confidence in the participants' beliefs regarding their own content knowledge as we move from no freedom, to some freedom to absolute freedom. Only future research might determine how these two variables are related, if they are related at all.

The raw data of the twenty-fourth test revealed that females tend to be more confident of their physics knowledge compared to males. However, this difference is not significant based on the sample from which the data were obtained. The large mean values for this variable do suggest that all teachers, regardless of gender, perceived themselves as secure of their physics subject knowledge.

The twenty-fifth test revealed that there is not a significant relationship between the participants' years of experience as teachers and the perceived degree of confidence in physics knowledge they have. As in the previous test, two of the seven categories have less than ten participants. The new categories, similar to the previous test, were also analyzed statistically and significant differences were not detected (F = 0.153, p = 0.858). The large mean values for this variable do suggest that all teachers, regardless of teaching experience, perceived themselves as confident of their physics knowledge.

The twenty-sixth test revealed that there is not a significant relationship between the teachers' perceived degree of confidence in their physics subject knowledge and their experience as physics teachers. In other words, their confidence remained stable across all experience levels, which suggest that they are reporting that they are confident about the physics knowledge needed to teach that particular course (probably with that particular test). It might also suggest that there is no growth in their preparation over time nor "decay" caused by being out of college for a number of years. As in the previous test, the last three categories were collapsed into one and the statistical analysis was repeated. No significant results were found (F = 1.633, p = 0.188). Since the reported means are larger than four, it can be argued that physics teachers perceived themselves as confident of their physics knowledge regardless of years of experience teaching physics.

The twenty-seventh test did not revealed a significant relationship between the participant's perceived degree of confidence in their physics knowledge and the number of students they have in their groups, even after collapsing the first two categories into a new one (F = 0.225, p = 0.799). This result suggests that physics teachers are confident of their physics knowledge regardless of the number of students they receive in their classrooms, which we expected.

The twenty-eight test, which explored a relationship between whether the participants believed they have freedom to modify the course content in general, and their perceived degree of confidence in their physics knowledge, was significant. This result might suggest that teachers reporting having no freedom to change the course content are also less confident of their physics knowledge, however, the Levene test for homogeneity of variance determined that the data was heteroscedastic. Since heteroscedasticity plus an unequal sample size (11 for the "no freedom" category, 57 for the "some freedom category" and 19 for the "absolute freedom" category) makes this test inaccurate, it was reported but discarded.

The twenty-ninth test exploring a relationship between the participants' evaluation of the textbook quality and the perceived degree of confidence in their physics subject knowledge failed to detect a significant relationship. This result indicates that all physics teachers, regardless of how they evaluate the physics textbook's quality, perceive themselves as confident in their physics subject knowledge. Test number twenty-six was reported, but it will be discarded because it might be inaccurate. A reason for this is that the Levene test for homogeneity of variance determined that the data was heteroscedastic plus the fact that sample size per category is unequal.

The thirtieth test found a statistical relationship between the participants' ideological beliefs and their perceived degree of confidence in their physics knowledge, being pro-independence teachers more confident in their physics knowledge. However, the Levene test for homogeneity of variance determined that the data was heteroscedastic. Since heteroscedasticity plus an unequal sample size (ranging from 25 in the "pro-commonwealth category to 8 in the associated republic category) makes this test inaccurate, it was reported but discarded. Also, Model One found a significant Levene test ($L = 3.194$, $p = 0.047$), so the significant relationship discovered ($n = 70$, $F = 3.302$, p

= 0.043) must also be considered inaccurate and disposable. Model Two was homoscedastic (2.187, $p = 0.120$), but failed to detect a significant relationship between the variables compared ($n = 70$, $F = 1.584$, $p = 0.213$).

Overall the last ten tests presented relatively large means, which is convincing evidence, regardless of the independent variable, that Puerto Rican physics teachers feel that they are knowledgeable, at least in the content they teach to high school students.

Summary of Univariate Tests

In summary, from among the thirty univariate statistical tests performed in this section, there were six significant results:

- Test 1 (S): Average change in physics content presentation is significantly related to the participants' physics teaching experience.
- Test 2 (S): Average change in physics content presentation is significantly related to the number of students per group the teachers have.
- Test 3 (S): Average change in physics content presentation is significantly related to the participants' perceived freedom to choose and modify their teaching methodology.
- Test 11 (S): Average change in teaching methodology is significantly related to the participants' gender.
- Test 12 (S): Average change in teaching methodology is significantly related to the number of physics semesters teachers have.
- Test 21 (S): Perceived degree of confidence in the teacher's physics knowledge is significantly related to the number of physics semesters teachers have.

In addition, four non-significant trends were noted:

- Test 4 (T): Average change in physics content presentation might be connected with the number of physics semesters teachers have.
- Test 13 (T): Average change in teaching methodology might be connected to text quality as evaluated by the participants.
- Test 22 (T): Perceived degree of confidence in the teacher’s physics knowledge might be connected with the schools’ geographical location.
- Test 23 (T): Perceived degree of confidence in the teacher’s physics knowledge might be connected to the perceived freedom of the participants to modify their teaching methodology.

Also, twelve tests reported no significant results and no obvious trends, and seven tests, both significant and not significant, were discarded because they did not fulfill the assumption of homogeneity of variance combined with unequal sample sizes.

Findings: Multivariate Statistical Tests

Despite the fact that separately, the independent variables “years of experience as physics teacher” and “physics semester courses” have no significant relationship with any of the dependent variables of the study (average change in content presentation, perceived degree of confidence in physics knowledge, and average change in teaching methodology), multivariate analysis might show additional information. The independent variables were selected a priori.

Using the original coding for the variables in the multivariate analysis created a 5 x 7 matrix, which presented some problems because there were cells with only one participant. As a consequence, some categories were combined.

<u>Multivariate Comparison One</u>

Table 41 shows a 3 x 2 matrix with years of experience as physics teachers (between 1 – 5, 6 – 10, and more than 11 years) in one axis, and academic preparation in physics (between 0 – 5 semesters, and more than 6 semesters) in the other axis. The dependent variable in this case is the average change in physics content presentation. Means and standard deviations are shown in the interior cells. The test for homogeneity of variance was not significant.

Table 41: Means and Standard Deviations for the Dependent Variable "Change in Physics Content Presentation" via the Independent Variables "Years of Experience as Physics Teachers" and "Academic Preparation in Physics".

	1 – 5 Years	6 – 10 Years	11+ Years
0 – 5 Semesters	3.0021/ 1.2086	3.8879/ 0.6721	3.9496/ 0.9732
6 + Semesters	3.7193/ 0.8973	3.9002/ 1.1199	3.5774/ 0.8130

The statistical analysis showed that there is not a significant relationship for the main effects of years of experience as physics teacher ($F = 1.781$, $p = 0.175$) or academic preparation in physics ($F = 0.235$, $p = 0.629$). The interaction between the independent variables is also not significant ($F = 1.921$, $p = 0.153$).

Multivariate Comparison Two

Table 42 shows a 3 x 2 matrix with years of experience as physics teachers (between 1 – 5, 6 – 10, and more than 11 years) in one axis, and academic preparation in physics (between 0 – 5 semesters, and more than 6 semesters) in the other axis. The dependent variable in this case is the perceived confidence in their physics knowledge. Means and standard deviations are shown in the interior cells. The test for homogeneity of variance was not significant.

Table 42: Means and Standard Deviations for the Dependent Variable “Change in Teaching Methodology” via the Independent Variables “Years of Experience as Physics Teachers” and “Academic Preparation in Physics”.

	1 – 5 Years	6 – 10 Years	11+ Years
0 – 5 Semesters	1.7032/ 0.6170	1.6406/ 0.3748	1.5793/ 0.7094
6 + Semesters	1.4706/ 0.3016	1.3995/ 0.4344	1.2471/ 0.3350

The statistical analysis revealed that there is not a significant relationship for the main effect of years of experience as physics teacher ($F = 0.756$, $p = 0.473$) or for the interaction between the independent variables ($F = 0.072$, $p = 0.931$). However, there is a significant relationship for the main effect of academic preparation in physics ($F = 4.724$, $p = 0.033$), which suggest that the more academically prepared the teachers are, their perceived confidence in his physics knowledge increases. This is equivalent to the result found on the univariate test number eleven.

Multivariate Comparison Three

Table 43 shows a 3 x 2 matrix with years of experience as physics teachers (between 1 – 5, 6 – 10, and more than 11 years) in one axis, and academic preparation in physics (between 0 – 5 semesters, and more than 6 semesters) in the other axis. The dependent variable in this case is the average change in teaching methodology. Means and standard deviations are shown in the interior cells. The test for homogeneity of variance was not significant:

Table 43: Means and Standard Deviations for the Dependent Variable "Teachers' Subject Matter Confidence" via the Independent Variables "Years of Experience as Physics Teachers" and "Academic Preparation in Physics".

	1 – 5 Years	6 – 10 Years	11+ Years
0 – 5 Semesters	3.4838/ 1.0823	4.0151/ 0.5144	3.9269/ 0.6038
6 + Semesters	3.8938/ 0.6284	4.2033/ 0.9409	3.6649/ 0.7953

The statistical analysis found no significant relationship for the main effects of years of experience as physics teacher ($F = 1.325$, $p = 0.271$) or academic preparation in physics ($F = 0.285$, $p = 0.595$). The interaction between the independent variables is also not significant ($F = 0.995$, $p = 0.374$).

Discussion: Multivariate Statistical Tests

Although some of the univariate tests suggested significant relationship or non-significant trends relating the two independent variables of interest and the dependent variables, none of the multivariate tests performed showed that the combined effects of the two independent variables selected have a significant effect on the dependent variables. If there are, in fact, significant relationships between all or some of those variables, the relatively low sample size in some cells might cause the multivariate tests not to be powerful enough to detect them. Probably more research in this area, especially with a larger sample size and more precise data-gathering instruments, is necessary.

Summary of Fourth Chapter

The descriptive data for the independent variables provided insight and context about the participants' characteristics. For example, there was a remarkable difference between experience in teaching and experience in physics teaching. The result showed that most physics teachers are relatively inexperienced compared to their total teaching experience. Some possible explanations for this difference were stated. Also, it was found that one in four teachers have less than two semesters of physics, possibly a year of physical sciences or a year of general physics. The implications of this for teaching quality and the inclusion (or non-inclusion) of contextual and culturally relevant approaches in physics teaching are undeniable. If the 1:4 ratio is representative of all physics teachers in Puerto Rico, as I think it is, then there are a large number of teachers without the deep knowledge necessary to use a contextual and culturally relevant approach effectively in the teaching of physics.

It was also learned about the overcrowding of some physics classrooms and the effect this might have in the quality of teacher instruction, and about how most teachers appear to tailor the physics curriculum to the needs of their students, instead of following the physics curriculum prescribed from the Puerto Rico Department of Education. On the other hand, we saw teachers who think they have no freedom to change their teaching methodologies despite the fact that the Puerto Rico Department of Education leaves this decision to each teacher.

The descriptive information for the dependent variables is also enlightening. We saw how that, for the variable “average change in physics content presentation” the topics that are reported as made more contextual and culturally relevant changes, are usually those taught more frequently in the first semester of the course. Being taught more often, teachers have a good grasp of them and can make the changes. Overall, most of the reported means are larger than three, which suggests that teachers do make appreciable changes to their physics content presentation. For the variable “average change in teaching methodologies”, the range of responses was broader, but most of the means are larger than three, which implies that teachers also made changes to their methodologies to make them contextual and culturally relevant. Data from the third dependent variable suggests that a great majority of teachers feel confidence about their physics knowledge. As I pointed out elsewhere, an interesting follow up to this study might be to reconcile, if possible, the teachers perceived confidence in their subject area and the poor preparation in physics that some teachers appear to have.

Results from the univariate test showed that the reported mean change in physics content presentation is statistically related to the teachers’ experience teaching physics, class size, and whether they believe have freedom to change their teaching methods. Also, the reported mean change in teaching methodologies is statistically related to gender and academic preparation in physics. The participants’ confidence in their physics knowledge was significantly related to their academic preparation in this area. Some of the tests that were not significant are also valuable as a validity tool because no significant relationship was expected and none was found. Some examples of these tests are those related to the schools' geographical location and school size.

The multivariate test between the two previously selected independent variables (academic preparation and experience teaching physics) and the three dependent variables was unable to detect a statistical relationship. Notice that some of the univariate tests using these independent variables do provide significant results (academic preparation was related to changes in teaching methodology and confidence in the subject knowledge; physics teaching experience was related to changes in physics content presentation) and interesting trends (academic preparation might be associated with changes in physics content presentation). These facts suggest that the combination of the two pre-selected independent variables are no more effective in explaining changes in the dependent variables compared to their individual explanatory power. Another possible explanation is that the sample size of the subcategories is not large enough for the test to have enough power.

CHAPTER 5

QUALITATIVE ANALYSIS: SHORT ANSWER DATA

Overview

In the following section, the findings from six short answer questions posed to the 92 participants through the written questionnaire are presented. The purpose of these questions was to gather qualitative data about the participants' knowledge and opinions regarding contextual and culturally relevant physics teaching, and the textbook that is actually used in Puerto Rican high schools. Also, to gather large amounts of qualitative data without interviewing each participant. These questions were:

- Do you think that physics concepts should be taught in contextual, culturally relevant ways for Puerto Rican students? Why or why not?
- Do you think that teaching physics concepts in a contextual, culturally relevant way can improve Puerto Rican students' academic achievement in physics? Why or why not?
- Do you think that the textbook you are using is appropriate to the context and cultural background of Puerto Rican students?
- How do you incorporate modifications in the physics curriculum to make it contextual to your students? Please provide a few examples.
- How do you incorporate modifications in the physics curriculum to make it more culturally relevant to your students? Please provide a few examples.

- How do you modify your teaching strategies and techniques to help your students learn the physics content better?

Although teachers were instructed to use additional paper to elaborate on their responses, very few did, limiting themselves to a small space under each question.

The basic approach used to analyze this qualitative data began with establishment of categories based on the teachers' responses. These categories are presented, along with representative quotes and weighted subcategories. I thought this way of analyzing the data, as opposed to the more common method of classifying persons according to their responses, was much more efficient, especially with a large sample size like the one obtained in this study. After each findings section, a discussion of the findings follow, in which the most important findings will be summarized. Also, statements that might explain particular findings and additional context will be provided. At the end of this section, a summary highlighting the research findings will be included.

Findings: Short Question One

This section summarizes the participants' responses to the question: "Do you think that physics concepts should be taught in contextual, culturally relevant ways for Puerto Rican students? Why or why not?" Eighty-six teachers, out of 92 participants answered this question. Of those, 71 participants answered affirmatively (approximately 83%), 10 answered affirmatively but with conditions (approximately 12%), and four participants answered negatively (approximately 5%). Only one participant answered that there might be no difference between using contextual and culturally relevant strategies or not.

From the group of participants who answered affirmatively, eight (approximately 11%) provided only a general statement (yes, of course). The rest of the participants in this category (63 participants, or approximately 89%) provided more specific statements, that included reasons why they thought physics could be taught to Puerto Rican students in a contextual and culturally relevant way, and some examples that might be used for this purpose. Based on the participants' responses, the reasons why they believe in teaching physics with a contextual and culturally relevant component are (n = 63 statements):

- Students will see and understand the relationship between the physics concepts they study and their daily life experiences (19 statements, or 30%).
- Students will learn physics in a way that is pertinent and meaningful to them, as opposed to rote memorization of isolated facts (15 statements, or 24%).
- Students will learn physics and knowing about their history, culture and society at the same time (13 statements, or 21%).
- Students can learn better physics when the teachers scaffold the physics content using their previous knowledge and experiences (6 statements, or 10%).
- Students will be interested and motivated to learn physics if it is presented in a contextual and culturally relevant way (5 statements, or 8%).
- It prevents teachers from using the current textbook as the sole source of information (3 statements, or 5%)
- Students will get better grades if physics is presented in a contextual and culturally relevant way (2 statements, or 3%).

From the group of participants who answered that physics concepts should be taught in a contextual, culturally relevant way for Puerto Rican students only if some preconditions were met, these are the main preconditions the teachers mentioned (n = 10 statements):

- Teachers need locally made materials (textbook, guides) that use contextual and culturally relevant strategies extensively (5 statements, or 50%).
- Teachers must have experience and be very knowledgeable of both the physics concepts and the cultural context in which they live; otherwise it will be extremely difficult to be effective (4 statements, or 40%).
- Students must be mathematically ready to learn physics, that is, mathematics gaps and deficiencies must be corrected before teaching physics in a contextual and culturally relevant way (1 statement, or 10%).

There were also a number of participants who answered that physics concepts could not or should not be taught in a contextual, culturally relevant way for Puerto Rican students. The reasons they argued against this practice are (n = 5 statements; some participants gave more than one reason):

- Physics is a universal science, and should not reflect local particularities or biases (2).
- High school physics should be taught in the same way it would be taught in college, otherwise students will be confused (2).
- Some physics topics are difficult to explain in a contextual and culturally relevant way (1).

Interestingly, several teachers who answered affirmatively also pointed out the fact that physics is a universal science. Their argument was that (n = 11 statements):

- Physics is universal and does not have cultural specificity (6 statements, or 55%).
- Physics can be taught using both local relevance (for the physics concepts to be understood better) and global relevance (for the students' physics knowledge to be expanded and extrapolated to new situations) (3 statements, or 27%)
- Teaching physics in a contextual and culturally relevant way will limit the students' perspective and focus (2 statements, or 18%).

Discussion: Short Question One

An examination of the data from the short question #1, it is evident that the great majority of the teachers interviewed believe that teaching physics with a contextual and culturally relevant emphasis is achievable. This might be one of the reasons why the statistical analysis found that physics teachers made noticeable changes in both physics curriculum and methodology to make them more contextually and culturally relevant to local students. This finding is also very important because teachers must believe that a particular reform movement might be viable for them to be interested, learn it, and apply it in their classrooms. In this case, they are convinced of the merits of this teaching perspective and the positive effects it might have on students' understanding of physics.

However, some teachers answered affirmatively the question but were not willing or able to provide a rationale about why teaching physics with a contextual and culturally relevant perspective might be beneficial. It is quite possible that a number of the teachers do not have the knowledge or the opportunity to teach physics in that way, although they think it might be positive for the students.

The categories that came out of the teachers who responded affirmatively to the question tell me that they are aware of the benefits of using a contextual and culturally relevant perspective in the physics classroom. They mentioned that the applied nature of physics would be more obvious to students, that the creation of mental connection 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.

Some participants recognized that just implementing a new perspective on physics teaching might not be enough. They argued that teachers must be extensively prepared, not just in physics, but in applied physics, engineering, and Puerto Rican history, sociology, and culture. This means both preparing a full-fledged professional development program for classroom teachers, and reforming science teacher education in Puerto Rico. In addition to more preparation in the natural and social sciences, teachers need materials adequate for satisfactory implementation of the contextual and culturally relevant perspectives. Teachers suggested that the textbook must be locally produced and that supplementary teaching guides must also be provided.

But not just the teacher must be prepared. The participants argued that if students were not up to the challenge, the new perspective would be worthless. In this and other places a recurring theme is the local students lack of basic mathematical skills needed to tackle some of the more complex problems in the traditional physics course. In other words, just making proactive changes in one aspect of the students' learning experiences is deemed to failure. A more general science and math education reform must be put into place so that students will be ready to deal with high school physics.

Not everybody agrees that teaching physics in a contextual and culturally relevant way is adequate. Some teachers believe that using this approach 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. Of course, it would be interesting to know what percentage of high school physics students will continue undergraduate studies in the natural sciences (students in other areas might never take a physics course again). My guess is that most students who take physics, especially now that is required, will not go into college and might never see physics again. Are these teachers being elitist in the way they think about their class?

Another argument, presented by both teachers who answered the original question affirmatively and negatively is that the universality of physics must be taken into consideration when examining what new perspectives we can use to teach this subject. These teachers 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. 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 considers 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 natural science.

Findings: Short Question Two

This section summarizes the participants' responses to the question: "Do you think that teaching physics concepts in a contextual, culturally relevant way can improve Puerto Rican students' academic achievement in physics? Why or why not?" Eighty-eight teachers, out of 92 participants, answered this question. Of those, 74 participants, or approximately 84%, answer affirmatively, 7 participants, or approximately 15% answered that it might be done if some issues were addressed beforehand, five participant, or approximately 6%, answered negatively, and two participants answered with a statement that was ambiguous and could not be classified.

For those who answer affirmatively (n = 80 statements; some answered affirmatively but gave no details, others gave more than one reason), most of the main reasons proposed were very similar to the reasons provided in the previous question:

- Students will learn physics in a way that is pertinent and meaningful to them (22 statements, or 28%).
- Students will see and understand the relationship between the physics concepts they study and their daily life experiences (16 statements, or 20%).
- Students will be interested and motivated to learn physics if it is presented in a contextual and culturally relevant way (13 statements, or 16%).
- Students will conceptualize and comprehend better the physics material when using a contextual and culturally relevant perspective (11 statements, or 14%).

- Students can apply their physics knowledge, learned through contextual and culturally relevant ways, to local problems and situations (9 statements, or 11%).
- Students will develop a consciousness of the importance and use of physics (5 statements, or 6%)
- Students will learn physics and knowing about their history, culture and society at the same time (4 statements, or 5%).

From the group of participants who answered that physics concepts taught in a contextual, culturally relevant way for Puerto Rican students might improve their academic achievement only if some preconditions were met, these are the main preconditions the teachers mentioned (n = 7 statements):

- Factors affecting academic achievement other than the application of a contextual and culturally relevant perspective in physics teaching (no details provided) must also be studied and controlled (2 statements).
- Well-equipped classrooms, with laboratory equipment must be provided to do experiments and complement the new teaching perspective (1 statement).
- Deficiencies in mathematics and science must be addressed for the contextual and culturally relevant strategy to be satisfactory (1 statement).
- Statistical research must be performed comparing traditional and contextually and culturally relevant approaches before affirming that this approach will promote student achievement (1 statement).
- Students' future goals (going to college) must also be considered in changing the traditional teaching perspective, especially for those interested in the sciences (1 statement).

- Some thought should be put into how assessment will be performed using the new strategy. (These quote, taken in the context of the larger statement is referring to what new assessment techniques must be implemented, how are grades from the different teaching perspectives be comparable, and whether teachers will still use old assessment techniques to assess new strategy.) (1 statement)

Finally, the main reasons why some of the participants believed that implementing contextually and culturally relevant physics teaching will not improve academic achievement area (n = 5 statements)

- General skepticism (no additional details were provided) (2 statements).
- Students do not have interest in the class (1 statement).
- Students are deficient in mathematics (1 statement).
- We should not isolate ourselves from the rest of the world by teaching a local physics version. (1 statement).

Discussion: Short Question Two

After examining the responses participants gave to question #2, it is clear that most of the physics teachers believe that using a contextual and culturally relevant approach to teaching high school physics will result in better grades and more understanding. This might be another reason why the statistical analysis found that physics teachers make noticeable changes in both physics curriculum and methodology to make them more contextually and culturally relevant to local students. They believe that not using this approach will make students more apathetic and unresponsive to their class. Based on additional qualitative data, in which some teachers declare that students' grades are low and that they do not like physics, I theorize that a number of teachers might be trying to teach physics in a contextual and culturally relevant way, but they might not be doing so effectively, possibly because of lack of academic preparation (statistical data supported this aspect), or deep knowledge of the Puerto Rican history, sociology and culture.

Interestingly, most of the reasons teachers gave to support their belief that physics taught with a contextual and culturally relevant emphasis will positively affect their students' academic achievement were identical to those mentioned in the last section. This suggests consistency among the teachers, that they know, either by experience or professional preparation, that these reasons are why they either did or would make the changes. They repeatedly mentioned pertinence, meaningfulness, interest, and motivation as their justification to use a contextual and culturally relevant approach. As always, some teachers are more cautious in asserting that this approach will increase grades at all.

I think that the reasons the some teachers are skeptics are very well thought-out and reflect the reality of Puerto Rican schools. Two such issues are the lack of adequate materials and equipment to teach physics laboratories and to perform demonstrations and the deficiencies in basic mathematics and language-related skills (comprehension of written material, redaction) that students allegedly have. Other teachers are more inquisitive and argue that research must be done before reaching fast conclusions about the advantages of a particular teaching approach.

Findings: Short Question Three

After analyzing the 88 responses provided by the participants (four responses were either blank or unclear) to the question: “Do you think that the textbook you are using is appropriate to the context and cultural background of Puerto Rican students?” it was found that 15 participants, or approximately 17%, believe that the physics textbook is appropriate for local students, 26 participants, or approximately 30% believe that the textbook might be appropriate but that some other considerations must also take place for this to be true, and 47 participants, or approximately 53% believe that the textbook is not adequate for the Puerto Rican students they have in their classrooms.

The main reasons provided by the teachers who answered “yes” to the proposed questions, other than the three general statements of approval, are (n = 16 statements):

- The textbook presents physics content in a universal or general way (5 statements, or 31%).
- The textbook visuals, topics and/or exercises do apply to our society (5 statements, or 31%).
- The textbook is designed to be adapted to any culture (3 statements, or 16%).
- The textbook allows teachers the freedom to present and adapt the physics content according to the type of student (2 statements, or 13%).
- The textbook is in Spanish (1 statement, or 6%).

As I said, about 30% of the participants believe that the textbook they have might be adequate if some other factors or issues are taken into consideration first. Not considering three statements that a locally adapted textbook might not be enough to teach Puerto Rican students (no additional details), some of these factors and issues are:

- The textbook might have some portions that are not compatible with our culture and context (13 statements, or 42%).
- The textbook might have some parts that students would not understand (5 statements, or 16%).
- The textbook translation is inadequate to local students (4 statements, or 13%).
- More local visuals should be included (2 statements, or 6%).
- Students are not interested, or prepared to learn physics (2 statements, or 6%).
- The textbook should be revised and actualized (2 statements, or 6%).
- Physics should be perceived as a universal science (1 statement, or 3%).
- More materials and equipment are required (1 statement, or 3%).
- Teachers should not follow any textbook too closely (1 statement, or 3%).

Most of the participants reported believing that the physics textbook provided by the Puerto Rico Department of Education is not appropriate to the local population they have. Three teachers provided a general negative statement, with no additional details. The rationale behind the other participants' answers can be synthesized in the following statements (n = 65 statements):

- The physics content presentation is not consonant with our students' needs, experiences, and daily lives (22 statements, or 34%).
- The textbook does not present examples that show Puerto Rican culture (14 statements, or 22%).
- The textbook translation is poor and confusing (11 statements, or 17%).
- The textbook is not pertinent and meaningful to students (3 statements, or 5%).

- Students are not prepared for the mathematical approach of the textbook (3 statements, or 5%).
- The textbook structure and organization are poor (3 statements, or 5%).
- Schools lack the necessary materials and equipment (3 statements, or 5%).
- Topics are presented in a superficial way (2 statements, or 3%).
- The textbook has mistakes in problems (2 statements, or 3%).
- The textbook's authors do not know the needs of Puerto Rican students (2 statements, or 3%).

Discussion: Short Question Three

The available data demonstrate that most of the teachers believe that the textbook they are using is not adequate for the local population they serve. By arguing that the physics content presentation does not include a contextual and culturally relevant approach, teachers are clearly saying that effective physics teaching is achieved by taking into consideration, in the examples, exercises, or explanations, the experiences of our students and their culture. It is also evident that teachers expect that a textbook used in Puerto Rican schools be customized to that population.

In addition to the lack of a contextual and cultural perspective in the physics textbook, teachers also presented more general objections to the text. For example, they complained about the text's structure, organization, mathematical approach, and mistakes. The participants also mentioned the mediocre translation, suggesting that a book can be translated, but translation does not equal contextualization.

Other teachers said that the textbook was not totally inadequate and that some changes, including an overall update, the revision of some sections that might not be relevant to local students, the simplification and contextualization of the physics content presentation, an improved translation, and more visuals from Puerto Rico might make it a better educational tool. It would be interesting to explore whether a patchwork strategy will be enough to make an acceptable Puerto Rican textbook of physics, or whether the number of revisions and changes is too large, and starting from scratch may be a preferred option. Another option might be to complement the textbook with modules or units specially designed by Puerto Rican physicists, science educators, and physics teachers to provide context and culturally relevance to the physics content.

A number of teachers pointed out that the textbook is one of many education components that must work in unison to promote academic achievement. Other factors that must also be considered are general lack of students’ interest in physics, poor mathematical skills, and the absence of physics equipment and materials. This implies, as we all know, that education is a multi-factorial endeavor that requires multiple perspectives for its improvement.

There were some participants who believed that the textbook, as is, is adequate for their students. They argued that a generic physics course (one that does not take into consideration any culture in particular) is the right approach to teach physics. An implicit reasoning is that including a contextual and culturally relevant approach to a physics course will do a disservice to students, more than helping them, that seeing physics with a cultural lens is misleading and subjective.

Another explanation for these participants' responses is that there is really not a significant difference between the Puerto Rican and American culture, that both cultures have a western tradition, as opposed to other cultures, and that cultural boundaries are being blurred by our political relationship.

Findings: Short Question Four

This section summarizes the participants' responses to the question: "How do you incorporate modifications in the physics curriculum to make it contextual to your students? Please provide a few examples". Eighty-eight teachers, out of 92 participants, answered this question. Of those, 21 participants, or approximately 24 % provided general statements of support to the idea of making the physics class more contextual, but failed to provide specific examples. An additional 60 participants, or approximately 68% provided statements of support to contextualization and gave specific examples of how they make their physics class more contextual. Finally, three participants, or approximately 3% said that they make no changes to contextualize their class, and four participants provided ambiguous statements that could not be classified in any of the above categories.

Some of the general statements provided by the participants are similar to these:

- Once we study the theory and physics concepts, we can develop labs based on real situations here in our country and worldwide."
- "My changes are based on a diagnosis I made that allows me to place the students in contextual, cultural and intellectual frames."

- "There are daily situations that, with a little imagination, can be transferred to the [physics class], making it more interesting."
- We discuss life experiences [associated with physics] and how they impacted them."
- "I make theory to apply to the students' daily life realities, I explain daily situations [where physics in present] but students do not know how."
- "I use additional references and daily life situations."
- "[I] use drawings in the chalkboard that are familiar to the students."
- "Daily life examples are provided so that students can find the course's pertinence."
- "[I] present exercises with situations they live, real cases they must confront."
- "[I] find the way to relate theory with the realities of daily life."
- "[Doing labs I] try to use everyday materials and equipment."
- "[I] use the students' names [in exercises]."
- "Through action research in our school, community and home."

From those who provided specific examples of how they contextualize their physics class, most can be classified in the following alphabetical categories (with representative quotes):

- Architecture

  --"[I gave them] knowledge about building construction, roads, houses."

  --"In the last years there has been an increase in construction using materials and construction methods resistant to the forces of nature."
- Automobiles

  --"They calculate acceleration and velocity by using car race videos, and we discuss the results."

--"To calculate distance, acceleration, and time we use car races."

--"For Newton's first law, I mentioned that in Puerto Rico roads are very curvy, when the car moves to a side, the [human] body get displaced to the opposite side because the body keeps the same state of motion it had."

--"I use car accidents to show the terrible effects of not knowing or practice Newton's laws."

--"We study changes in velocity and acceleration studying car accidents and the lives they take."

- Homes and electricity

--"I teach how to calculate kWh using their power bill, and to read their home power meter."

--"I show them how to read their power meter when we talk about electricity."

--"[We discuss] the reasons why despite Puerto Rico being threatened by hurricanes, electric lines are not placed underground."

--"I create consciousness about how does their home electric receptacles work."

--"How to save energy in their home by knowing how much energy each electric appliance use."

--[We talked about] electricity consumption and circuits in their homes."

--"For example, when using electricity, the importance of knowing the benefits of electricity, what equipment is helpful for them in their homes and how to identify them."

- Internet

  --"I use a lot the Internet to make my curriculum more current. I look at some universities' syllabuses."

- Live demonstrations

  --"I climb on a skateboard, push the wall and then I ask who pushed me; I guide this open debate so that we could define Newton's third law…"

  --"The students must throw an object, measure its height in meters, the [horizontal] distance, its speed, and the time it takes to fall."

  --"To understand motion in two dimensions, students go out and throw balls at different angles to study horizontal and vertical speed."

  --"When we discuss about sound, I invite the music teacher to talk about music and physics. Since I play the guitar, I also talk about the different sounds you can get from it using local music (aguinaldo, decimas)."

- Local events

  --"Explosion in Rio Piedras (gases)."

  --"The 'Tren Urbano', utility, advantages, fuel, energy expenditure, etc."

  -- "Energy changes in Aguirre [thermoelectric plant]."

  --"We gather information about the effect of noise on the people of Vieques' hearts, and the vibroacoustics study."

- Measurement

  --"From a sample of red beans, mass and average weight is measured."

  --"I use measurement conversions in preparing a local recipe, sale of agricultural products, etc."

--"[I show them] the use of length measurements, we measure the basketball court, the hallway, etc."

--[We talked about] conversion factors and some medications, the units we use here in Puerto Rico."

- Natural events

--"A simple example of energy transfer through a mechanical wave, my town is near the sea, most students practice surfing, so they use sea waves to illustrate the concept."

--"We talked about earthquakes, hurricanes, tremors, weather conditions, changes in the space, astronomical studies, etc."

- Newspapers/media

--"As teacher I use the newspaper, magazine articles from PR and Latin America."

--"TV news and newspapers provide situations that can be related to physics, and we include them when we discuss different topics."

- Sports

--"When calculating displacement, velocity, acceleration I use sports and the names of known local athletes to present the physics concepts."

--"We discuss the concepts of velocity, acceleration and straight motion by relating them with sports that are familiar to Puerto Ricans."

--"Straight motion; lots of students practice some sport, 'field days'."

--"To calculate distance, acceleration, and time we use athletic events."

--"If a pitcher give too much impulse to the ball, it is possible for the batter to hit it harder because momentum increases."

--“Basketball, baseball and pool are excellent games to explain motion in one and two dimensions and momentum.”

--“I generally use examples and exercises related with sports.”

- Toys

--“We use toys to calculate speed, time and distance.”

--“In the labs we use more pertinent materials, like Hot Wheels toy cars and paper planes, etc.”

--“In labs we incorporate toy cars to prepare motion graphs, balls to explain momentum.”

Discussion: Short Question Four

I think that the most interesting finding in this section is that 30% of the teachers who admitted using contextual approaches to teach physics did not provide examples of exactly how they do it. Several explanations are possible, including: (a) these teachers believe in the contextualization of physics, but do not understand it enough to apply it at all in their classroom, (b) these teachers believe in the contextualization of physics, but do not understand it enough to apply it effectively, (c) teachers did not take the time to provide examples, or (d) teachers did not believe in contextualizing physics but they wanted to “save face” or wanted to be perceived as knowledgeable, or untraditional (avant-garde).

The other 70% provided a wide variety of examples of ways to contextualize their physics class. The most common responses were the study of electricity using their students’ home wiring, appliances, circuits, and power meter (7 teachers reported using this strategy), and the inclusion of sports, athletics, famous local athletes in a variety of physics topics, like measurement, kinematics, dynamics, momentum, energy, and work (7 teachers also reported using this strategy). The use of sports in physics has, I think, a double advantage, because it serves to present the physics in a familiar way, and also motivate students to learn physics because of their love of sports.

Another contextualizing factor that is also a strong motivator is the use of automobiles in teaching physics (mentioned by five teachers). It was reported used to teach kinematics, Newton’s laws, friction and other topics. Nearly all students have had a chance of riding in a car, and most juniors and seniors are especially eager to learn about car, car races, or car crashes. Interestingly, none of the teachers mentioned the mechanical components of an automobile and how physics explain its use (brake systems and fluid dynamics, transmission and gears, electric system of the car, etc.). Other daily life application in physics include the use of live demonstrations with simple and inexpensive materials, use of local events as reference for examples, and use of familiar places to do measurements on (four teachers mentioned each one of them).

Unfortunately, some of the statements of how teachers contextualize their physics teaching are so general and vague that they are difficult to interpret. It is obvious that most teachers report knowing about contextualization, and the topics they contextualize, but there is very little evidence of this approach as a major philosophical foundation of these participants’ educational practices. Probably the type of data that was gathered via short-answer question was not specific enough to probe into the participants’ philosophy of teaching as well as the relationship that contextualizing the subject matter has with this philosophy.

Interestingly, the least mentioned contextualizing options was the use of the Internet (one teacher acknowledged using Internet for his classes and professional development), in contrast to the Internet boom in education that is going on in the United States. Some possible explanations for this finding might be: (a) the idea that the Internet is not for education but for entertainment, (b) limitations in the English language prevent teachers from examining important education resources in this language, (c) a general lack of skill in searching the Internet for educational materials, (d) economical constraints might affect the teachers' ability to buy a good computer and to pay for the internet service, long distance and upgrades, and (e) computer aversion, especially for older teachers.

A final note: A few teachers reported not contextualizing their physics teaching at all. These are their responses:

--"The problem is not in the concept, but in the mathematical applications."

--"We have been assimilated by the technical changes of the United States. Industries, baseball parks, courts [basketball, tennis], automobiles, houses, all are foreign models."

--"I teach the concept as they appear on the textbook."

--"I only provide general examples that might happen anywhere on Earth."

--"I do not include Puerto Rican topics."

These teachers probably believe in teaching physics in an objective, global way, with generic applications.

Findings: Short Question Five

This section summarizes the participants' responses to the question: "How do you incorporate modifications in the physics curriculum to make it more culturally relevant to your students? Please provide a few examples". Eighty teachers, out of 92 participants, answered this question. Of those, 24 participants, or 30% provided general statements of support to the idea of making the physics class more contextual, but failed to provide specific examples. In addition, 44 participants, or 55% provided statement of support to contextualization and gave specific examples of how they make their physics class more contextual. Finally, 7 participants, or 8.75 % said that they make no changes to contextualize their class, and 5 participants provided ambiguous statements that could not be classified in any of the above categories.

Some of the general statements provided by the participants are similar to these:

- "By adapting examples to common situations for Puerto Ricans."
- "I use examples from our Puerto Rican culture all the time."
- "As the class progresses, students provide their own examples of things that happened to them [as they relate to physics]." (2 similar statements)
- "[I teach by] using known phenomena from our surroundings."
- "I bring examples or situations in which the students are guided to define the concepts operationally and, through their experiences, the students understand that some terms are culturally wrongly used."
- "I adapt problems to things that students know and use everyday."
- "Modifying [problem] situations with current situations of the Puerto Rican culture."

- “If a new textbook is written, the examples must include cultural aspects so that students become familiar with them.”
- “I make physics pertinent from our social reality.”
- “Changes are not made to the concepts, but to the situations that make us understand those concepts.”
- “[Students do] projects so that they acquire cultural knowledge of our country where physics is relevant.”
- “Mostly we try to present situations that affect us as a nation and that we are capable to solve applying those knowledge that let us develop our economy, technology, and democracy of our nation.”
- [I include culture by] presenting known situations, demonstrations, and recreational activities.”
- “I always try to use examples and applications of physics concepts in [the students’] homes or their surroundings so that students can understand and apply those concepts.”
- “Physics concepts are identified and relationships with our daily live are developed so that pertinence and relevance are made evident.”
- “We do field trips so that students can see the application of [physics] concepts to their daily lives.”
- “By discussing some concepts that can be applied to the origin of our race [ethnicity].”
- [We learn physics] through examples lived by the students in their homes and workshops, and then apply them to physics.”

- "By presenting situations related to physics in which we can use cultural language."

From those who provided specific examples of how they include the Puerto Rican culture in their physics class, most can be classified in categories that are very similar to those developed for the "contextualization" short question, including:

- Architecture

  --"The most notable example is the use of architecture and construction materials. They are fundamental to prevent catastrophes because of earthquakes, like the one on El Salvador."

  --"We study the structures found in Puerto Rico."

  --"[We do] some exercises related to buildings and construction."

  --"Trying to combine theoretical aspects with the Puerto Rican reality, like temperature, why [concrete] roofs get cracked, simple machine and window operators."

- Automobiles

  --"The concept of friction is related to road accidents and the road condition."

  --"For example, the law of inertia can be incorporated to explain the problem of excessive speed in our roads."

  --"In the sound unit, students talk about the noise level in Puerto Rico and the laws that exist but we do not obey. They talked about the Puerto Rican love of a car for each individual and the rejection of public transportation and the problems this present."

  --"[We speak about the students'] experiences with clandestine car races and car crashes."

--"[We talked about] distance and speed on the highway, time and distance in the Salinas Speedway, the importance of using the safety belt and the law of inertia."

- Internet

--"We are in an information age, so we should incorporate it and train ourselves to know and accept those changes."

- Live demonstrations

--"I use demonstrations using students…"

--"To study about power, how fast work is done, I do competitions to determine which student is the most powerful [can produce more power] and they make the calculations."

--"In the chapter of work, students use a lawnmower at different angles to determine how much work is realized at different angles."

- Local events

--"Taking them to recognize the Puerto Rican problems and their possible solutions using physics concepts, like the Carbon [energy] plant."

--"When doing graphical analysis, we use data from things that happen in Puerto Rico, like inches of rain per month or year."

--"[We talked about] situations that happened in our country and how they can be explained by integrating scientific concepts (earthquakes, gas leaks)."

--"For example, a contractor needs to place a new statue in a pedestal on a Puerto Rican 'plaza' (square) but he cannot use a crane not to spoil the 'plaza' floor. What type of simple machine would you use and how?"

--'We discuss energy generation, like in the Aguirre thermoelectric plant."

- Newspaper/media

  --“We use the newspaper twice a week.”

  --“I use the science section from the newspaper.”

  --“On some occasions I use news or local events to apply the material I taught.”

  --“The best I do is to use the days’ news that have some physics applications.”

- Natural events

  --“In a lab on a local river, the speed of the current, depth, and water quality parameters were measured.”

  --“[To teach waves I use] observations of the sea and a fisherman’s boat, or lake observations.”

  --“[We discuss] the effects of natural phenomena, like hurricanes.” (2 similar statements)

- Measurement

  --“In our country we still do not have the international system of measurements [SI], we weigh ourselves in pounds, and our height is in feet and inches.”

- Sports

  --“I use baseball, which is a national sport, [to teach physics].”

  --“[I use data from] intercollegiate athletics (Justas Intercolegiales) and marathons to teach velocity and acceleration.”

  --“Sometimes textbook use foreign athletes to explain or use some physics concepts; I substitute them with Puerto Rican athletes.”

--"If the book talks about tennis or bowling in an example about conservation of momentum, through socialized discussion I ask students how many have had the experience."

--"We can calculate speed using horse races."

--"[We discuss] Puerto Rican sports, kites, basketball, baseball, volleyball [in the physics class]."

-- "[We] solve problems related to baseball and basketball athletes."

In addition, other unique categories can be inferred from the teachers' answers, including:

- Technology

  --"I use the technology that is invading the students' daily life."

  --"[We study] the pros and cons of using nuclear power to society's benefit, how our Puerto Rican industry has advanced with the use of technology, we visit the Arecibo radar system … how communications has improved in Puerto Rico with laser and fiber optics technology, how we use solar energy as an alternate source of energy because we have sunlight year round."

- Puerto Rico's geographical location

  --"To teach vectors I use the map of Puerto Rico to locate places."

  --"When I talked about temperature, we talked about Puerto Rico's tropical location."

  --"Puerto Rico is a tropical island with typical [high] pressure. Mexico [City] is very high above sea level. A recipe will take longer to cook in Mexico than in Puerto Rico because of the lesser pressure in this area [Mexico City]."

- Puerto Rico's history

  --"I leave space to transmit contemporary and historical components of Puerto Rico. For example, the dangers of potential energy cause by tension of a locomotive's steel cable that was pulling 13 sugar cane wagons in Ponce and snapped, killing four people (1930's)."

- Puerto Rican artifacts

  --Maracas, kites, local games, cuatro, guiro, pandero, congas, pitirres (singing frequency). (7 statements; not all items were mentioned in all statements)

- Puerto Rican literature

  -- Poems, local music (bomba, danza, plena), drama, local language and vocabulary (8 statements; not all items were mentioned in all statements)

- Puerto Rican traditions

  --"Shooting to the sky on New Years Eve and gravity [lost bullet]." (2 similar statements)

  --"Projectile motion and throwing eggs the first day of school."

Finally, some teachers admit that they "do not know" (1 statement) and "do not have a clear idea" (1 statement) about how to include aspects of the Puerto Rican culture in their physics classes, or that is "extremely hard" (1 statement) to do so. Other teachers say that they do not make any changes in their physics class to introduce components of the Puerto Rican culture. Some reasons include:

- "I do not make any changes [to include Puerto Rican culture]." (3 similar statements)

- " I do not do any effort to include components of the Puerto Rican culture [in the physics class]. I think that physics concepts should not be adjusted to a particular culture; it is the culture that must adjust to the concepts."
- "The methods teachers use and student participation should create motivation, and not adding components of the Puerto Rican culture."
- I do not use the text to include components of the Puerto Rican culture because it is not prepared to do so."
- I make very few changes because a guide to develop laboratories or lab materials are provided."
- "I use general examples that can be applied to any point in the planet."
- "I teach physics by applying it to both daily situations, and to general and universal applications."

Discussion: Short Question Five

The facts that this question dealt with combining culture and physics, that approximately 20% of the participants either leave the question blank or provided ambiguous responses, and that approximately 30% provided just a general statement of approval (without examples or additional details) are not isolated happenings. After inspecting the rest of the answers and how similar some of the categories were compared to the previous question, it is clear that most teachers cannot establish clear differences between culture and context. Answers like "I use examples from our Puerto Rican culture all the time', or "I make physics pertinent from our social reality" are barely informative and not very helpful.

Based on this, I might argue that physics teachers have a good grasp of what contextual teaching is, but they are not clear about what culturally relevant teaching is, or how to include the local culture in the physics class. Given the interrelated nature of these concepts, I completely understand their responses. I see context as a subgroup within the concept ‘Puerto Rican culture’. Other subgroups might include language, spirituality, politics, and creative expressions, just to mention a few (note that these subgroups also intersect with the ‘context’ subgroup is some way). It is very difficult for me to establish, however, how large the ‘context’ subgroup is, compared to the concept of ‘Puerto Rican culture. However, I do believe that those concepts can be differentiated and require slightly different bodies of knowledge to be used effectively in physics teaching.

From the categories that are similar to the ones from the previous question, the use of sport and athletic examples in teaching physics was the most frequently cited to combine physics and the Puerto Rican culture. Other strategies frequently mentioned were combining physics with automobile references, local events, and newspaper/media information. Again, the use of the Internet as a tool to make physics culturally relevant was mentioned by one teacher (not the same teachers as in the earlier question).

Some of the new categories, like the use of Puerto Rico’s geography, history, artifacts, literature and traditions were encouraging to discover, but not very helpful on some occasions because teachers did not provided enough detail. For example, they mentioned two poems by name (Rio Grande de Loiza and Preciosa), but the teachers never said how they incorporate them in the physics class. This, in addition to the acknowledgement by some teachers that it is very difficult to combine physics and the Puerto Rican culture, can be considered evidence that teachers might not know how to combine culture and physics effectively. Of course, other explanations are also possible. For example, teachers might be concentrating their efforts in more pressing duties, like assessing or classroom management, and might not be placing effort in including cultural aspects in the physics class.

As in the previous section, there are a number of teachers who do not believe that a culturally relevant approach is adequate to teach physics to Puerto Rican students. Although some of these participants provided no explanation or rationale for their position, others did. The argument that physics is a universal, objective science appears here again, clearly stated in the statement: “Physics concepts should not be adjusted to a particular culture; it is the culture that must adjust to the physics concepts”. Also, some teachers proposed that they did not make cultural changes because the textbook does not present them, suggesting that if the physics textbook is modified to include cultural relevance, they might be open to teach physics in that way.

Findings: Short Question Six

After analyzing the 89 responses provided by the participants (three responses were either blank or unclear) to the question: “How do you modify your teaching strategies and techniques to help your students learn the physics content better?” it was found that teachers use different approaches to modify their teaching methods in search for education effectiveness. Some of the participants’ statements are (n = 47 statements):

- “Through examples and activities, I show them how what is learned can be applicable to their daily lives.” (14 statements, or 30%)

- “It is important to vary the teaching methods to avoid monotony. Each topics suit itself for different methods and laboratories.” (7 statements, or 15%)
- “I tailor [the teaching strategies] based on the situations that happen in the moment and the learning level of each group.” (5 statements, or 11%)
- “I use additional references that expand or provide more examples of a concept.” (3 statements, or 6%)
- “Since each student has a different learning style, I present the concepts in different ways.” (2 statements, or 4%)
- I try to make learning more pertinent and practical, learning by doing.” (2 statements, or 4%)
- “I summarize what the textbook says and adapt it to their reality.” (2 statements, or 4%)
- “I am always looking for innovations in education to make my teaching methods better.” (2 statements, or 4%)
- “I make an analysis of the material and extract what I think they might use in the future.” (2 statements, or 4%)
- “Since not all students are apt to tackle the course, because of their math deficiency and poor attitudes and interest, I try to use techniques that encourage the course’s acceptance.” (1 statement, or 2%)
- “[Teaching] methods must be fun, they must be like an attractive hook that let students be successful, creative, and free in actions and thought. If the class is fun, pleasurable, and intellectually challenging, they might learn some physics.” (1 statement, or 2%)

- “By covering those concepts that are most relevant to the students’ interest.” (1 statement, or 2%)
- “The material is discussed in a slow rhythm so that students can understand it.” (1 statement, or 2%)
- “By being very creative. I use everything within my reach to help students understand a concept.” (1 statement, or 2%)
- “I present the topics and let students think for themselves and infer. Then I guide them to the specifics of the concept they should learn.” (1 statement, or 2%)
- “I make students build their own physics laboratory equipment.” (1 statement, or 2%)
- “By adapting the [teaching] techniques to the material I cover.” (1 statement, or 2%)
- “I try to demonstrate the theories and laws of physics.” (1 statement, or 2%)

In addition, the participants reported using a variety of teaching strategies and techniques. These are, in descending order of frequency (n = 110 statements; in most occasions, teachers reported using more than one of the following teaching strategies):

- Laboratory (13 statements, or 12%)
- Demonstrations (12 statements, or 11%)
- Technology/computers (11 statements, or 10%)
- Audiovisuals (11 statements, or 10%)
- Group work/cooperative learning (10 statements, or 9%)
- Research projects/reports (10 statements, or 9%)
- Laboratories with simple/inexpensive materials (7 statements, or 6%)
- Discussion (5 statements, or 5%)
- Individualized teaching/tutorial (4 statements, or 4%)

- Scientific/graphic calculator (4 statements, or 4%)
- Lecture (3 statements, or 3%)
- Readings (3 statements, or 3%)
- Problem (exercise) solving (3 statements, or 3%)
- Homework (2 statements, or 2%)
- CBL (2 statements, or 2%)
- Hands-on activities (2 statements, or 2%)
- Open notebook tests (1 statement, or 1%)
- Integration of physics class with other subject areas. (1 statement, or 1%)
- Open-ended questions (1 statement, or 1%)
- Field trips (1 statement, or 1%)
- Execution manuals (modules) (1 statement, or 1%)
- Take-home tests (1 statement, or 1%)
- Learning cycle (1 statement, or 1%)
- Oral tests (1 statement, or 1%)

Discussion: Short Question Six

As with the previous two sections, the most relevant finding is that almost half of the teachers reported doing something to their teaching methods to help students learn and understand the physics concept, but not much detail was provided about how these changes were made or what the philosophical reasoning behind the changes is. The most common way teachers modify their methods are by including examples and activities that relate what the students are learning with their experiences, needs, and interest, by changing methods frequently to prevent boredom, and to present a concept in a variety of ways. There is not a statement about what examples of physics are valuable in the students' daily life, what other references teachers use and why those are used, or how concepts are presented to suit different learning styles. On the other hand, the responses as a whole suggest that teachers are concerned about student learning and what might be the most effective ways to teach physics.

For this question, teachers also reported what teaching methods and techniques they used and modify to try to improve physics learning. Laboratories (standard and with simple and inexpensive materials), demonstrations, and the use of audiovisuals are commonly used, correlating well with what a traditional physics classroom might look like. In contrast, more constructivist teaching methods, like the learning cycle, open-ended questions, hands-on activities, or alternative assessment are the exception more than anything else. These two findings suggest that teachers are conservative in their teaching philosophy, so the reported changes to the teaching methods might not be profound or radical. The fact that only two teachers reported using CBL plus my experience visiting the participants' classroom tell me that most of these classrooms do not have the equipment teachers need to be more student-centered in their class. Three teachers reported not doing significant changes to their methods because of the lack of equipment and materials:

- "The main teaching technique is based on presenting possible examples, because I do not have the equipment to develop these concepts through discovery learning."
- "We could use a variety of teaching methods and techniques, but without equipment and materials it is very difficult to offer the class we would want to offer."

- "I have no [physics] equipment; I must provide it [from my salary]."

The lack of materials and equipment has been a common theme throughout the qualitative data gathered.

Summary of Fifth Chapter

Despite the sometimes limited or imprecise nature of some of the participants' responses to the short questions presented in the questionnaire, which make difficult an assessment of the teachers real actions and philosophy compared to their reported statements, some interesting pieces of information can be emphasized. In general, teachers are convinced that teaching physics with a contextual and culturally relevant emphasis can be done. In fact, a number of the participants reported using a contextual and culturally relevant approach in some form or another in their classroom. This is very important because for a future education reform in context and cultural relevance to be successful, teachers must believe in it, that is, "the reforms must make sense to them" (Rosow and Zager, 1989). As a consequence, including the topics of contextual teaching and learning, and culturally relevant science education, in either the formal training of science teachers or in professional development, might not face skepticism or rejection from the education community.

The inclusion of more physics courses in science teacher education, especially if they are designed to expose teachers to the applicability of physics to the students' culture and society, is also suggested. The argument is that teachers cannot make changes in physics content to make it contextually and culturally relevant if they lack subject matter knowledge and a framework of change they can work with. The majority of physics teachers in Puerto Rico also believe that using a contextually and culturally relevant approach in teaching physics might lead to better grades for students.

Another interesting finding is that Puerto Rican physics teachers are not satisfied with the textbook they are using, especially because it does not include any examples or applications in which the local culture might be reflected, but also because of general problems, like a poor translation, a mathematical approach that does not match the students' reality, and a number of editing mistakes that were not corrected. Teachers are divided on whether changes to the actual textbook might be enough or if a new textbook, developed in Puerto Rico by Puerto Rican physicists, science educators, and physics teachers might be necessary.

For a variety of reasons, including the teachers' view of the nature of science, and student preparedness and lack of interest, not all teachers agree that teaching physics using a contextual and culturally relevant perspective is desirable. Some of them believe that if a student has mathematics and reading deficiencies, no new strategy will help them in learning physics the way it is actually taught in Puerto Rico. The same holds true if the students are not interested at all in the class, or if they see the class as an additional requirement they must have, and not as a learning opportunity. Also, if the classroom learning environment is inadequate (no laboratory equipment or physics laboratory at all, no textbooks, instructional technology, etc.) then students are at a disadvantage, not to mention the more general social problem that students face.

CHAPTER 6

QUALITATIVE ANALYSIS: INTERVIEW DATA

Overview

In the following section, the findings from the interviews of 21 participants are presented. Six questions were used. The purpose of these questions was to gather qualitative data about the participants' knowledge and opinions about contextual and culturally relevant physics teaching, and the textbook that is actually used in Puerto Rican high schools. These questions were:

- What do you do to contextualize your teaching? What examples from the students' everyday life do you use?
- Do you think that physics concepts and our Puerto Rican culture can be combined?
- What is your opinion about the physics textbook that you are currently using? What would you do to improve the textbook?
- What do you think is the students' opinion of the physics textbook they use?
- Do you think that a teacher who has a pro-statehood ideology will be less critical of the physics textbook actually used because it was made in the United States?
- Do you think that teachers who believe in commonwealth and independence will include more aspects of the Puerto Rican culture in their physics class?

The basic approach used to analyze this qualitative data was similar to the one used for the short answer section. It begins with establishing categories based on the teachers' responses, and continues with the determination of the relative frequency per category and the selection of representative quotes. After each findings section, a discussion of the findings follow, in which the most important findings will be summarized. Also, statements that might explain particular findings and additional context will be provided. At the end of this section, a summary highlighting the research findings will be included.

Interviewee's Profile

Before going into the data analysis, the following interviewee profile is presented as a way to provide some context to the 21 participants' responses. Pseudonyms are used to protect the teachers' confidentiality.

Arturo (21402) is a male teacher, between 41 and 45 years old. He has 16 – 20 years of teaching experience, but only 1 – 5 years of physics teaching experience. Arturo has 0 – 2 semesters of physics courses. He works in a large, rural, public school, with 30 or more students per class. Arturo believes the school system provides him some freedom to change physics curriculum and teaching methodologies, and that the physics textbook he uses is good. He believes in the associated republic status option.

Berta (21401) is a female teacher, between 36 and 40 years old. She has 6 – 10 years of teaching and physics teaching experience, and 18+ semesters of physics courses. She works in a large, rural, public school, with 30 or more students per class. Berta believes that the school system provides her some freedom to change physics curriculum and teaching methodologies, and that the physics textbook she uses is good. She believes in the commonwealth status option.

Cesar (21505) is a male teacher, between 46 and 50 years old. He has 21 - 25 years of teaching experience, but only 6 – 10 years of physics teaching experience. Cesar has 3 – 5 semesters of physics courses. He works in a large, urban, public school, with 21 - 30 students per class. He believes the school system provides him absolute freedom to change physics curriculum and teaching methodologies, and that the physics textbook he uses is good. He does not report believing in any status option.

Dolores (21403) is a female teacher, between 51 and 55 years old. She has 30+ years of experience in teaching, but only 1 – 5 years of physics teaching experience. Dolores has 3 – 5 semesters of physics courses. She works in a medium, urban, public school, with 21 – 30 students per class. Dolores believes that the school system provides her absolute freedom to change physics curriculum and some freedom to change the teaching methodologies, and that the physics textbook she uses is good. She believes in the associated republic status option.

Eduardo (21510) is a male teacher, 61+ years old. He has 26 – 30 years of experience in teaching, and 16 – 20 years of physics teaching experience. Eduardo has 6 – 8 semesters of physics courses. He works in a medium, urban, private school, with 0 – 10 students per class. Eduardo believes that the school system provides him absolute freedom to change physics curriculum and teaching methodologies, and that the physics textbook he uses is good. He believes in the commonwealth status option.

Frances (21603) is a female teacher, between 41 – 45 years old. She has 16 – 20 years of teaching experience, but only 1 – 5 years of physics teaching experience. Frances has 3 – 5 semesters of physics courses. She works in an urban, public school, with 30+ students per class. Frances believes that the school system provides her some freedom to change her teaching methodologies, and that the physics textbook she uses is excellent. She believes in the statehood status option.

Gustavo (22202) is a male teacher, between 36 – 40 years old. He has 11 – 15 years of teaching experience, but only 1 – 5 years of physics teaching experience. Gustavo has 3 – 5 semesters of physics courses. He works in a large, urban, public school, with 21 – 3- students per class. Gustavo believes the school system provides him some freedom to change physics curriculum and teaching methodologies, and that the physics textbook he uses is average. He believes in the independence status option.

Hortensia (22201) is a female teacher, between 46 – 50 years old. She has 16 – 20 of teaching and physics teaching experience. Hortensia has 9 – 11 semesters of physics courses. She works in a large, urban, public school, with 21 – 3- students per class. Hortensia believes that the school system provides her some freedom to change physics curriculum and teaching methodologies, and that the physics textbook she uses is good. She believes in the independence status option.

Ismael (21507) is a male teacher, between 46 – 50 years old. He has 21 – 25 years of teaching experience and 16 – 20 years of physics teaching experience. Ismael has 9 – 11 semesters of physics courses. He works in a medium, urban, public school, with 11 – 20 students per class. Ismael believes that the school system provides him some freedom to change physics curriculum and teaching methodologies, and that the physics textbook he uses is good. He believes in the commonwealth status option.

Josefina (30702) is a female teacher, between 31 – 35 years old. She has 6 – 10 years of teaching experience and 1 – 5 years of physics teaching experience. Josefina has 0 – 2 semesters of physics courses. She works in a medium, rural, public school, with

30+ students per class. Josefina believes that the school system provides her some freedom to change physics curriculum and teaching methodologies, and that the physics textbook she uses is average. She does not report believing in any status option.

Leonardo (21605) is a male teacher, between 41 – 45 years old. He has 11 – 15 years of teaching and physics teaching experience. Leonardo has 0 – 2 semesters of physics courses. He works in a medium, urban, public school, with 30+ students per class. Leonardo believes that the school system provides him no freedom to change physics curriculum and teaching methodologies, and that the physics textbook he uses is good. He believes in the commonwealth status option.

Maria (21503) is a female teacher, between 46 – 50 years old. She has 11 – 15 years of teaching experience and 6 – 10 years of physics teaching experience. Maria has 6 – 8 semesters of physics courses. She works in a large, urban, public school, with 21 – 30 students per class. Maria believes that the school system provides her some freedom to change physics curriculum and teaching methodologies, and that the physics textbook she uses is deficient. She did not report believing in any of the status options.

Nicolas (21606) is a male teacher, between 36 – 40 years old. He has 11 – 15 years of teaching experience and 6 – 10 years of physics teaching experience. Nicolas has 3 – 5 semesters of physics courses. He works in a small, urban school, with 21 – 30 students per class. Nicolas believes that the school system provides him some freedom to change physics curriculum and teaching methodologies, and that the physics textbook he uses is good. He believes in the commonwealth status option.

Ofelia (21504) is a female teacher, between 26 – 30 years old. She has 0 - 5 years of teaching and physics teaching experience. Ofelia has 0 - 2 semesters of physics courses. She works in a large, urban, private school, with 30+ students per class. Ofelia believes that the school system provides her some freedom to change physics curriculum and that the physics textbook she uses is average. She believes in the independence status option.

Pablo (30704) is a male physics teacher, between 26- 30 years old. He has 0 - 5 years of teaching and physics teaching experience. Pablo has 3 - 5 semesters of physics courses. He works in a medium, urban public school, with 30+ students per class. Pablo believes that the school system provides him some freedom to change physics curriculum and teaching methodology, and that the physics textbook he uses is good. He did not report believing in any of the status options.

Rosa (21506) is a female physics teacher, between 41 – 45 years old. She has 16 – 20 years of teaching experience and 6 – 10 years of physics teaching experience. Rosa has 6 – 8 semesters of physics courses. She works in a medium, urban, private school, with 21 – 30 students per class. Rosa believes that the school system provides her some freedom to change physics curriculum and teaching methodologies, and that the physics textbook she uses is good. She believes in the independence status option.

Samuel (30706) is a male physics teacher, between 26 – 30 years old. He has 6 – 10 years of teaching experience and 0 – 5 years of physics teaching experience. Samuel has 18+ semesters of physics courses. He works in a medium, rural public school, with 21 – 30 students per class. Samuel believes that the school system provides him absolute freedom to change his teaching methodologies, and that the physics textbook he uses is excellent. He believes in the statehood status option.

Teresa (21601) is a female physics teacher, between 51 – 55 years old. She has 30+ years of teaching experience and 11 – 15 years of physics teaching experience. Teresa has 3 – 5 semesters of physics courses. She works in a large, urban public school, with 21 – 30 students per class. Teresa believes that the school system provides no freedom to change physics curriculum and some freedom to change teaching methodologies, and that the physics textbook she uses is deficient. She believes in the independence status option.

Virginia (22204) is a female teacher, between 46 – 50 years old. She has 26 – 30 years of teaching experience and 21 – 25 years of physics teaching experience. Virginia has 0 – 2 semesters of physics courses. She works in a medium, urban public school, with 11 – 20 students per class. Virginia believes that the school system provides her some freedom to change physics curriculum and teaching methodologies, and that the physics textbook she uses is good. She believes in the statehood status option.

Wanda (30701) is a female teacher, between 36 – 40 years old. She has 11 – 15 years of teaching experience, but only 0 – 5 years of physics teaching experience. Wanda has 6 – 8 semesters of physics courses. She works in a medium, rural public school, with 30+ students per class. Wanda believes that the school system provides her some freedom to change physics curriculum and teaching methodologies, and that the physics textbook she uses is average. She believes in the commonwealth status option.

Zoraya (30705) is a female teacher, between 26 – 30 years old. She has 0 - 5 years of teaching and physics teaching experience. Zoraya has 18+ semesters of physics courses. She works in a large, rural public school, with 30+ students per class. Zoraya believes that the school system provides her some freedom to change physics curriculum and teaching methodologies, and that the physics textbook she uses is excellent. She did not report believing in any of the status options.

In order to provide additional context and inform the reader about the teachers interviewed, it is important to know how they score themselves in the degree of change in physics content presentation and teaching methodologies, and how confident of their physics knowledge they believe they are. Table 44 summarizes the participants' scores on the three dependent variables.

Table 44: Interviewee's Means for the Three Dependent Variables.

Participant's pseudonym	Change in physics content presentation	Change in teaching methodology	Subject matter confidence
Arturo	3.733	3.611	5.000
Berta	5.000	5.000	5.000
Cesar	3.650	4.389	4.850
Dolores	3.250	4.789	4.150
Eduardo	4.100	3.800	No report
Frances	3.400	4.632	3.900
Gustavo	2.500	3.444	3.850
Hortensia	3.867	4.200	5.000
Ismael	2.200	3.083	4.300
Josefina	4.235	4.600	4.158
Leonardo	4.385	4.667	4.750
Maria	5.000	4.947	4.900
Nicolas	2.571	3.789	4.700

Ofelia	3.500	3.105	4.450
Pablo	1.850	2.000	4.700
Rosa	4.800	4.263	4.650
Samuel	3.059	2.706	4.300
Teresa	4.000	4.067	2.500
Virginia	4.563	4.133	4.187
Wanda	4.308	4.471	4.385
Zoraya	2.125	3.353	4.647

For the first dependent variable, it can be seen that Berta, Rosa, and Virginia reported making the most changes in the physics content presentation to make it more contextually and culturally relevant to Puerto Rican students. In contrast, Pablo, Zoraya, and Ismael reported making least changes to their content presentation. For the second variable, Berta, Maria, and Dolores reported making the most changes in their teaching methodologies to make them more contextual and culturally relevant to Puerto Rican students. In contrast, Ismael, Pablo and Samuel reported making least changes. Finally, for the third dependent variable, Arturo, Berta, and Hortensia reported being more confident in their physics content knowledge, while Teresa, Frances, and Gustavo reported being least confident in this aspect.

Findings: Interview Question One

In the first question, teachers were asked: "What do you do to contextualize your teaching? What examples from the students' everyday life do you use?" The answer to these questions can be classified in four main areas: general statement of support to the idea of contextualizing their teaching, specific examples in different content areas, specific examples with different teaching methodologies, and statements from teachers who argued that other factors also affect student learning.

General Statements Supporting Contextualization

Almost all teachers talked about how important it was to contextualize teaching and how they did it, but without providing specifics. A few representative statements are provided by Cesar, Eduardo, and Leonardo. Cesar, for instance, stressed the importance of everyday examples to create relevance and contextualization:

> [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 also believed that the use of everyday examples and relevance are important to establish a tie between the physics topics and the students' lives:

> 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.

Leonardo provided some details on actions and objects he used to make physics relevant and contextual, while mentioning the importance of the larger picture, the contextualization of physics at a national level:

> Constantly in the course we are integrating everyday examples, like lifting a box, the way we walk, examples related to cars, machines, sports … we integrate physics to everything that is happening, including daily events that happen in the classroom, the hall, the school … I bring examples that are related with the students' daily routine at home, like cleaning, work, maintenance, use of tools, construction, home building, sports … Beyond those examples, I also use examples of things that are happening in the country.

Berta mentioned how she plans her contextualizing strategies. She also mentioned that, unlike in the United States, in Puerto Rico a specific type of classroom planning is recommended by the Puerto Rico Department of Education:

> First, obviously, ECA planning is required (Exploration-Conceptualization-Application). For exploration we introduce a topic or concept with concept maps, a comic strip, a reflective reading, or the newspaper … we also use audiovisuals and interactive software. For conceptualization, it is almost always done with activities, demonstrations, and laboratories. Comic strips, conceptual maps, exercises, problem solving, and field trips (in and out of school) can also be used. For application, we also use field trips (in and out of school), other assessment techniques, or drama.

Taken as a whole, the previous representative quotes emphasize the role of everyday examples to create relevance and context in the physics classroom. However, no useful, specific examples were provided. Other teachers were more detailed about their experience in making physics more pertinent to students, as it is seen in the next section.

Specific Content Examples Supporting Contextualization

For this category, quotations from a variety of content areas are included to demonstrate what Puerto Rican physics teachers are doing to make their class more contextually relevant. The fact that only one quote per topic is included does not reflect the number of times teachers mentioned a given topic. The rationale for this organization was to provide the reader evidence that teachers contextualize their physics teaching in a variety of topics. Also, different teachers were selected for the different topics to provide as much opportunity as possible for the reader to ascertain from as many teachers as possible how they contextualize their teaching.

For the topic of vectors, Virginia used the island's geographical location to explain the importance of both magnitude and direction in a vectorial quantity:

> When I talk about vectors we talked about how we are vectorially located in the planet. What will happen if I change the direction of a vector, that is, if I give you my country's location but I exchange "east" for "west"? Where do I arrive? In that way, students realize that it is not the same if I am traveling to the United States or Europe. If I am confused with the direction of the vector, instead of arriving to Madrid I will hit New York. The idea is that students locate themselves in their own perspective.

For the topic of motion in a straight line, Ofelia used statistical data from the Olympics to have students calculate distances, speeds, and accelerations:

> Every morning I brought statistics of how much a particular athlete ran, because we were studying acceleration, velocity, speed, so that the students got motivated … which athletes ran faster than others, calculate how fast they were running.

For the topic of free fall, Pablo used a simple demonstration with common materials:

> When we talk about gravity, I use regular and crumpled paper with the same mass to demonstrate that when an object is falling, mass is not a factor, but the area that is colliding with air particles.

For the topic of projectile motion, Gustavo used the end-of-year celebrations to both teach about a concept and gave an important life lesson:

> For the case of projectiles, [I include] a problem, not now but it is at the end of the year, some times there are gunshot accidents and the students do not understand how if a person fired a gun here (to the air), somebody died in another, far place. I bring this example so that students understand that the speed of the bullet is the same when it is fired and when it hit that person.

For the topic of forces (statics), Cesar combined engineering, architecture, and a hands-on approach to demonstrate the interrelationship of forces in a structure:

> I make them build a little bridge, discover what main characteristics a bridge must have, and what is its use. I make them build a little car, to discuss its characteristics, why cars' shape has changed [over the years] because in the past cars were boxier and now they have a much more aerodynamic shape, why is that? Depending on the topic, I actualize it and take it to relevant things.

For the topic of Newton's first law, Frances and Josefina used cars as a way to create context. Frances focused on the dangerous effects a collision might have on a person and how inertia is related

> On one occasion, a student had an accident and the topic of airbags came out, so I started explained the importance of Newton's laws of motion and why we should

> use safety belts. Not because of avoiding a ticket, like some of them believed, but because your life might be at risk without the safety belt. Each student brought their own experiences and how Newton's laws applied.

Josefina took a different approach, correctly relating the "force" people feel when they move around a curve with the law of inertia, and not with the infamous centrifugal force:

> When we talked about the law of inertia I mention travelling inside an automobile. In Puerto Rico, curvy roads are very typical, so I ask: Why if a car goes in a give direction, takes a curve, then your body moves in the opposite direction of the car taking the curve?

For the topic of Newton's third law, Ismael used sports such as baseball and tennis to explain this concept:

> If you want to talk about Newton's 3rd law, for each action there is a reaction with equal magnitude and opposite direction, it is easy to explain if you think about baseball. If a pitcher throws hard, it is very possible that the game will end in a home run, because if the ball comes fast to the home, when there is contact between the ball and the bat, the ball will go out hard in the opposite direction … If you want to change sports, we can talked about tennis. If a tennis player has a good service, when that service is broken he finds himself in deep trouble because he cannot come close to the net fast enough to attack. There are some players that can hit the tennis ball at 100 mph, and because the collision is mostly elastic, the ball might return to the player at the same speed, and he might not have enough time to respond.

For the topic of waves, here is an example from Wanda, who used our beaches and the experiences students have there to explain waves and reflection:

> When I talked about waves I mentioned sea waves frequently, when they go to the beach, they explain this movement, like: What happened when a sea wave hits the beach? I use this to explain wave behavior. For reflection, [I also use sea waves] we talk about a wave breaker and why it is made in angle so that the waves get reflected. With this, students can see that if a wave hits the wave breaker at an angle, it will be reflected at the same angle, and water is a perfect example to show that.

For the topic of engines, Leonardo used the problems of public transportation and pollution to create context:

> For example, in Puerto Rico we have a problem with mass transportation. Then I ask: What types of engines are more efficient? Why using an internal combustion engine, which is less efficient than an electric one? What engines are more efficient? We talk also about pollution and how to decide a car to buy.

For the topic of heat, Virginia provided a detailed description of how she used Puerto Rico's location and climate to make his class more relevant:

> I start my class with an example of physics that is related to unique things we have, either because of our condition as a tropical island, or because of our Puerto Rican culture. For example, we were talking today about thermal energy. We are located in a tropical zone, so the thermal energy our country receives [from the Sun] is obviously different from the energy received at the poles, or in the United States. We do not have noticeable seasons. Students recognize that [the concept

> of] thermal energy is not isolated from our everyday lives. One of the things I show them was the effect of the solar radiation we receive, on white and black fabric. I talked about the fact that objects in our country should not have dark colors if we want them to keep fresh [cool], like automobiles, clothing. Sometimes even we put tar on our roofs to make it impermeable, but since tar is black we also are warming the roof, putting there a heat collector that will increase the temperature inside the residence.

For the last topic, electricity, Maria and Samuel provided their contribution to this analysis. Maria mentioned some of the topics activities she used to make these topics more pertinent to students:

> For example, today we were talking about electricity, about charging by induction and [what happened when they were] getting close to a TV set. We talked about balloons, and what happened when we rub them and put them close to our skin, especially for hairy students.

Samuel briefly mentioned teaching electricity and electrostatics by using the experiences of students who lived in the United States and feel static shocks during winter. As the reader might know, cold air tends to be drier than warm air. This prevents static charges from escaping a charged object via water molecules in the air, producing a rather painful static shock.

A number of teachers mentioned that they use local events or Puerto Rican places to contextualize their content presentation. For example, Maria took as a reference the implosion of an old residential building in San Juan to explain some physics topics:

> When we were talking about forces and work, I mentioned the Acacias [name of the old residential building] and how it was demolished.

Rosa and Eduardo talked about using natural events in their class. Rosa took advantage of Puerto Rico's location in the Caribbean Plate to talk about earthquakes.

> I use events that had happened in the country, for example, if there is an earthquake, I can use it to explain physics concepts, and it is an earthquake that happened in our country.

Eduardo used atmospheric events, more common than earthquakes, to apply some of the physics concepts they discuss in class:

> We are on a tropical island that is prone to storms and hurricanes, and we can use physics concepts to create explanations for students to understand why those phenomena occurs.

Some teachers prefer to use the names of local places and towns when providing physics examples. This gives students a familiar reference that might make the physics explanations easier to understand. For example, Teresa said:

> If I am discussing displacement, distance, and the difference between them, I use local places inside Gurabo or neighboring towns they know [like Caguas], because if I am going to talk about places they have never visited, that is not pertinent to them.

Frances talked about free fall, air resistance and hang gliding by mentioning a well-known place in Gurabo where hang gliding is practiced:

> When we talked about air resistance, free fall, if they fall at the same rate or not, I used examples from the students' daily lives … we discuss surface area versus

> mass for free falling objects, and how that applies to parachutes and hang gliders. Students came up with the hang glider example because there is a hill here in Gurabo where people practice this sport. Even people from other towns come here for hang gliding.

Virginia presented an additional example of using the names of local places and towns when doing physics, but in the context of vector addition:

> Sometimes the examples textbooks provide [about vectors] are good, Lyon, Paris, that type of thing, but I prefer Cayey-San Juan, San Juan-Arecibo and Arecibo-Cayey, how much distance and displacement I had. Really, I try to use my country in the directions north, south, east, west, when we are working with vectors.

Ofelia mentioned a famous speedway in Puerto Rico and how she used it for his physics class:

> I do not know much about cars, but we used the Salinas Speedway and we did oral reports in which students tried to relate physics to the speedway.

It is evident that Puerto Rican physics teachers are very creative in coming up with examples and situation that are familiar to students when they are teaching. These teachers also reported about how they select their teaching methodologies to include the local context. This is the topic of the next section.

<u>Specific Teaching Methods Examples</u>

The use of newspaper clippings with scientific news was commonly mentioned. Berta described how she integrate science news with the topics she was covering, focusing on how this source of information is more current than the textbook they use:

> For that I use the newspaper, we look for current problems and issues and we emphasize them, we start [our discussions] from there. Each Wednesday we recycle the newspaper and we search for science oriented, high-impact news, especially those with current topics. Also, those concepts are presented in different ways.

Rosa also commented about the use of newspapers in the physics class, although she use it because students find it easier to read, suggesting that its language and presentation might be more effective than the textbook's:

> I use a lot of examples from their everyday life, I use newspapers. I think that [newspapers] are one of the techniques that can be used daily in the classroom because you can find many examples, and students are more familiar with them than with the textbook.

The use of laboratories was mentioned by four teachers. For example, Rosa preferred laboratories with everyday materials because of economical reasons, and to promote recycling at the same time:

> [I use] laboratories that students can do by themselves. Since the physics laboratory equipment is a bit costly, readily available household objects and recyclable materials [are used for labs].

Pablo preferred laboratories made with common materials because it helps students replicate the experiment at home and see physics in a more real way, compared to using fancy equipment that students might never see again:

> I do laboratories with materials that are readily available for the student. In that way, they see the topics discussed in a more real way. If you use extremely

> sophisticated equipment for a regular level, students will not understand the concept completely. If I can demonstrate physics concepts with the materials students already have, then perfect.

Also, some teachers contextualized their methods by examining and reflecting on student’s individual learning differences. Take Nicolas as an example:

> First of all, we must examine the type of students we are working with, our clientele. From there I depart to determine how I am going to teach the class, what activities you are going to do, and how the textbook can be made closer to the students.

Ismael elaborated on this theme, exposing the dilemma teacher face with heterogeneous groups and good teaching for all of them:

> Since we have heterogeneous groups, when I teach, if I elevate too much the curricular content and I make extremely hard questions, then students who are less talented will become bored and will not understand. On the other hand, if I lower the level too much, then the good students will become bored. To teach physics to a heterogeneous class, we must bring a lot of everyday elements so that the good and slow students can enjoy.

Finally, Leonardo contextualize his class by using curious aspects of physics and by addressing students’ science misconceptions:

> I constantly combine aspects from the students’ lives [with physics], trying to find curiosities, something that make them think about some misconceptions they have … [By using a variety of examples], I can amaze the students. Some examples work for some students and some other examples work for other.

Interestingly, this contrasts with similar data found in the short answer questions and the statistical analysis. Because only a few teaching methods were mentioned, we can infer that teachers might be less knowledgeable about how to make their teaching methods more contextual. This is not a surprise to me because, as teachers, we learn a number of teaching methods but not necessarily how to modify them for our local context. It is assumed that teachers will know how to do it. Another explanation might be that the question did not specifically ask for comments on their teaching methodology, so the participants focused more on physics content presentation rather than methodology.

Additional factors Affecting Student Learning in Puerto Rico

Interviewed teachers mentioned several factors that neutralize their efforts in contextualizing their physics teaching. One of these is the lack of support from the school structure. Among others, these are the words of Arturo and his struggle between the school system and the students' educational needs:

> I have to search [printed materials, references] in out-of-the-ordinary ways, including former students, or students' parents who are college professors … due to the lack and need of texts, and of the lack of creativity from the school's organization, which did not listen to the teachers and their needs.

Arturo also mentioned the lack of basic materials and equipment for physics demonstrations and laboratories. He had his own students build laboratory materials:

> The students created their own labs … and they build the equipment that they will need for the laboratories and the class. I do not guide myself by the textbook, or the school's directives because we do not have materials; we do not have a

> classroom prepared for physics. And it is not just physics, we also lack materials in biology and chemistry.

Likewise, Leonardo mentioned the lack of equipment for laboratories, but focused on some specific areas of physics:

> Unfortunately, we work very little with waves or electricity. We do not have safety features of the equipment [for these topics].

An additional factor that neutralizes their efforts in contextualizing their physics teaching might be students' negative attitudes. Ofelia talked about students who were not interested in physics because they will not need it, and because physics does not lead to an economically rewarding career:

> The most I can do is to make them conscious of what physics is for, for what we use physics, what physics concepts we use everyday, and what careers use those concepts. But students only see what professions are more lucrative.

She also mentioned that the students' interest in physics is minimal, despite the fact that she gave from her planning time so that they can come and ask questions. Teresa mentioned an interesting problem about contextualizing the physics class: that physics is taught using mostly the international system of units (SI) however, because of the influence from the United States, we use some English units:

> I have the difficulty that the students I have are from different [vocational] workshops, and in some of them they use SI, but other use English units. I have not figured out how am I going to solve this problem.

This is a problem that is not limited to Puerto Rico. I am sure that physics teachers from the United States also face the same dilemma.

Discussion: Interview Question One

After examining the interview data for the first question, it is evident that physics teachers contextualize both their physics content presentation and their teaching methodologies for the students' needs and experiences. The variety of physics topics they mentioned, from vectors and Newton's laws to heat and electricity, as well as the use of local events, towns and places, is also evidence supporting this claim.

In terms of teaching methodologies, laboratories are the most commonly contextualized with inexpensive and easily available materials, suggesting that physics teachers tend to be very concrete in the belief that this leads students to be able to understand as much as possible. I think that Leonardo proposed a good way to make the physics content easier and more relevant to the students, by using curiosities, addressing misconceptions, and "surprising" students with counterintuitive physics activities.

As in previous sections, teacher mentioned the lack of equipment to perform laboratories and demonstrations, and students general disinterest for the course, as factors that affect the positive effects that physics contextualization might achieve in Puerto Rican high schools. Another interesting aspect was mentioned by Teresa: Should vocational and general high school have the same type of physics courses?

In summary, it is clear that is very common for physics teachers to use local events and places, everyday situations and examples and readily available materials in their class. Although some teachers were more specific and detailed about their contextualizing strategies than other, this contextualization is clearly happening across most of the topics usually covered in the physics textbook. Less clear is the process of contextualization of teaching methodologies, given the fact that in another section, teachers reported using a great variety of teaching methods, but only some of them were evident in the interviews. Finally, there is a small group of teachers who offer a variety of reasons that affect negatively their effectiveness and their students' learning.

Findings: Interview Question Two

In the second question teachers were asked: "Do you think that physics concepts and our Puerto Rican culture can be combined?" The answers to this question has been combined into categories: general statements of support for the idea of including aspects of the Puerto Rican culture in their teaching, statements in which the concepts of culture and context are used interchangeably, statements in which a global perception of physics, as opposed to a regional perception, is presented, and statements in which culture and context are considered separately.

General Statements

Most of the teachers talked about how important it was to include aspects of the Puerto Rican culture in their physics teaching, but without providing specifics. A few representative statements were provided by Frances, Cesar, Dolores, and Virginia. Frances said, for instance: "Yes … physics is with us everyday, is part of our lives". This is quite similar to Cesar's position: "Undoubtedly yes, physics is part of our Puerto Rican culture". Dolores provide a bit more detailed answer, creating a relationship between the use of cultural components in the classroom and effective learning: "Undoubtedly, nothing that is not combined with culture is effective".

Virginia stated that combining Puerto Rican culture and the teaching of physics is essential:

> It is not that it might be combined [physics concepts and Puerto Rican culture], it must be combined.

Only one participant, Ofelia, admitted that including aspects of the Puerto Rican culture could be difficult, especially because of his poor preparation in the area:

> I think that it can be done [combine physics and the Puerto Rican culture], is difficult, but I am no expert in physics and it is very hard for me to relate it. It is not just culture, it is physics itself … I do not know if for other teachers with more experience and academic preparation it is easier, but I had been in activities with other physics teachers and they told me the same thing. Our cultural thing, it is not being taught.

These statements are too general to provide a useful insight of what Puerto Rican teachers really think about combining physics and local culture. Fortunately, other teachers were more explicit in their responses, as it would be seen in the next section.

<u>Culture as Context</u>

It was interesting to notice that most participants proceeded to talk about context (everyday experiences of students, local events and places) when asked specifically about culture. A similar pattern was detected in the short answer qualitative data. Some representative statements, expressed by Berta, Dolores, Zoraya, Rosa, Teresa, Eduardo, Gustavo, Wanda, and Leonardo follow. Berta, for example, implicitly equates culture and content by talking about her students' daily experiences, while adding the social aspect to her definition of culture:

> Puerto Rican culture, if we are talking about aspects of everyday life, social problems that are relevant, for example when I discuss about graphics we can include statistics of criminality, and teenage drug addiction and pregnancy.

In the same fashion, Dolores mentioned students' previous knowledge, but she used them as deductive scaffolding for explaining physics:

> We need to start from the students' experiences to develop the [physics] concepts, from the general knowledge they have to the specifics.

Zoraya also mentioned students' experiences as an instance of culture, although she used that knowledge to connect the application of physics concepts:

> Yes, they can be combined, bringing experiences to the students, getting out of the concepts some applications from experiences students live everyday.

Rosa's response was broader, suggesting that an aspect of culture might be an awareness of the country's events:

> Yes, I think so, all you have to do is knowing what is going on in our country and use it with your students, so that they get informed also, using TV news, newspapers, magazines, and so on. Yes, I think that the Puerto Rican culture can be included [in the physics class].

Teresa was also broader in his response, but her focus is on the innumerable ways physics is manifested in student's lives:

> Yes, the more pertinent physics become [the best for the students] … everything that surround us is physics, everything that surround us is controlled by the laws of physics.

The context of Puerto Rico geographical location was mentioned by Eduardo as his way to include culture in his class:

> Yes, it is evident that Puerto Rico and physics have a relationship. As I said before, we live on a tropical island and there are [natural] phenomena that students must understand.

Gustavo and Wanda were the only teachers who linked the textbook in their responses of how they combine physics and culture. Gustavo emphasized the textbook's difficulty to create context by using places students have never seen or imagine:

> One of the criticism I can do to the textbook is that it uses places that students, or even teachers, do not know. They talk about a French city, Lyon. I do not know if it is pronounced 'Lion' or 'Lyon', the way it is spelled. If I talk to my students about San Juan, Mayaguez or Ponce, that is a whole different story.

Wanda took a slightly different approach by criticizing the textbook's lack of local context and relevant examples:

> Puerto Rican physicists should try to create a textbook with examples from things that happen in our country, examples from free fall to motion, but they must mention things from Puerto Rico. Also using examples from distinguished Puerto Rican physicists, or NASA engineers. Instead of talking about foreign physicists, bring more topics from Puerto Rico.

Leonardo referred to how he used transportation problems on the Island as an aspect of the culture he included in his class:

> We enter into historical and cultural contexts when we talked about the problem of transportation and how it is managed here, where the benefits of selling and all

> the consumption associated with cars outweigh the development of an effective mass transit system. We talked about what model students' will use. What type of vehicle would they use for mass transit? What are the advantages and disadvantages of the train? What implications do a solid wheel and a solid rail have? But also it's disadvantages, because [for a solid wheel] you need a special road, which is the rail. With a solid and narrow wheel you cannot drive in asphalt!

Two particular examples about architecture were mentioned by Cesar and Nicolas. Cesar said, for instance:

> Undoubtedly, yes, physics is part of the Puerto Rican culture. Our architecture, that is physics … It is essential that we take into consideration our culture and to take our students there.

And likewise with Nicolas, although he was a bit more specific by mentioning specific physics topics in which he use Puerto Rican architecture:

> If we are talking about free fall, I use a building from San Juan, I bring a picture of a building from San Juan … so that they feel pertinence with what we are doing, and I get the physics curriculum closer to the student.

Berta's approach to the question was very different, arguing that physics teachers must also have a multicultural perspective because there were a number of students from different cultures:

> I like to include multiculturalism, because sometimes I have students from other cultures and I cannot stay only in the micro-cosmos; I must expand to the macro-cosmos. One time we had a student from Denmark who spoke no Spanish and very little English and we have to talk about example from his culture. It was a

> nice and enriching experience because the students brought examples from her culture … Today we have about ten students that are not Latinos [Puerto Rican?], two of them speak no Spanish.

All these quotes are similar in a way because they present context and culture as being equivalent, similarly to responses in the short answer section. Other teachers do not believe that the Puerto Rican culture has a place in a science course. This is the category for the next section.

<u>Physics as a Global Science</u>

Two teachers, Maria and Pablo, provide in their classroom a more universal perception of science, arguing that physics is a global science that can be understood regardless of local cultural variations. For example, Maria made this point:

> 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.

Similarly, Pablo also provided his perspective about presenting physics in a global way:

> 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.

This theme of physics as an objective endeavor appeared also in the short answer questions, which suggest consistency among those who believe in this perspective.

Puerto Rican Cultural Aspects in Physics

Only two teachers, Ismael and Leonardo mentioned examples of Puerto Rican culture, as I defined it, that could be introduced in the physics class. Ismael talked about “Paso fino”, a horse sport historically famous in the island:

> Yes, I think so. I am very Puerto Rican. For example, our national sport is “Paso fino”. Then, it is comfortable 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 created an analogy between work and sugarcane production to introduce the concept of work:

> We talked about some historical facts, like the problem of sugarcane production in the 1930’s. Sugar represents a concrete form of work (sugar-money), and we talk about the social problems of sugar cane production in which we produced collectively, but the appropriation of wealth is individual. I provide a historical context and it is part of our culture to recognize the struggle of our ancestors in those times.

He also uses a historical event to talk about potential and kinetic energy:

> 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 our lives. I talk about this event that happened in Central Mercedita, 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 three persons in half, just like a knife. So, Was there danger or not? I am combining history, real events, and physics.

Discussion: Interview Question Two

Just like in the short answer qualitative data, almost all teachers agreed that a physics course might include components of the Puerto Rican culture, but not all of them could enunciate specific examples of how these components could be effectively integrated in the class. And of those who provided specific examples, most mentioned those that I might considered more contextual rather than cultural, that is, very similar to those mentioned in the previous interview question and in the short answer question. Only Ismael and Leonardo provided examples that I consider cultural.

As I said elsewhere, it is extremely difficult to establish to what extent culture and context are two separate concepts or in what ways they are interrelated. However, based on the data, it is evident that Puerto Rican physics teachers are much more familiar with the use of context in physics teaching that with the inclusion of cultural aspects. It is difficult to ascertain whether teachers do not know enough of either physics or Puerto Rican culture to combine them effectively, or if they have a different definition of culture from the one I have.

Not all teachers believe that the inclusion of culture and physics is the most effective way to teach this subject. Maria and Pablo provided an insightful counter-argument by saying that the laws of physics are the same for everybody and that can be taught in any culture. Also they mentioned that students must be exposed to a variety of physics examples and applications, not just those relevant to the local culture.

Summarizing, it is quite evident that most teachers use culture and context almost like synonyms. It is my understanding however, that context is a subgroup in the overarching concept of culture. For example, there are cultural concepts that are not in the students' everyday lives, like history, literature or folklore. They are also contextual aspects that are foreign to our culture, like some types of music, and other media. Just a few teachers provided historical examples to explain physics topics. There is also a group of teachers who do not seem to believe in including cultural components in the physics class because they see science in an objective, global way. Since it is very likely that the preparation of physics teachers lack a local perspective, it is possible that, in general, they might not be prepared to include culture in their physics classes effectively.

Findings: Interview Question Three

In this question teachers were asked: "What is your opinion about the physics textbook you are currently using? What would you do to improve the textbook?" The answers to these questions can be combined into categories:

Positive Opinions

Eight teachers (Berta, Cesar, Dolores, Rosa, Frances, Nicolas, Zoraya, and Samuel) use positive adjectives, such as "good", "very good", and "excellent" to describe the physics textbook they actually use. Take, for instance, the following representative statements by Frances, Samuel, and Cesar. Frances is obviously thinking about physics as an objective endeavor when she gave this response:

> The textbook is very good, because the physics concepts can be applied everywhere, independently of where we are located, Mexico, Puerto Rico, United States because the natural laws apply [everywhere].

Similarly, Samuel evaluated the textbook as good, but more because of the way it is structured, and not on local context or culture:

> The book is very good, specific, and takes students from the simplest to the more complex for their [academic] level.

Likewise, Cesar considered the textbook as good, although he mentioned the presence of some errors. Also, he might be suggesting that if students want to learn, any textbook would work:

> In terms of content, the book is very good; although it has some minor mistakes that must be corrected. It is very simple, it just that in physics you must think, and that creates a problem for those who do not want to think.

Finally, Dolores and Berta pointed out that the book is good, considering the subject area and the quality of the students. Dolores stated that the book might be dry, “but considering that it is physics, it is quite acceptable”. She seemed to believe that physics is invariably boring and arid, and that there might be nothing she could do to change that fact. Berta stated that “The textbook is very simple … complete … very good, considering the population we serve”. Like Dolores, Berta has a preconceived notion, about students in this case. She seemed to believe that students are not able (or willing) to learn physics, and that there is nothing she can do to change this.

In this section, teachers reported believing that the textbook was good. Other teachers, however, have a very contrasting opinion about that same textbook.

Negative Opinions

Nine teachers (Berta, Arturo, Dolores, Gustavo, Teresa, Wanda, Josefina, and Leonardo) have a negative opinion of the textbook. In particular Berta, Arturo, Dolores, Gustavo, Teresa, and Leonardo used adjectives such as the following to describe the physics textbook they actually use: “low-level” “raw [as in sketchy]”, “rustic” “elemental”, “too easy” “needs depuration”, “obsolete”, “fatulo [false, invalid]”, “arid”, “dry”, “mediocre”, “very weak”, “inadequate”, “not flexible”, “limited utility”, “out-of-date”, “shallow”, “unattractive”, vague”. Here are some more detailed comments from Teresa, Leonardo, Wanda, and Josefina, expressing their opinions about the physics textbook they now use. For example, Teresa criticized the textbook’s encyclopedic approach, as well as the lack of local examples designed to create content for local students:

> The text lack detailed explanations. If I were to give the course conceptually, so that the students could read the book and understand the concepts, the text might not be enough. It lacks conceptualization, and the examples are also not from here. They are not from the daily lives of the students.

Leonardo is also critical of the textbook’s comprehensive but shallow design and its lack of context, considering senseless.

> I use the text as a dictionary and an exercise bank. It has many errors in the problems, and even as a dictionary is inadequate because the definition are so out of context that students read them and do not understand them … it makes a succinct and concise abstraction that is meaningless to the students.

He also went beyond whether the textbook is good or bad and focused on methodological changes that will make the book more interesting and useful:

> The textbook [we have now] does not create controversy, do not raise academic restlessness, it's like a, B, C, D, E, F, G, and that's it. The book does not bring challenging topics, or alternatives for those who want to go beyond or those who want to stay lower.

Wanda attacked the textbook on different grounds, especially for its wordiness and the small number of exercises, learning activities, and laboratories. She also mentioned the textbook's translation as an obstacle for students' understanding:

> I use the textbook mostly as a reference source. It should be improved; adding more illustrations, more practice exercises, improve the translation because the translation is not very good and students do not understand it. We need a more delightful book, with more laboratory experiences. The book [we have now] just has a brief explanation and a few problems, but no activities to develop with the students to reinforce the concepts.

This is quite similar to Josefina's response to the question:

> I think the book needs more [detailed] explanations … more examples, more practice exercises, and that they be written in a simpler way.

The fact that teachers used nineteen negative adjectives to describe how inadequate the textbook was (compared to the three adjectives the textbook defenders mentioned) is very revealing. The following group of teachers focused on the textbook's translation as a source of problems for Puerto Rican students.

Textbook Translation as an Issue

Seven teachers (Maria, Ofelia, Rosa, Ismael, Nicolas, Gustavo, Virginia, and Wanda) mentioned the fact that the book is a translation of a book in English, which might affect its readability and comprehension. The following representative statements were expressed by, Virginia, Rosa, Nicolas, Maria, and Ismael, respectively. Virginia said, for instance:

> For students it is very difficult to understand because of the way it is written. It is a translation from English and that create problems for students to understand from it. Even the teacher find it hard sometimes to understand.

Rosa has a similar argument with respect to the textbook's translation. She acknowledged the use resources from lower grades to compensate for the textbook' s deficiencies. In Puerto Rico, some elementary and middle school science textbooks are made locally, like Ciencias en Nuestro Puerto Rico (Santiago, 2000):

> The book is good, but it is a [translation of a] text in English and that create some learning difficulties. Pictures are not from Puerto Rico; examples are not familiar to students. Sometimes I have to use elementary school books because it is better explained and there are illustrations that are familiar to students.

Nicolas also acknowledged that science textbooks made in Puerto Rico for Puerto Rican students are available:

> The textbook physics' content is good, maybe in some topics is a bit high, but it is a translation of a book in English that is not pertinent, does not talk about Puerto Rico, like other books I have seen.

Maria and Ismael are also critical of the textbook's translation, but from opposite viewpoints. Maria is opposed to the translation of physics textbooks written by physicists, arguing that they might not understand the public school students' needs and vocabulary capacity. She suggested that science educators should have the main role in translating science textbook, if translation is necessary at all.

> In the book we use, which is a 'so-so' translation, students sometimes find words that they do not understand, the vocabulary is sometimes hard because, in most cases, most translations are done with people that are not educators, but scientists who have a hard time finding the right words for students to understand. In other occasions, not in this case because this book was translated by Puerto Ricans, translations come from Mexico or Spain, which sometimes have different words to explain concepts, and both students and teachers have a hard time understanding the text.

On the other hand, Ismael is opposed to translations done by people with limited scientific knowledge. He implicitly suggested that physicists should translate physics textbooks:

> I think that the problem we have is when the books is translated … it looks like the books was translated literally. It seems that Dr. Caraballo [one of the translators] delegated in people who know about language, but not about science. It is very difficult to translate from English to Spanish without the scientific knowledge. There are questions in the book in which I think that the translator was 'cantinfleando', talking a lot but saying nothing.

It is evident that translation issues are definitely part of the teachers' criticism of the current textbook.

Student Lack of Preparation to Take Physics

Although most teachers criticize the textbook, they also pointed out at the lack of essential skills of students as the main difficulty in teaching physics. Implicitly, they are saying that any physics textbook, especially those mathematically inclined, will not be very useful if students lack the pre-requisite mathematics skills necessary to understand physics. These comments from Ofelia, Cesar, Frances, Hortensia, and Pablo represent this point of view. For example, Ofelia's frustration as a physics teacher who faces mathematically unprepared students everyday is evident in her response to this research question:

> I had to teach a mathematics class [inside the physics course], which I do not have to do, but is very sad that they do not master anything [mathematical skills] … students have lot of deficiencies in all areas … the book combines theory and exercises in the same section and that is very confusing for students. Maybe my students do not have the capacity [to work with this book].

Cesar considered both the mathematical approach of the textbook and the students' deficiencies in this area as a fatal combination:

> For some students the book is excellent, but for others the text do not reach the students, and it is because of the amount of mathematics on it. Most of my students do not master even the most basic mathematics skills.

This is quite similar to Frances viewpoint. She suggested that only seniors might be prepared to tackle this course. In some Puerto Rican schools, the course is taught as low as 10^{th} grade.

> The most difficult part for students to understand was the mathematics. For a student to take physics, he needs some basic knowledge of mathematics, equations, solving for an unknown, linear and parabolic equations. I think that the course must be taught in grade 12.

Hortensia has taken a more drastic, although not unique, approach based on the reality she lived at her school by stop using the textbook altogether and customizing her teaching to the students that she has served:

> At this point I am not using the textbook. Why? Because I understand that the group of students I have now do not have the basic skills to work with the book, which is very high [difficulty]. This book is for good students [but] not for the ones we have.

Pablo also believed that the textbook's complexity does not match the students' cognitive readiness:

> The textbook was written for students in a higher [academic] level than most of our regular students. The book reaches the minority, not the majority of the students.

These teachers seemed to suggest that education is multi-factorial and that examining only one aspect of it, textbook relevance in this case, is not enough to comprehend the nature of the problem of physics education in Puerto Rico. However, I believe that acting on all factors at the same time is close to impossible and that the exploration of contextual and culturally relevant issues in physics teaching, that is, the curriculum aspect of physics education, is as good place to start as anywhere else.

Local Textbooks as a Possible Answer

Some teachers, like Rosa, Teresa, Nicolas, and Virginia perceived that the development of a local physics textbook might be an option to make the class more relevant to the students. Rosa said, for instance:

> I would really like to have a textbook written by a Puerto Rican, with local pictures, and things that had happened here, and events related to physics that had happened here.

Teresa strongly believed that Puerto Ricans are prepared to take physics education in our own hands:

> I always believed that here in Puerto Rico we can make a textbook that is adapted to our reality. Physics is physics everywhere, but we must change the way of saying things, the examples, so that students can understand physics better with what they have here in Puerto Rico. That can be done and here we have prepared people to do it.

Nicolas and Teresa are thinking in essentially the same way, based on his response:

> [I think that] a team of three or four prepared people can create a local book, more pertinent, it will be fantastic because then they will use situations, buildings, features of our culture to include them in verbal problems in that textbook.

Virginia’s answer is generally similar, however she added the design of a teacher’s guide to complement a Puerto Rican made textbook. She also pointed out that different schools should have different types of locally made textbooks, arguing that students in general and vocational schools have different needs:

> The book is basically a translation with a few local pictures added. I think that we must do a [physics] textbook here, a book with a clear teacher's guide, a book more adequate to the reality of our students in Puerto Rico … And not just that, but if there is only one book, it should have a guide specifically designed for vocational schools. I think that physics for students in car repair [workshop] should have a different emphasis from the physics students in electricity [workshop] must take. For students in the electronics workshop, they already take a specialized physics, a different curriculum with computers and other laboratories.

Interestingly, Dolores, Berta, and Maria suggested that the fact that the textbook might be local does not imply necessarily more student understanding, especially if it is written by college physicists alone. For example, Dolores argued that they might not have a clear idea about what the high school physics students need or want:

> I think so [creating a local textbook], but if they are physicists from the universities, I doubt [it will work], because they do not have the essence of a real high school student, students that usually do not reach them.

Berta suggested that a group of educators (presumably science educators or physics educators) might be more effective in developing a local physics textbook:

> I think it would be nice if a staff of people prepared in education, they could work [the local textbook] better.

Maria insightfully cautioned that the fact that a Puerto Rican (physicist or educator) tries to write a locally relevant textbook, his/her nationality is not a guarantee of success:

> It also depends on the perspective and the experiences of each contributing person. It might be that a Puerto Rican professor had a variety of experiences here in Puerto Rico and could contribute his knowledge, or it might be that a foreign professor who had lived in Puerto Rico for a given time also has these experiences. He does not have to be Puerto Rican to write a [physics] textbook that is pertinent to the students and based on the Puerto Rican culture. Being Puerto Rican is not a synonym of better quality, but being part of our culture and knowing what is relevant for the students is.

Again, the debate between people who prefer scientific knowledge to pedagogy and those who believe in the opposite perspective is clear. Also, Maria's comment is an excellent attention getter. For example, Tony Croatto, a singer and songwriter originally born in Argentina or Italia has been in Puerto Rico for more than 30 years and it is considered very knowledgeable about Puerto Rican culture, music, and ecology. There are many people who have a similar case, people who migrated to Puerto Rico from a variety of countries and see themselves as Puerto Rican. On the other hand, there are hundreds of thousand of second and third generation, self-proclaimed Puerto Ricans who were born in the United States and have never been on the island and speak no Spanish.

One of the teachers argued that a group of teachers was selected to choose a physics textbook for high school. And the one the majority chose was not the one selected. Since I heard this story from another independent source as well, I want to include it to demonstrate that there might be more going on in terms of textbook selection than meets the eye. I asked Teresa about why we do not have a local textbook if we have prepared people to do it. Her response was:

> There are other things, private interests in the government. Publishing companies come here and meet with people in the Department of Education. They are simply the one who offers the most [under the table]… we must be very clear with this. There are private interests and payments under the table, because there are much better textbooks than the one we are using. Some schools received some textbooks for examination, although most teachers recommended other books, this one [the one they have now] was the one who won.

Of course, this does not necessarily mean corruption in the Puerto Rico Department of Education (although it might). An alternate explanation might be that the Department of Education's top science education personnel wanted a mathematical approach for high school physics to differentiate from the physical science course taught in middle school.

Suggestions for Improvement

For this section, I will paraphrase and summarize with bullets the main recommendations provided by the teachers. This list is representative of the opinion of 20 participants (Frances said that the book was very good, that not many changes were required, but she quickly pointed out that she might not have enough academic preparation in physics to provide a good answer to this question). In addition, I will include a few relevant and more detailed quotations regarding this topic.

To make the textbook better for Puerto Rican students, it must:

- Include more activities and learning experiences

- Have a clear and detailed teacher's guide, laboratory manual (to perform labs with common household materials), and audiovisual package.
- Be simpler in the way it is written (vocabulary, sentence structure), and in how it explains the concepts.
- Include much more examples, practice exercises (with different levels of difficulty).
- Restructure its contents, removing topics and chapters that are less important and enriching those that are more important, including modern physics (less is more approach).
- Focus more on graphical interpretations.
- Do an urgent revision and update.
- Make the narrative more interesting, fun, controversial, and surprising.
- Include local examples, places, events, people, illustrations, and applications.
- Be written in Spanish to prevent problems associated with translations.
- Include physicists, physics teachers and education specialists in the development of a new, local book.
- Avoid a full-fledged mathematical approach and focus on a more conceptual physics (a la Hewitt).
- Be divided in small booklets covering overarching themes in physics, instead of having one thick book.
- Be tailored to both general and vocational tracks.

Here are more detailed comments from Rosa, Ismael, Nicolas, Gustavo, and Josefina on improving the textbook. For example, Rosa's comment hinted that she perceives an intrinsic difference in culture and context between Puerto Ricans and people from the United States:

> I would make the more actual, especially for a population of Latinos that live in the tropics.

Ismael made some suggestions on how to make the actual physics textbook more Puerto Rican:

> I think that this book must be ‘Puertorriqueñizado’, for example by bringing renowned and international Puerto Rican athletes [in the examples] … People see physics as an abstract class, but if you can provide ‘live’ examples and you can combine your class with events happening [it is better].

In his response, Nicolas agreed with a previous statement from Rosa in terms of including context and culture in high school physics textbooks, just like it was dome with science textbooks from lower grades:

> I would make this book like the 9th grade earth science book, which has geological and topographical references from Puerto Rico, and even a Puerto Rican road map is presented. If the students see a book with aspects of Puerto Rico, they get more interested. In physics we do not have that opportunity.

Gustavo contributed the following thoughtful comment to the discussion on ways to improve the textbook that he used:

> I would make the book more agreeable, more attractive to the student, that they can see examples closer to them, that the situations presented are from their daily experiences, that the students can see a pertinence, a daily life application of what they are being taught.

Josefina complemented Gustavo's comment by suggesting different ways to improve the text:

> I would add more laboratory activities with materials accessible for both the students and the teacher. I would also include integrations with other subject areas, like chemistry and biology. In addition, I would like a book that invites students to realize research, to discover new things, to investigate more about physics.

There are some teachers, like Leonardo and Hortensia, who would not modify the actual textbook, but will make a new one from scratch. Leonardo said, for instance:

> I think we need another textbook. I think that the changes that must be made are so big that it is impossible to say whether or not it will be the same book. I think that the book must include more contextual aspects and be more polemic with the students. For example, if it is going to present work, it is not enough to say: 'work is force times distance, it is not a vector and this is its unit … I would present the concept in short polemic stories and to bring curious and useful facts … the textbook must have a number of short stories, and those stories must include 'mini-debates' in which the student is surprised by a concept [he had misconception on]. In addition, I would have a separate problem bank with different levels of difficulty. In that case the student has the option to get to the levels he is interested in arriving. Some of my students want to be engineers, and other want to graduate to go work at K-mart. Why the second group needs calculus? … There is also the need for complementary audiovisual materials that also serves to generate controversy in the physics classroom.

Hortensia made a similar comment, adding the use of technology as a possible substitute for the textbook she used:

> I would change it completely in terms of our realities. I think we are in a point in Puerto Rican education where students should not use textbooks, with all this access to technology, the Internet, computers. I think that students will perform better [with technology] than with a textbook.

The teachers' comments about how to make the physics textbook a better tool for students to use and learn are, in my opinion, excellent and a nice starting point for teachers to debate on the issue. Hortensia's comment on the use of the Internet to substitute textbooks might be visionary. However, caution must be taken not "to change oranges for bottles", that is, not to embrace a new technology that might be as decontextualized and culturally irrelevant as the textbook.

Discussion: Interview Question Three

An examination of the data in this section found some interesting dichotomies. The number of teachers who considered the physics textbook they use as good or excellent is roughly similar to those who have a more negative perception of the book. However, twenty of the teachers contributed detailed suggestions on how to improve the textbook. This suggests that even those teachers who believe that the book is good, think that there are some steps that must be taken to make the textbook more contextual and culturally relevant. In addition, some of the teachers who have a positive impression of the book evaluate it more in terms of general characteristics of the book, as opposed to a more critical examination of its lack of relevance for local students.

Teachers who have a negative opinion about the textbook were much more explicit in their description and more detailed in their criticism. This makes me think that they might have thought about the quality of the textbook previous to my research and were not happy with it. The issue of the textbook's translation was mentioned quite often by the participants as one of the sources of their criticism, despite the fact that three Puerto Rican professors participated in the translation process. Other criticisms are related to the mathematical approach of the text (or the lack of mathematical abilities of their students), the complexity of the presentation (or the students inability to understand the content), and the lack of local references. To counterbalance these deficiencies, some teacher use the books as a guide, while other do not use them at all.

The creation of a local physics textbook was suggested by a number of teachers, arguing that in that way the textbook would not have to be translated, that the authors would create a textbook more in affinity with the students needs, experiences, and preparation in mathematics. Teachers are aware that in Puerto Rico we have the human resources to do such a task. I believe additional reasons (economical, political, or philosophical) other than the recruitment of qualified physicists, science educators, and physics teachers might obstruct the creation of a local textbook in the future.

The second dichotomy that was evident from the data was that teachers have different ideas about who would be the most qualified person to create a contextual and culturally relevant textbook. While some teachers preferred a group of educators and physics teachers, other suggested the inclusion of university physicists and other scientists who know their science.

The theme of students not being prepared for the physics course is present in this section as well. Without more research in this area, it is difficult to ascertain to what extent teachers' perception of the students is real, or whether teachers use students as a scapegoat to their inability (in physics, pedagogy, psychology, etc.) to engage students in meaningful physics learning.

The suggestions for improvement given by the participants are, in my opinion, an excellent guideline to create a better textbook and should be seriously taken in consideration if a local physics textbook is ever attempted. I think the suggestions are especially enlightening because, in contraposition to recommendations from scholars, educational researchers, or science teacher educators who may have been away from the classroom for too long, these were produced by physics teachers who face daily the problems and situations associated with not having the best resources to engage in the best instruction they can achieve. I believe that inviting them to contribute to the creation of a Puerto Rican physics textbook might be an extremely empowering experience.

In summary, although some teachers believe that the physics textbook they are using is good, most teachers interviewed believe that the textbook is inadequate for the student population they serve. Some of the reasons pointed out for their dislike of the textbook are a lack of detailed explanations and a conceptual approach, too much emphasis on mathematics, a inferior translation, and a mismatch between the textbook goals and the students' abilities.

A number of teachers suggested the creation of a local physics textbook by a group of physicists, science educators, and physics teachers. However, teachers are well aware that for the textbook to be effective it must go beyond the nationality of its authors and the politics of the local Department of Education. Finally, teachers provided a long and illuminating list of suggestions to make the physics textbook more contextual and culturally relevant, or for the creation of an original, Puerto Rican high school physics textbook.

Findings: Interview Question Four

In the fourth question teachers were asked: “What do you think is the students’ opinion of the physics textbook they use?” The overwhelming majority of teachers, 18 out of 21, said that students have a negative opinion of the textbook, basically that they read it and do not understand it. However, when teachers answered this question they might or might not have separated the students’ opinion of the textbook (based on their interaction with the students and anecdotal evidence), and the teachers’ perception that students lack the mathematical skills needed to tackle physics, and that they have a negative attitude toward physics. It is very hard to determine if students dislike the textbook because of the way it is written or the way the content is presented, or is it because they do not understand the mathematics associated with physics or they do not have motivation to learn the topic and look for unknown words. It must be mentioned that these answers represent the participants’ opinion of what the students “might” think about the textbook. Only research data gathered from the students themselves can provide more definite answers to this question.

What do Students Think About the Text?

Here are some quotations that answer, in my opinion, the original question. These quotes are representative of 18 participants. Teresa, Zoraya, and Samuel reported not knowing what their students thought about the textbook. For example, Berta pointed out the fact that students have a hard time using the textbook productively. She suggested that the textbook might have been intended for a population other than the one she serves:

> It is hard for students to understand the book … the book aims too high, it should be made more conceptual and less applied.

Arturo agreed with Berta when he talked about the students' problems with the textbook: "Frankly, students do not understand that textbook." And like wise with Dolores: "Students read [the text] and do not understand it."

Pablo believed that they textbook might not be as explicit as it should be. He believed that the lack of explicitness is a reason why students think that the textbook was intended for college students:

> Since I have regular students, they say that the book is university-level, its level is very high for them … the textbook does not explain [explicitly] many things and it is impossible for the students to figure it out by themselves.

Frances' statements are especially synchronous with Berta's and Pablo's when she said that the book might be too difficult for her students. She hinted at the mathematical approach of the textbook as a possible cause of her students' perception of the book. This topic will be revisited shortly:

> [Students say] that the book is hard, that they do not understand it. Most of the things in the book go toward the mathematical area, and that makes it very hard for students.

Maria seemed to suggest that students might not have much trouble reading the narrative, but the wording of the sample problems and exercises might be confusing to them: "Some students say that they do not understand some of the examples."

Cesar tended to agree with Maria, proposing that students are not bad readers, but that reading a problem in order to obtain valuable data to solve a problem require different skills, which his students might lack:

> The opinion of the students is that they read and do not understand. Why? Because they read, but when they have to [use the information they read to] solve problems, they can't. The book is based on the premise that the students have previous knowledge and experiences, so it is not detailed.

Ofelia departed slightly from the previous teachers by focusing on the students' perception of the text: "Students perceived the book as burdensome." However, with the data available it is not clear whether students see the book as burdensome and as a result do not make an effort to understand it, or if the students cannot understand the textbook and as a result they label it as burdensome.

Ismael agreed completely with Ofelia when he said that students literally fall asleep when asked to read the textbook during class:

> Students find the book completely boring. You talk to them and they look motivated; you put them to read and in three to five minutes they all are asleep. I think that the book must be more interesting, so that students get more motivated.

Leonardo pointed out the fact that the textbook's errors and omissions (either on the original version or during translation) made students even more confused:

> They say that the problems are incomplete, that they do not understand the problems, that there are no diagrams that illustrate what the problems are saying … other thing that bother students is that some problems have errors, either in the answers or in the problem itself, when the values for some variables are inverted.

Gustavo's statements are perfect for concluding this section, as they summarize the consensus among almost all of the teachers interviewed:

> Students find the book tedious, too long, unattractive, they do not understand it. The reality is that very few students understand the problems.

In summary, teachers believe that students seemed to have problems understanding the textbook's narrative. They also seemed to lack the analytical skills required to extract data from a verbal problem. Students even believe that the textbook is more suited for a college physics course. In addition, students perceived the book as boring, burdensome, and unattractive. Finally, those who do understand the textbook well enough to tackle some of the verbal problems face additional obstacles, like editing error and omissions.

Again, is it the Text or the Students?

The following commentaries do not answer the original question, but might point out to the fact that students are not prepared to take a mathematically oriented physics course. For example, Berta pointed to specific mathematics topics that are essential in physics, but that students either have not covered or have not mastered after covering them in lower grades:

> [Students] do not have enough [intellectual] baggage to deal with the textbook. For example, in vector addition the textbook discusses trigonometric functions, however they are just starting geometry and do not have the slightest idea about

> how to measure an angle. It is extremely difficult to talk about trigonometric functions when they do not know how to measure an angle … in the part of scientific notation, exponents, positive and negative signs, decimal addition, fractions, students supposedly covered that before but they either did not master the skills or something, but the physics teacher loses much time trying to re-teach those skills.

Arturo agreed with Frances when he talked about the intimate relationship between mathematics and physics in the school's curriculum:

> Remember that mathematics is the essential foundation of physics; if you do not master mathematics, physics will be impossible to work with.

And likewise with Cesar:

> Unquestionably. Students find the book difficult because they do not have developed mathematical skills; if they do not have the skill of knowing what is a linear equation or solve for a variable, they cannot deal with physics.

Acting on her students lack of basic mathematics skills, Frances developed supplementary written materials to cover the prerequisite mathematics topics in a fast and easy way at the beginning of the semester:

> I had to make very simple mathematics modules of things they should master, like exponents, equations, solving for an unknown, so that they understood that and then we entered in physics.

Wanda suggested that students might be arriving at the physics class with their minds set on how terrible the course will be if they are not excellent in mathematics:

> I have found that students do not like physics, maybe because of the way it has been presented in other grades. Also, students relate physics with mathematics, and usually math is not very pleasant for them.

Dolores gave a more general statement, arguing that both the mathematical and conceptual components must be paraphrased into something more intelligible for the students:

> I have to translate the physics concepts into layman's terms so that students understand it. But you must ask: Is it the textbook or the students' condition? Because I have students that will not understand a text, no matter how it is written. Sometimes you say the same thing individually and students get it.

Ofelia presented an argument similar to Dolores, however some of Ofelia's frustration showed in her comments:

> When I make them read in the classroom, it is like wasting my time. I have reached a point where I make them read aloud each paragraph and I explain and add more information.

According to Ofelia, Gustavo, and Leonardo, in addition to lack of mathematics skills, students seem also to have reading problems. Ofelia, for example, believes that the Spanish words used in the textbook are appropriate for high school students. In a way, she blames the Spanish classes for not promoting a rich vocabulary:

> The Spanish I see in the book is easy, but there are words they do not understand, simple words, and that is a problem of the Spanish class, that they lack richness in their vocabulary … but they also lack the motivation to go find the words [in a dictionary].

Implicitly, Ofelia pointed out the fact that a locally produced physics textbook, even if it includes contextual and culturally relevant approaches, might not be useful for students if they have limitations in reading Spanish and lack the motivation to search for unknown words in a dictionary.

Gustavo agreed with Ofelia. He emphasized that students cannot understand relatively simple written materials, while implicitly blaming something other than the textbook as the responsible for the students' lack of Spanish literacy:

> The reality is that students do not know how to read, they have problems with reading because they cannot understand even simple stuff ... there is a series of knowledge gaps that do not have to do with the textbook.

On the other hand, Leonardo believed that some of the Spanish words used in the textbook might be unfamiliar to students, and might be too technical. He also mentioned that students prefer that the teacher explain the physics concepts rather than reading them for themselves. Based on the data available it is not possible to determine whether students are auditory-oriented, reading-challenged, or lazy readers:

> [Students] tell me that they read and do not understand what they read. When I asked they to read they say: 'I am not going to read this. I am not going to understand it. I prefer to wait for you to discuss it' … even high achieving students read the text and they say: 'This text is out of the ordinary, that textbook does not work.' I read and do not understand'. I am talking about students with [a G.P.A. close to] 3.97, 3.85, good students … Students want to work with problems, but it bother them to read a problem and not understand it because they do not understand the words … Sometimes the words are very elaborated and

> students do not know what they mean. Sometimes the construction of the sentence does not help either.

Some teachers, like Maria and Virginia, decided not to use the textbook at all and they create their own physics classes customized for the student population they attend. Notice that Maria included contextual references as a way to present the physics concepts:

> I seldom use the problems in the textbook. I create my own problems, usually with common references, like a car, a toy car, or an object. I look for things that can be understood by my students.

In contrast, Virginia included culturally relevant aspects to create a more pertinent physics class:

> I am always adapting problems, I can use only one or two problems from the textbook. What I do is to change the problems to something more relevant, Puerto Rican places, local realities, cars students like.

It is clear that teachers seemed to believe that textbook problems are not the only responsible for the students' lack of interest and poor performance in high school physics. They mentioned mathematical and reading knowledge gaps that students seemed to have. Some of the teachers decided not to use the textbook, but to customize their students learning by including contextual and culturally relevant approaches. An implicit fact is that the textbook might be inappropriate because it is deficient in these two important areas.

Two Physics Courses as a Possibility

Two participants, Berta and Maria, suggested that two physics courses should be available for students: a conceptual physics course and a mathematically oriented physics course, and that students should pass a placement test. Berta is the teacher who suggested the desirability of having two separate high school physics curricula, although she did not mentioned how students would be placed on either course:

> [I think we should] have two curricula [courses], one for those with mathematical skills and another with a more theoretical, conceptual, daily-based physics.

Maria is more specific in her statement, suggesting that students should be placed on either a conceptual or a mathematically oriented course based on some evidence (I believe that a placement test might have been on her mind). She also pointed out that both talented and slow students would benefit from these new courses:

> I think physics students should be classified by mathematical level when they are going to take physics because, on many occasions, students who can work physics problems at a more advanced level get left behind because we cannot more forward with them and leave the others behind … this limit talented students which we could more at a higher academic level.

Based on my interviews and my knowledge of Puerto Rican high school physics education, I have the feeling that their suggestion is being implemented in some schools. A number of teachers told me that they try to avoid giving complicated mathematical problems to students, focusing more on concepts and definitions.

<u>A More General Problem?</u>

A few teachers mentioned that students have a more general attitude problem, not just in physics. Ofelia said that students "do not see the value in any textbook", that "there is no motivation [in the students]", that "they do not care whether they pass the class or not", and that she do not expect all students to go to college, but she "want them to be productive and responsible, but they are not." Another teacher, Eduardo, talked about the larger problem in education: "Nowadays, education has changed a lot. Students are not very enthusiastic about textbooks." Finally, Gustavo talked about the textbook authors and the book's target:

> The book is not very attractive, how it is organized, how it is written, I think authors do not take into consideration to whom the textbook is targeted. In this case the textbook is targeted to an adolescent population. This is a very important consideration when preparing books for this level.

These statements place our research question on the proper perspective. The problems teachers and students face in Puerto Rican classroom (and probably in classroom around the world) are extremely complex and multifaceted. I remember one of the interviewed teachers saying that changing the textbook to one more contextual and culturally relevant is not going to solve the problem. That is one of a number of alternatives to improve high school physics education.

Teachers also Stated not Knowing their Students' Opinion of the Textbook

As I pointed out before, Teresa, Samuel, and Zoraya argued that they do not know their students' opinion about textbook. I found this odd because, when I was a high school physics teacher in Puerto Rico, I remember that some students were explicit about their opinions of the textbook and the class. However, this finding was far from unique. It seems that students either do not question the authority of the teacher, or teachers are not aware of their students' perceptions of the text. When asked about the students' opinion of the text, Teresa answered:

> I have not had that experience with my students … throughout the years, students never questioned me about that … never told me directly about that.

Likewise with Samuel:

> Students usually do not have an opinion of the textbook, they have an opinion about how much workload they receive.

Zoraya's language was more matter-of-fact. Her statement does not consider the possibility that her students do have an opinion about the textbook, but that she does not know what it is: "Students do not have an opinion about the textbook".

Unfortunately, it is impossible to obtain clear answers to why some of the teachers said that students had no opinion, positive or negative, about the textbook based on this data. An interesting follow-up student might be to interview students to ascertain their opinion of the textbook.

Discussion: Interview Question Four

I think this question is deceptively simple, but it has some very interesting answers provided by the teachers. Most teachers reported that students do not like the physics textbook they use. They hypothesize some reasons for the students' dislike of the text, including overall lack of interest in school, lack of motivation, and inadequate mathematical and reading skills. However, without additional research, it is difficult to determine the students' real perception of the text and the possible reasons of their attitude toward it.

The fact that the overwhelming majority of teachers believe that students do not understand the textbook is very disturbing. Based on my interaction with the teachers, I got the impression that most teachers have the impression that physics equals applied mathematics and that only a selected few should take physics. Interestingly, although teachers agree that a conceptual approach to physics might be more effective for the population they serve, they tend to believe that because of the apparent lack of mathematics skills of their students and not because they think that conceptual physics is “real” physics (mathematically oriented physics). I remember a teacher saying to me that most of the teachers who advocated a mathematical approach to physics knew mathematics, but very little physics. An interesting study might be to research what the teachers think physics is and is not, that is, what they believe about the nature of the discipline.

Another explanation of why teachers believe that students dislike the physics textbook and the class might be in the concept of self-fulfilling prophecy. It is well-known in education that the teacher expectations of a students can predict changes in student achievement and behavior, that is, one's expectations about students can eventually lead them to behave and achieve in ways that conform to those expectations (Tauber, 1998). I think it might be possible that teachers expect students to perform poorly in physics because teacher from previous years had told them about how lazy, unprepared and unmotivated students were.

By examining the data I tried to ascertain what the participants believed was their role as physics teachers. Most of them told me how poorly prepared students were, how badly they were doing in physics, but very few shared with me their plan of how to make this better, how to make students learn some physics, as if they were reporting to me a status quo in which they could do nothing about. A few teachers even told me that even if we changed the textbook to include contextual and culturally relevant approaches, students would not perform better in the class. Others told me how their approach to teaching, using everyday examples and conceptual physics was effective. In fact, until a group of science educators create and pilot a physics textbook that uses context, cultural relevance, and the viewpoint of physics teachers, it is very difficult to determine which groups of teachers are right.

If the teachers' statements about the students' opinion of the textbook and the class are true, then the whole education system in Puerto Rico must be examined closely to discover why students in 10th grade are taking physics without completing some mathematics pre-requisites, and why students in 11th and 12th grade are reaching those grades with the alleged deficiencies in basic skills, like mathematics and reading.

A mention must be made about the three teachers who reported not knowing what the students thought of the textbook. As a teacher, it is hard for me to believe that these teachers had no idea of their student opinion of the text. Are they answering defensively, fearing that I might think negatively of them as physics teachers because the students do not like the textbook or the class? On the other hand, if their statements are true, then it might be interesting to explore more deeply what makes these teachers different from the rest of the participants, at least in this aspect.

Summarizing, it is obvious that teachers believe that students do not like the textbook because they lack the skills necessary to understand it. Contrary to another question, in which the textbook is criticized harshly, in this case most of the blame is placed on the students and the perceived lack of mathematical and reading skills and negative attitude toward learning and science. Some blame is also placed on the textbook, perceived as complex, mathematically oriented, and uninteresting. It is very hard to separate to what extent the problems in physics teaching in Puerto Rico can be traced to the textbook, the students, or both. Can it be that physics is offered to students who do not have the prerequisite courses approved?

Unlike in the United States, where a single high school might have conceptual, general, honors, and AP physics courses, in Puerto Rico there is, theoretically, only one physics course. The teachers' suggestions of having at least two courses and to place students according to their interest and mathematics skills seems like a good idea in theory. Finally, it was a bit strange that some teachers say that they do not know what their students thought of the textbook. Are they alienated from their students, or do they have a particularly authoritarian type?

Findings: Interview Question Five

In this question teachers were asked: "Do you think that a teacher who has a pro-statehood ideology will be less critical of the physics textbook actually used because it was made in the United States?" The majority of the teachers (12 out of 21) said that their ideological/political beliefs are independent of their teaching. However, eight participants believed that some pro-statehood teachers, especially those considered "fanatic" and "close-minded" would be less critical of the textbook. The two main categories for this question are:

Ideology and Teaching are Independent

Twelve participants (Berta, Dolores, Maria, Ofelia, Cesar, Leonardo, Nicolas, Virginia, Wanda, Pablo, Zoraya, and Samuel) reported that the political ideology of pro-statehood teachers should not influence or inform their teaching practices. These are representative statements from Berta, Maria, Ofelia, Leonardo, Pablo y Zoraya, teachers who believed that the teachers' ideological/political beliefs should not affect their teaching decisions, including their assessment of the physics textbook they use. For example, Berta proposed the qualities of objectivism and professionalism as the ones who might determine whether a pro-statehood teacher will be less critical of an American textbook (or its translation, as in this case):

> If [the physics teacher] is an objective person, committed to what he is doing [teaching], I think he will separate his political ideology from what he is doing [professionally].

Maria also mentioned professionalism as a quality that might affect the teachers' beliefs and actions, in terms of his or her pro-statehood ideals. In addition, she used the term open-mindedness in a similar fashion:

> If the person has an open mind, whose academic preparation has reached its goals, then I do not think that [his political beliefs] are going to influence [his teaching]. However, if it is a person that, despite his academic preparation, has a closed or narrow mind, then it is definitely going to influence.

Ofelia believed that the problems associated with physics teaching and political ideology are incompatible. She used the words "real teacher" to describe teachers who are not professionally affected by their pro-statehood beliefs:

> I do not think so, one thing does not have anything to do with the other, independent of the teacher's ideology. Once the teacher see the problems associated with [teaching] his students, I do not think he is going to relate

> [ideological beliefs and teaching] … For a real teacher, ideological issues do not affect his teaching.

Leonardo is more general in his statement, arguing that political ideology, regardless of what status option defends, have no place in education:

> I have talked with colleagues who are pro-statehood, pro-independence, and pro-commonwealth and most of them do not like the textbook. The criticisms to the book develop because it is a poor educational instrument, independently of the teachers' ideology.

He also seemed to imply that no matter the teachers' political affiliation, they perceived the book as inadequate for their students. This is additional evidence to support the findings on the interview question number three.

Zoraya's statement summarizes the general opinion of the majority of the interviewed teachers. Also, she emphasized that the students' welfare and interests are at stake in the physics classroom:

> I do not think so. I think that teaching has nothing to do with political parties. Each teacher has his own ideas … but we work for the well being of our students.

Although most teachers are reluctant to disclose their political beliefs, Nicolas and Pablo admitted that they believed in statehood, but that does not affect their teaching. Nicolas said:

> I am pro-statehood and I do not mix politics with education. If I am an educator, I am here so that students can receive an education, and I am effective at that, regardless of my political beliefs. I think that if we can adapt this textbook to the Puerto Rican reality, we will have better academic achievement.

And likewise with Pablo:

> It is indifferent for me. What is important for me is the material the textbook has, its level of difficulty, and I compared that with the students' academic level, high, regular, low. If I believed in statehood, I would not see teaching from that perspective. If I am going to evaluate a textbook I need to do it based on what the textbook says.

In particular, I like the analogy Dolores made between fanatic teachers and "Don Eleuterio". He is a character in a radio comedy show. "Don Eleuterio" is an old and uneducated Puerto Rican man who represents the ridiculous extreme of pro-Americanism, defending the economic, social and cultural Americanization of Puerto Rico while, at the same time, denying his Puerto Rican culture and language. He is basically an ultra-conservative republican that abhors being born Puerto Rican:

> If the teacher is like 'Don Eleuterio', he undoubtedly will not criticize the textbook, but if the teacher is a real scientist, I doubt it. The experiences of the classroom and the students are independent from politics.

One of the reasons explicitly mentioned about why ideology and teaching are not related is the perception that science in an objective, rational, and unbiased endeavor. Cesar implicitly suggest that scientists and science teachers are objective enough not to combine their pro-statehood ideology with their teaching:

> I never thought about questioning my teaching from a partisan perspective. I have never seen that perspective with other [science] teachers as well. If they are scientists, they will not go to the fanatic extreme of analyzing a book based on

> political ideology, unless the teacher is a fanatic that sees everything from the point of view of a color [political parties are identified by colors].

Wanda is also implicit about her belief of an objective science versus other subjective disciplines. However, she did not discard the possibility that some teachers might view their teaching from a pro-statehood ideological perspective:

> I do not see much relationship between physics and political ideology. Maybe somebody combines them, but that is more common in other subjects, but not in science.

Contrary to Cesar and Wanda, Virginia is explicit about her belief that science cannot be tainted by the subjectivism of ideology, pro-statehood in this case. She also enumerated three aspects that will determine to what extent a teacher might combine his or her pro-statehood ideas with physics teaching: teacher professionalism, teacher commitment to the subject area, and textbook quality:

> As scientists, we tend to be more neutral in terms of our identity as people, we see ourselves as more global … Believing in statehood is a concept that is completely separated, divorced, [of my teaching]. The fact that I might believe in statehood, I do not think it is going to affect my [professional] vision. [What is going to affect it is] how I am as a teacher, how committed I am teaching physics, and how practical is the textbook, based on what I want to transmit to my students, independently of being pro-independence, pro-statehood or whatever. It is like trying to mix gymnasium and magnesium [milk of magnesia]; they sound similar but mean different things.

Finally, Samuel talked about some type of conflict that some pro-statehood teachers might have:

> I do not know whether a pro-statehood teacher will be less critical or not [about the textbook]. [I think it] depends on how pro-statehood the person is, how inside are his conflicts. A teacher should not have those conflicts.

The conflict Samuel might be talking about is, in my opinion, a very serious one for people who believe in statehood for Puerto Rico. It can be summarized in four rhetorical questions:

- To what extent are Puerto Ricans like people from the United States?
- To what extent are Puerto Ricans different from people from the United States?
- To what extent are Puerto Ricans like people from other Latin American countries?
- To what extent are Puerto Ricans different from people from other Latin American countries?

A percentage of pro-statehooders might see themselves as American as anyone from the continental United States. Others believe that Puerto Ricans are different, but as American citizens, Puerto Rican have most of the responsibilities and benefits of any other American citizen. This is definitely an identity conflict that is, in my opinion, common among pro-statehooders.

<u>Ideology and Teaching are not Independent</u>

Eight participants (Arturo, Rosa, Ismael, Teresa, Frances, Hortensia, Gustavo, and Josefina) reported that the political ideology of pro-statehood teachers might influence and inform their teaching practices. The following are quotations from Ismael, Hortensia, Gustavo, Teresa, Josefina, Frances, and Rosa, teachers who believe that ideological/political beliefs do affect statehooders' teaching decisions, including their assessment of the physics textbook they use. Ismael relied on his knowledge of other teachers to form his opinion about the question:

> Yes, I believe so, I am completely convinced about that [the fact that some teachers include their ideological beliefs in their teaching]. I know a lot of colleagues who defend the book quite much.

Hortensia, on the other hand, blame the actual political status (which some people see as ambiguous and temporary) for the way some pro-statehood teachers might be teaching physics:

> Based on the political reality of this country, I think so. A pro-statehood teacher will not be critical at all [of an American textbook] because of the political status we have.

Gustavo presented a more philosophical argument, suggesting that it is almost impossible to act independently of our belief system. He also mentioned that pro-statehooders might believe that the textbook in English is a better option for students:

> In my opinion, I think so. We must see things from a reality perspective. Our beliefs influence on practically all of our activities and our life. A pro-statehood teacher will be less critical of the textbook. Furthermore, a pro-statehood teacher might argue that the textbook should not be in Spanish, but in English.

Teresa also talked about the thick ideological atmosphere that Puerto Rico lives as a possible cause for some teachers to teach high school physics from a pro-statehood stance:

> Yes, based on how things are in this country, definitely. If the textbook is America, they are good for those teachers. They do not consider the fact that we have physics professors, people well qualified, with knowledge, people that are teachers more than professors. People that can be together and work on a [local] textbook and do a good job, because we can do things here as good or better than in other places. Not just the United States, but other places as well.

Josefina made use of the language issue and of the descriptor fanatic, one more time in this section, to acknowledge that some pro-statehood teachers might be less critical of the textbook they use:

> I think that a pro-statehood teacher will be less critical of the textbook compared to teachers who believe in commonwealth or independence. For example, we just receive some books in English. I know that a fanatic pro-statehood teacher might say: 'very well, we have the textbook in English so students can learn English'.

Frances qualified some pro-statehood teachers whose teaching is molded on their ideological beliefs as narrow-minded. However, she also pointed out that teachers with ideological beliefs other than statehood might also be narrow-minded too. I think that the analogy of the horse's blinders is very enlightening:

> Yes, I think that [teachers include their ideological beliefs in their teaching] will not question the textbook as much, pro-statehooders with closed minds. Because you can find both statehooders with closed minds and "independentistas" with closed minds, they see everything with blinders, they have a lens, a glass that make them see things the way they want to see them. Sometimes just because

> something come from the United States they stamp it and say: ‘this is the greatest, an American did this, and this is great. Most statehooders have this type of vision.

Rosa pointed out to a “self-esteem” problem that some pro-statehooders might have. She also mentioned that although education and ideology might not be related in theory, in reality the story is different:

> Unfortunately, I think so. The tendency is to find people who, because of his political ideology and way of thinking, believe that the United States is better, and it is not always that way. When we go to the praxis, even when we do not want to see education politicized, there will be teachers who will reflect his political beliefs to the students.

There was one participant, Eduardo, who did not responded specifically to the research question, arguing that being a foreigner, he do not have all the information required to answer the question properly.

In summary, these teachers believe that pro-statehood teachers have a difficult time teaching physics from an apolitical perspective. Different causes for this phenomenon are proposed, like the political status of the Island, the Puerto Rican culture, the teachers’ attitude toward their ideology, or the fact that our belief system control, to a certain extent, our personal and professional decisions.

Discussion: Interview Question Five

Although the majority of the teachers think political ideology and science education should not be related, the fact that they are a 60% of the sample tells me that there is not a consensual opinion about this topic. The main reasons reported by teachers who believe that ideology and education should not be combined are: (a) political decisions might not always be sound educational decisions, (b) politics and education have disparate goals (the promotion of a status option, versus the well being of the students), and (c) science education is an objective endeavor, while politics are not. In terms of the textbook, the participants' responses suggest that using the ideological lens in evaluating a textbook is not in the best interests of local students.

On the other hand, a group of teachers believe that politics is influencing educational decisions at the teacher level. They argue that our beliefs guide all aspects of our life, including our professional decisions. There are historical reasons that support this practice. Because of our colonial (or post-colonial) relationship with the United States and the role of this country as a world power and economy, some Puerto Rican teachers believe that if the physics textbook come from the United States, it must be excellent, compared to any local effort in producing a local textbook. This mental subordination might still be common among some Puerto Ricans, especially those who believe that the Island should be a state of the Union.

Another explanation for the participants' beliefs that politics and education are related is the example they see from our local government and the Department of Education. With a change in administration, new education officials are appointed, and it is well known that the nominees are usually from the same political party as the government. Also, Puerto Rico's educational philosophy changes (sometimes rather abruptly) with changes in administration.

Something I noticed when analyzing these data was that some teachers gave answers to two slightly different questions: (a) Do you think that a teacher who has a pro-statehood ideology will be less critical of the physics textbook actually used because it was made in the United States? and (b) Do you think that a teacher who has a pro-statehood ideology should be less critical of the physics textbook actually used because it was made in the United States? The teachers' responses suggest that ideology and politics is being combined on some occasions, especially by more right-winged (Eleuterio-type) teachers, but it should not be combined because it might jeopardize their students' learning.

On some occasions, teachers did not give a categorical answer, but were more conditional. Berta, Maria, and Dolores statements in the first part of this section are clear examples of this, when they say that politics and ideology should not relate if the teacher have this or that characteristics. This is also evidence that what happens in reality might be different from what it should theoretically happen, a promising new line of research.

In summary, the majority of the interviewed teachers believe that, as scientists, there should be no relationship between political beliefs and teaching practices for science teachers. They feel that their main objective is to create an adequate environment for students to learn physics. Political evangelization and biased educational decisions based on ideology should not find a place in Puerto Rican schools. Furthermore, these teachers believe that only "Don Eleuterio"-type teachers will try to combine both. On the other hand, a number of teachers argue that the reality is that some teachers do make educational decisions based on their political beliefs, arguing that beliefs guide everybody's actions, including their professional judgment and teaching philosophy.

Findings: Interview Question Six

On the sixth question, teachers were asked: "Do you think that teachers who believe in commonwealth and independence will include more aspects of the Puerto Rican culture in their physics class?" In contrast to the previous question, in which the majority of the teachers say that their ideological/political beliefs are independent of their teaching, in this case most of the teachers (12 out of 18) believed that pro-commonwealth and pro-independence teachers will include components of our local culture, that is, that pro-commonwealth and pro-independence ideologies can be interrelated with physics education without much opposition. These teachers see this inclusion as a natural consequence of being a Puerto Rican teacher, and not necessarily as an ideological or political issue. On the other hand, six teachers still believe that political ideology and teaching should be kept independent of each other. Three teachers provided either no response or unqualified (ambiguous) responses.

Ideology and Teaching are Independent

Here are some quotations from Berta, Dolores, Frances, Virginia, Pablo, and Nicolas, teachers who believe that the teachers' ideological and political beliefs should not affect their teaching decisions. For example, Berta argues that since the prescribed high school physics curriculum does not include aspects of out local culture, teachers should abstain from teaching physics using their pro-commonwealth or pro-independence lens:

> I do not see many [ideological] situations from our everyday lives that can be brought [to the physics class] … Neither the textbook nor the physics curriculum say we should include political issues … the curriculum was not designed to

> include political ideologies or political issues in the classroom. I can see it for a history class, but not for a physics class.

Dolores said that "truly professional" teachers would not let their pro-commonwealth or pro-independence ideology influence their teaching:

> It is possible that [a pro-commonwealth or pro-independence teacher] might be more conscious [about the Puerto Rican society and culture]. Again, if the teacher is truly a professional, I doubt [that ideology and teaching might be combined]. If you are a professional, you must work within your work area, regardless of political matters. Education should be our politics; that should be our political party. You must start from the deficiencies and needs you see in your students. That is basic form me. Which are my students' needs? Under what context we are working?

Frances statements implied that those teachers who include aspects of the Puerto Rican culture into their physics classes are teaching physics from a narrow, insular perspective, when in reality physics teachers should provide universal examples to promote an increased global culture:

> What is the difference between applying physics here or in the United States? It is the same thing. Probably some examples, but they have cares here and there, planes here and there, and even if we do not have the example here, we cannot limit our students to what we have in Puerto Rico only. We must have a broader culture. We cannot teach physics from a narrow perspective. Physics is for everybody, not just for Puerto Rico or the United States, but for Mexico, Italy, or England, it is the same. If people were mature enough [intellectually], there will

> not be any problems in teaching or using a translated book. So what if the textbook is a translation from the United States? It might be a translation from Spain, Mexico, wherever, but the physics is the same, the concepts are the same, wherever we go.

Virginia expressed that politics and education should not be related, although, unlike Frances, she believed that science teachers should make science more contextual:

> I think [politics and education] are independent. They have nothing to do with each other. I think that all teachers who love science must add our context and reality to our teaching, not just in physics but in all sciences … independently of our political ideas, we must live the realities of our country.

Pablo gave a short but straightforward answer to this interview question:

> If I am from a given political party, regardless of which, I will guide my teaching based on how physics should be taught, its level of complexity and the students' academic level.

Similarly, Nicolas' statement was short and precise:

> From my point of view, I do not see that if I belong to a given political party I will add more or less [Puerto Rican culture into the physics class].

In summary, six teachers defended the position that pro-commonwealth and pro-independence ideologies should not be used as a pretext to include aspects of the Puerto Rican culture into the physics class. Various rationales were provided to support their stance including teaching professionalism, the fact that the actual curriculum does not prescribe this inclusion, and the idea that including the local culture in a physics class might be limiting and misleading.

Ideology and Teaching are not Independent

Twelve of the teachers interviewed said that the teachers' pro-commonwealth and/or pro-independence ideology might help them in making the physics class more pertinent to local students by including more aspects of the local culture and context. Evidence to support this statement came from the teachers' expressions. Here are some quotations from teachers who believe that the teachers' pro-commonwealth and/or pro-independence beliefs influence their teaching decisions.

For example, based on her experience, Maria acknowledged that pro-commonwealth and/or pro-independence teachers do include more local examples in their class, but that they do it spontaneously because they want physics to be as real for their students as possible:

> The tendency is affirmative, they [pro-commonwealth or pro-independence teachers] tend to do it [include more aspects of the Puerto Rican culture in their physics classes]. At least, that is my experience. They know what is more pertinent to their students … that is part of their formation, it shows, crop out, shows automatically, they automatically think in the Puerto Rican culture … they bring more pertinent examples.

Cesar believed that pro-commonwealth and/or pro-independence teachers have the knowledge to make deeper connections between physics and the local culture:

> Surely. It is not that they will add more [aspects of the Puerto Rican culture], but they will go deeper into our native culture, our own. For example, instead of calculating the height of the Statue of Liberty, they will calculate the height of a

native tree or a sculpture created by a local author. The topic will be the same [but the example will be local].

Teresa agreed with Cesar in that pro-commonwealth and/or pro-independence teachers know more about Puerto Rico and its culture and context compared to physics teachers from other ideologies. She also mentioned that they might know about local research or local realities that can be easily incorporated into the curriculum:

> I think so, at least I expect so, that they have a more ample concept [of physics and Puerto Rican culture] … [Here in Puerto Rico] we are doing good research work in many [science] areas, that can be incorporated [in the physics class], what is our reality. I think we should work with our reality first … not just in physics … and students will do more with their time, because they see the class as more pertinent.

Josefina agreed with other teachers about the knowledge of both physics and the local culture that pro-commonwealth and/or pro-independence teachers have:

> Of course. I think that, if they could, they would add 100% Puerto Rican examples, with Puerto Rican renowned people, physics teachers, outstanding [local] people in the sciences. I think that a teacher who masters physics well will use many examples from the Puerto Rican culture.

Ismael admits being one of those pro-commonwealth and/or pro-independence teachers who include the Puerto Rican culture into his class. His reason for doing this is that it helps students in their development as Puerto Ricans, not just in the area of science:

> Yes, I think so. I am totally convinced about that, I even do it myself. When I am teaching physics I exhaust all resources to do it [include more aspects of the

> Puerto Rican culture in their physics class] because I believe in the development of the individual as a whole.

Leonardo's experiences and actions in affirming the Puerto Rican nationality and creating meaningful context for his physics students are evident in his statement:

> Definitely yes. The reason is very simple. When you want to affirm your nationality, you find the time to do it. In the context of a class, a teacher projects his ideology. My ideology is to make students aware of the importance of their history, their self-esteem and worth as a nation, so I introduce [in class] a number of examples and contexts that affirm their nationality, their identity … You do it on purpose, because you know that the physics course is not marginal to, but embedded in a context … a person that do not value his nationality, a person that believes that our nationality is less, his tendency is to include [in his physics class] less aspects of the country's history, and use more examples from the culture considered paradigmatic [United States] … Undoubtedly, my experience is that pro-independence colleagues and those pro-commonwealth teachers with a nationalist perspective will tend to reinforce and introduce elements pertinent to our history and culture.

Similarly, Hortensia believe that pro-commonwealth and/or pro-independence teachers have more patriotic consciousness and that it is reflected in how they teach physics:

> We do [include aspects of the Puerto Rican culture in my physics class] because we have more patriotic consciousness, above all. Pro-statehood teachers might have a perspective of Puerto Rican problems or things that impact the country, but teachers who believe in independence have a different way of thinking. I do it

> myself. I do not use examples from things that happen in the United States, but local examples, things that are happening now.

Wanda said that the reason why pro-commonwealth and/or pro-independence teachers might include the Puerto Rican culture into their class is because this might help students in identifying themselves with their culture while learning physics:

> Sure. [Teachers who believe in commonwealth or independence] will bring things related to Puerto Rico [to their classes] so that student identify themselves with their culture.

In his answer, Gustavo was slightly more specific that other teachers, correctly placing pro-commonwealth and pro-independence teachers into separate categories. According to Gustavo, pro-independence teachers are much more prepared to include components of the local culture into the class:

> Definitely. A pro-commonwealth teacher either will leave [the textbook presentation of the content] as is, or will add some cultural aspects. A pro-independence teacher will add much more elements [of the local culture], will make much more changes to the textbook and its contents.

In summary, teachers believed that pro-commonwealth and/or pro-independence teachers might be more prepared to include local cultural aspects into their physics class and are perceived as being more knowledgeable about local examples and situations that can enrich their course.

Discussion: Interview Question Six

On the question of whether teachers who believe in commonwealth and independence will include more aspects of the Puerto Rican culture in their physics class, the teachers interviewed were still divided. On one side, some teachers perceived politics and education as independent, arguing that the professional expertise, and not ideology, should guide teaching, that teachers must focus on the students' needs, and that physics is the same all over the world and should be presented with a global, objective perspective.

On the opposite position, teachers believed that ideology and education are interrelated, mainly as a way to contextualize physics teaching and to create consciousness about the students' nationality, history, culture and identity. Teachers who believe in commonwealth and independence are perceived as more capable of doing this.

The fact that in the last two questions, essentially the same question was asked, but the answers differed depending on the ideological status is very interesting. Although some teachers were firm in their beliefs that politics and educations should be separated, others conditioned their stance on the ideological viewpoint from which the question was presented.

On the other hand, Gustavo brought an excellent point, when he placed pro-commonwealth and pro-independence teachers in two different categories. Based on my experience as a Puerto Rican, I know that the Puerto Rican political reality is more complex, though. Among statehooders there are right-wingers (consistent with the Eleuterio comparison), left-wingers, and centrists. Among the pro-commonwealth group, there are also right-wingers (sometimes those might overlap with left-winged statehooders), centrists, and left-wingers (which sometimes agree with some of the independentist ideas). Among independentistas, there are sectors that do not favor violence as a mean to achieve their ideal and those who prefer armed resistance against the United States.

I think it might be an interesting follow up study to explore this topic deeper. Unfortunately, people in Puerto Rico are very cautious in disclosing their real political beliefs (this was the reason why about 20% of the teachers did not answer the ideology question in the written questionnaire). Interestingly, the evidence from this section suggests that pro-commonwealth and pro-independent teachers might be the best sources of information and knowledge about how to make the high school physics class more contextually and culturally relevant for Puerto Rican students.

Summary of Sixth Chapter

In the previous chapter, the findings and discussions based on the qualitative interview data were presented. Based on the interviewee's response to the first question, it was found that teachers contextualize both their physics content presentation and their teaching methodology to include contextual aspects. This is consistent with quantitative data and data from the short answer questions. In terms of the second question, the reader saw that for most teachers the concepts “context” and “culture” are strongly related. Overall, Puerto Rican teachers believed that it is positive to include the local culture in the physics class, although they might not be able or prepared to do it successfully.

The analysis of question number three showed that teachers have a lukewarm opinion about the book, consistent with previous data. Although for some teachers the book is satisfactory, most were quick in pointing out a variety of suggestions to make a better textbook or modify the existing one. Some of these suggestions included the use of context and cultural relevance. In the next question, the reader saw that, viewed through the lens of the interviewed teachers, students have a negative opinion of the textbook they actually use. The reasons for this were varied but can be classified in two groups: textbook deficiencies and students' knowledge gaps and attitudes.

The analysis of the fifth and sixth question showed that political ideology might be present when teachers make professional decisions although, in theory, the "official" position of the local government is that ideology should not inform classroom decisions. Interestingly, depending on the ideology of a hypothetical teacher, as presented on questions five and six, the teachers' stance about the question changed significantly in favor of pro-commonwealth and pro-independence teachers as promoters of the local culture and values.

In the final chapter, the research questions will be explicitly answered. Also, a discussion about the limitations of the study and possible avenues for further research are included.

CHAPTER 7

CONCLUSION

Overview

In the first chapter it was stated that the purpose of this study was to explore two main topics in relationship to physics education in Puerto Rico. First, whether Puerto Rican high school physics teachers used contextual and culturally relevant strategies in their classroom. Second, what factors influence the willingness of those physics teachers to modify their teaching methodology and physics curriculum so that the physics portrayed in the translated textbooks used in school become contextual and culturally relevant to the Puerto Rican culture.

In order to organize the exploration of those two topics via the use of quantitative and qualitative data, four research questions were proposed:

1. To what extent do Puerto Rican high school physics teachers modify the physics curriculum to make it more contextual and culturally relevant to the student population they attend?
2. To what extent do Puerto Rican high school physics teachers modify their teaching methodology to make it more contextual and culturally relevant to the student population they attend?
3. What factors determine if Puerto Rican high school physics teachers modify the physics curriculum to make it more contextual and culturally relevant to the student population they attend?

4. What factors determine if Puerto Rican high school physics teachers modify their teaching methodology to make it more contextual and culturally relevant to the student population they attend?

In the following chapter the answers to the four research questions will be presented. Also, the limitations of this study and the suggestions for further research will be addressed.

Answer to Research Question One

The first question of this research study was: “To what extent do Puerto Rican high school physics teachers modify the physics curriculum to make it more contextual and culturally relevant to the student population they attend?” Some answers to this question can be found in the quantitative analysis and in the qualitative analysis of short answer and interview question.

Research Question One and the Quantitative Analysis

As the reader might recall, the Textbook Relevance Degree of Change Instrument (TRI) was designed specifically to answer statistically this question. The Likert scale was created so that teachers could evaluate their degree of modification of twenty commonly covered physics topics to make them more contextual and culturally relevant to their students. The selection of the number “1” implied that the teacher did not make any modification in the way they presented the physics concepts discussed in the textbook to account for the characteristics and experiences of Puerto Rican students. On the other hand, the selection of the number “5” implied that the teacher used examples with common materials and familiar situations, applied the physics concepts to problems of local relevance, included components of the Puerto Rican culture in the explanations, and connected the physics concepts with Puerto Rican realities. The instructions for this scale were very detailed about what the extremes of the scale meant.

The analysis of this instrument revealed that the responses ranged from 3.79 on the high side (Forces) to 3.30 on the low side (Gas Laws). The overall mean for the twenty physics topics was about 3.5. These mean values suggest that Puerto Rican high school teachers make noticeable changes in their physics content presentation to make the class more contextual and culturally relevant to the students they serve. These values also suggest that local teachers might not necessarily make contextual and cultural relevance a central philosophical pillar of their modifications to the physics content, otherwise the mean values were expected to be higher than those obtained.

One reason that might determine whether the teachers include context and cultural relevance in their class is their confidence in the subject knowledge they teach. Results from another component of the TRI showed that Puerto Rican physics teachers are confident of their physics knowledge, or at least the physics knowledge they need to teach the course. The mean responses ranged from 4.85 on the high side (Uni-dimensional Motion) to 3.97 on the low side (Mirrors and Lenses). The overall mean for the twenty physics topics was about 4.45. From the 1668 pooled responses, almost nine out of ten teachers indicated being confident of their physics knowledge.

Research Question One and the Qualitative Analysis of Short Answer Questions

Data collected from the short answer questions is helpful in answering the first research question. It was clear that a strong majority of Puerto Rican teachers believe that physics can be taught in a contextual and culturally relevant ways. They argue that students will see and understand the relationship between the physics concepts they study and their daily life experiences, will learn physics in a way that is pertinent and meaningful to them, as opposed to rote memorization of isolated facts, and will learn physics and knowing about their history, culture and society at the same time. Teachers also pointed out that, for contextual and culturally relevant physics teaching to be effective, locally created supplementary content and teaching materials must be available.

Data for the fourth and fifth questions also suggest that Puerto Rican physics teachers are making their physics content presentation more contextual and culturally relevant. An overwhelming majority of teachers incorporate modifications in the physics curriculum to make it more contextual to students. They mentioned specific examples in a variety of contextual scenarios, such as local architecture and homes, automobiles, power systems, local events and places, sports, and toys.

Also, most teachers incorporate modifications in the physics curriculum to make it more culturally relevant to students. In this case, although a number of teachers mentioned examples from topics already mentioned in the contextual question (which suggests the close relationship between context and culture), some teachers provided situations in which the Puerto Rican culture was more evident, for example our technological position, geographical location, history, artifacts, literature, and traditions.

Research Question One and the Qualitative Analysis of Interviews

Based on data gathered from the first interview question, almost all teachers talked about how important it was to contextualize teaching. They also provided examples of contextualization for a variety of physics topics, like vectors, motion in a straight line, free fall, projectile motion, forces, Newton’s laws, waves, heat, engines, and electricity. The variety of physics topics teachers mentioned, from vectors and Newton’s laws to heat and electricity, as well as the use of local events, towns and places are evidence that they contextualize their physics content presentation to take into account their students’ needs and experiences.

Also, data from interview question two showed that teachers believe that a physics course might include components of the Puerto Rican culture. However, not all of them could enunciate specific examples of how these components could be effectively integrated in the class. Teachers were more specific providing contextual examples compared to cultural ones, implying that they are much more familiar with the use of context in physics teaching than with the inclusion of cultural aspects.

In summary, both quantitative and qualitative data provided strong evidence that Puerto Rican high school physics teachers are making changes in the physics content presentation to make it contextual and culturally relevant to their students.

Answer to Research Question Two

The second question of this research study was: “To what extent do Puerto Rican high school physics teachers modify their teaching methodology to make it more contextual and culturally relevant to the student population they attend?” Some answers to this question can be found in the quantitative analysis and in the qualitative analysis of short answer and interview questions.

Research Question Two and the Quantitative Analysis

The research instrument named Teaching Methodology Degree of Change Instrument (TMI) was specifically designed to answer this research question. It also used a Likert-type numerical scale (between 1 and 5) in which teachers evaluated their degree of modification of nineteen commonly used teaching techniques to make them more contextual and culturally relevant to the needs, experiences, and particularities of local students. The selection of the number “1” implied that the teacher did not make any modification in their teaching methodologies to account for the characteristics and experiences of Puerto Rican students. The other extreme of the scale implied that the teacher adapted his teaching methods to include problems and situations of local relevance, used materials and equipment readily available in the community, and included components of the Puerto Rican culture. As with the previous instrument, the instructions for this scale were very detailed about what the extremes of the scale meant so that teachers were informed before answering the TMI.

The analysis of this instrument revealed that the responses ranged from 4.27 on the higher end (Discussion) to 2.80 on the lower end (Guest Speaker). The overall mean for the nineteen teaching techniques was about 3.77. These mean values suggest that Puerto Rican high school teachers make appreciable changes in their teaching methodology to make the class more contextual and culturally relevant to the students they serve. As with the values from the TRI, these values also suggest that local teachers might not necessarily make contextual and cultural relevance a philosophical pillar of their modifications to the teaching methodologies.

Research Question Two and the Qualitative Analysis of Short Answer Questions

Data collected from the sixth short answer question specifically informs the answer to the research question under study. Teachers modify their teaching strategies and techniques in different ways. For example, they mentioned the inclusion of examples and activities that show students how what is learned can be applicable to their daily lives, the selection of different methods and laboratories depending on the topic, and the tailoring of the teaching strategies based on the everyday situations that happen and the learning level of each group. In addition, teachers reported making some modifications to a number of teaching strategies, including laboratories, demonstrations, group work, research projects and audiovisuals.

Research Question Two and the Qualitative Analysis of Interviews

Data from the first interview question suggests that most teachers modify their teaching methodology to make it contextual and culturally relevant, although detailed information about specifically how teachers do it was not available. Examples of this contextualization are the use of newspapers and media to connect current events and physics, the development of laboratories with simple, inexpensive, and locally available materials, and the use of curious stories about physics to address students' misconceptions.

In summary, both quantitative and qualitative data provide evidence that Puerto Rican high school physics teachers are making changes in their teaching methodology to make it contextual and culturally relevant to their students. The strength of the evidence is more obvious in the quantitative component.

Answer to Research Question Three

The third question of this research study was: "What factors determine if Puerto Rican high school physics teachers modify the physics curriculum to make it more contextual and culturally relevant to the student population they attend?" A component of the answer to this question was found in the quantitative data.

Research Question Three and the Quantitative Analysis

The first ten one-way ANOVA tests reported on the statistical analysis (pages 102-117) were designed to determine if any of the independent variables had an effect on the teachers' mean change in physics content presentation to make it more contextual and culturally relevant. Of those, three tests were significant and one test showed a non-significant trend.

The first test showed a significant relationship between the years of experience teaching physics teachers have and the average change in physics content presentation, with particular emphasis on the appreciable difference between novice teachers (less than five years of experience) and veteran teachers (21 – 25 years of experience). This test suggests that physics teachers do make changes to their physics content presentation, regardless of years of experience teaching physics, although there is a significant trend for veteran teachers to make more changes relatively to novice teachers.

The second test found a significant relationship between the number of students physics teachers have in their groups and the mean change they make to the physics content presentation to make it more contextually and culturally relevant. This test suggests that teachers with more students in their classes are relatively less likely to make their physics content presentation contextual and culturally relevant compared to teachers who have less students per group.

The third test revealed a significant relationship between whether teachers believed they have freedom to select and modify their teaching methodology and the reported mean changes in their physics content presentation to make it contextually and culturally relevant. This test suggests that teachers who believe they have no freedom to change their teaching methodologies are less likely to make their physics content contextual and culturally relevant. On the other hand, teachers who believe they have some or all freedom to decide their teaching methodologies are more likely to make changes in the physics content presentation.

The fourth test found no significant relationship between the participants' academic preparation in physics and the mean change in physics content presentation to make it more contextual and culturally relevant. However the data suggest that teachers tend to make more changes in physics content presentation as they become more knowledgeable of the subject.

It is clear that, based on the quantitative data, there are three or possibly four factors that determine if Puerto Rican high school physics teachers modify the physics curriculum to make it more contextual and culturally relevant to the student population they serve: (a) years of experience teaching physics, (b) class size, (c) whether teachers believed the Department of Education gave them freedom to select and modify their teaching methodology, and (d) academic preparation in physics.

Research Question Three and the Qualitative Analysis of Short Answer Questions

Data gathered from one of the questions from this type of qualitative data were very valuable in answering this question. Slightly more than half of the teachers believed that the textbook provided by the Puerto Rico Department of Education is not appropriate to the students they have. Teachers believed that the physics content presentation in the textbook do not parallel their students' needs, experiences, and daily lives, that the textbook does not present examples that show Puerto Rican culture and context, and that its translation is poor and confusing. The textbook's translation and incompatibility with the local culture and context might be a factor that move teachers to change their physics content presentation to make it more contextual and culturally relevant.

Interestingly, looking at the statement from teachers who are not in the majority is very informative and can lead to additional factors that might move teachers to change (or as in the next cases, not change) their physics content presentation to include context and cultural relevance. A factor extracted from this type of data might be the teachers' beliefs of the nature of science. Some teachers expressed that they do not make changes to their physics content to make it more contextually and culturally relevant because they believe that physics is a universal, objective science that should not reflect regional particularities or biases. A statement from one of the teachers is excellent to stress this point: "Physics concepts should not be adjusted to a particular culture; it is the culture that must adjust to the concepts."

Another factor might be that the teachers want to make high school physics a preview of what students will see when they go to college and take physics. These teachers believe that high school physics should be taught as it will be taught in college. As a consequence, the addition of contextual and culturally relevant aspects might be perceived by teachers as useless in dealing with college physics, limiting their students' perspective and focus.

Research Question Three and the Qualitative Analysis of Interviews

Interview data provided important data about factors that might influence teachers in their decision of modifying the physics content presentation to make it contextual and culturally relevant. Just as in the case with data from short answer questions, one of the factors that seem to determine whether physics teachers change the physics content presentation is the teachers' beliefs about the nature of science. Statements from Maria and Pablo in which they argued that physics laws were the same for everybody and could be taught in any culture suggest that they may see as unnecessary the regionalization of physics teaching.

Another factor that could be extracted from interview data was the textbook's deficiencies in making physics pertinent to Puerto Rican students. About half of the teachers were very critical of the textbook approach, content, translation, and generic nature. As a consequence, some teachers use it as a reference, exercise bank, or dictionary. Others do not use it at all, preferring to teach their students in more contextual and culturally relevant ways. Teachers were clear that a better textbook was needed to engage students in relevant examples and applications of physics. Interestingly, not all agreed that a locally made textbook might be the answer.

A third factor might be that students are arriving at the physics course with significant knowledge gaps in mathematics and reading, making the work of physics teachers more challenging. The data do not imply whether this factor might make teachers modify or not modify the physics content presentation. On one side, Leonardo mentioned that, given the students' lack of basic mathematics and reading skills, he decided not to approach his course from a mathematical standpoint. He used simple, everyday examples to create relevance without making the course too difficult.

An opposite perspective was provided by Ofelia and Hortensia. Ofelia decided to spend a considerable amount of time re-teaching mathematics and providing students with some conceptual definitions and simple examples. She believed that students (especially those interested in taking the college admission test) would be better served by focusing more on remedial math and less on physics. As a consequence, she might not make their physics content presentation more contextual and culturally relevant. Hortensia stated that she limited the physics applications she presented mostly to the students' vocational interests and not to Puerto Rican culture or context necessarily.

A fourth factor might be the teachers' ideological beliefs. About 12 of the teachers said that ideology and education were independent when asked whether a teacher with a pro-statehood ideology might be less critical of the physics textbook because it was made in the United States. However, only six teachers maintained their stance after the ideology of the teacher was changed to a pro-commonwealth and pro-independence one. Teachers believed that pro-commonwealth and pro-independence colleagues might be more capable of modifying the physics content presentation to make it pertinent to Puerto Rican students.

In summary, the factors that might influence teachers in their decision of making the physics content presentation more contextual and culturally relevant are: (a) years of experience teaching physics, (b) class size, (c) whether teachers believed the Department of Education gave them freedom to select and modify their teaching methodology, (d) academic preparation in physics, (e) textbook's translation and incompatibility with the local culture and context, (f) teachers' beliefs of the nature of science, (g) the vision of the high school physics course as a prequel of college physics, (h) students' significant knowledge gaps in mathematics and reading, and (i) teachers' ideological (status options) beliefs.

Answer to Research Question Four

The fourth question of this research study was: "What factors determine if Puerto Rican high school physics teachers modify their teaching methodology to make it more contextual and culturally relevant to the student population they attend?" Part of the answer to this question was found after the analysis of the quantitative data.

Research Question Four and the Quantitative Analysis

Univariate tests 11-20 reported on the statistical analysis (pages 117-128) were designed to determine if any of the independent variables had an effect on the teachers' mean change in teaching methodology to make it more contextual and culturally relevant. Of those, two tests were significant and one test showed a non-significant trend.

The eleventh test showed a significant difference in the change in teaching methodology to make it contextually and culturally relevant for male and female physics teachers. Male physics teachers make relatively more changes to their teaching methodology compared to their female counterparts. Although a difference in gender dynamics at various levels of their professional preparation and life as teachers might be associated with the significant result, more research might be required to determine the social reasons behind this result.

The twelfth test revealed a statistical relationship between the teachers' mean changes to their teaching methodologies to make them more contextual and culturally relevant and their academic preparation in physics. This result suggests that teachers who have taken more physics courses make more changes to their teaching methodologies compared to teachers who are less academically prepared in this subject area, that is, teachers who are not prepared enough in physics might not be able to see the necessity of making the strategies more relevant to Puerto Rican students. As I said elsewhere, this blurs the division between content knowledge and teaching knowledge, providing supporting evidence for what is known in the literature as pedagogical content knowledge (Shulman, 1987) or the different ways teachers and subject matter specialists perceive and interpret the knowledge in their discipline.

The thirteenth test suggests a trend toward increasing changes in teaching methodologies to make them contextual and culturally relevant as the evaluation moved from excellent, to good, to average, to deficient/poor in the textbook quality independent variable. This result might indicate that teachers who perceive the textbook as excellent tend to be guided by it more often and do not see the necessity of making their teaching methodology more pertinent. At the same time, teachers who perceived the textbook as average or deficient might tend to complement the textbook's perceived deficiencies with more pertinent teaching methods.

It is apparent that, based on the quantitative data, there are two or possibly three factors that determine if Puerto Rican high school physics teachers modify their teaching methodology to make it more contextual and culturally relevant to local students: (a) gender, (b) academic preparation in physics, and (c) perceived textbook quality.

Research Question Four and the Qualitative Analysis of Short Answer Questions

Although teachers reported modifying their teaching strategies and techniques, specifically mentioning some of them, there is not enough detailed data to pinpoint accurately the different factors that might make teachers modify their teaching methodology to make it contextual and culturally relevant. Some of the factors that are implicitly portrayed as important in this decision-making process seem to be the teachers' philosophy of education and the availability of materials and equipment.

According to the data in the sixth short interview question, teachers tend to prefer traditional, teacher-centered methods of teaching (e.g., laboratories, demonstrations, audiovisuals, lecture) to more student-centered methods (e.g., learning cycle, open-ended questions, and hands-on activities). This preference suggests that the teachers' educational philosophy might prevent them from using contextual and culturally relevant teaching methods that take control out of the hands of the teacher and place it into the students'. Also, teachers might be limited in the teaching methods available because they lack the appropriate materials and equipment. Indeed, most high schools do not even have a physics lab or adequate/secure storage areas for physics equipment.

<u>Research Question Four and the Qualitative Analysis of Interviews</u>

As with the short answer data, the lack of equipment and materials was cited by some teachers as a factor that neutralizes their efforts in contextualizing their teaching methodologies. For example, Arturo specifically talked about how the school system is slow in respond to the teachers' request for equipment. Leonardo also mentioned the lack of materials and equipment, especially for studying waves and electricity.

Another factor that might hinder teachers from making their teaching methodology more pertinent is the negative student attitude toward school in general and science in particular. My impression after interviewing some of the teachers was that, despite considerable efforts to present an interesting and informative class, they were disenchanted with their students' lack of interest and motivation. This might move physics teachers to apply minimum effort in their class by using teacher-centered methods, with little or no changes to make them more pertinent.

I believe that the teachers’ ideological beliefs might be a factor that informs whether they make their teaching methodology contextual and culturally relevant. As I said in the answer to research question three, teachers believed that pro-commonwealth and pro-independence colleagues might be more capable of modifying the physics content presentation to make pertinent to Puerto Rican students. Also, closed-minded pro-statehood teachers are perceived as making some educational decisions based on their ideology, for example, being less critical of the textbook because it originated in the United States.

In summary, the factors that might influence teachers in their decision of making their teaching methodology more pertinent are: (a) gender, (b) academic preparation in physics, and (c) perceived textbook quality, (d) teachers' philosophy of education, (e) availability of materials and equipment, (f) negative student attitude toward school in general and science in particular, and (g) teachers' ideological beliefs.

Limitations of the Study

Given the characteristics of the study, several shortcomings are apparent. In terms of the quantitative analysis, the sample size of 92 individuals was too small for more powerful tests, like two-way analysis of variance for all two variable combinations, to be performed. Unfortunately, replications of this study might face the same challenge given the number of public school physics teachers Puerto Rico has. The only way to somewhat overcome this problem is to include all physics teachers from public and private schools in the study. However, the time, effort, and resources to include all physics teachers might be very high. It took me eight weeks to visit schools (twice on most occasions) and meet teachers. Including all teachers might take close to a year, including time to pass through the bureaucratic obstacles that some private schools pose.

A second limiting factor was that the sampling was not random. In this case, a random sample might have implied visiting schools far away from each other, resulting in lower sample size. Also, since the number of physics teachers per school varied (from one to four teachers), random sampling of schools might have resulted in selecting schools with only one physics teacher, another factor contributing to lower sample size. This limiting factor was overcome somewhat by including as many municipalities as possible. In fact, almost 50% of the municipalities in Puerto Rico were visited, including some of the larger cities, like Bayamon, Guaynabo, Ponce, Caguas and Mayaguez.

Another limiting factor for the quantitative analysis was that a single form of some of the instruments was available, creating a possible item order effect, discussed on page 95 of the statistical analysis section. To minimize this, future replications of this research might include several instruments forms where the items (physics topic or teaching methodologies) are placed at random.

A fourth limiting factor might be the level of thought and effort teachers spend on reflecting before answering the research instruments. Some of the teachers filled the questionnaires in my presence, asked questions, and were very thorough. Others sent the questionnaires by mail so there was no evidence of this aspect.

In terms of the qualitative data component, other limitations of the study are obvious. First, the researcher’s skills in qualitative research are not as refined as the quantitative ones. This might have prevented the researcher from asking more relevant, in-depth questions and obtaining more detailed answers from participants, that might have provided the thick, rich descriptions needed for superior qualitative research.

A second limitation was the limited time available to carry out field interviews. All interviews were performed during the teachers' planning period or after class. This time constraint prevented the researcher from going into detail about each of the interview questions. Also, teachers were interviewed from different municipalities, so travel between one town and another took precious time.

Another limitation might be the selection of structured interviews to collect one of the qualitative data components. Although structured interviews provided the researcher with a parallel structure from which all teachers' responses were analyzed, the shortcoming is their rigidity.

A fourth limitation has to do with the translation of interviews from Spanish to English. Although the data analysis was performed in Spanish, the quotes were translated into English. The researcher not being a professional translator, there is the chance that the translations might not be precise, although a lot of effort was put into translating the main ideas behind the statements. Another disadvantage of analyzing the data in Spanish was that it was extremely difficult for non-Spanish speakers to monitor the data analysis. As a consequence, alternate explanations to the same data might exist if other researchers examine it.

The fact that I am a Spanish-speaking, Puerto Rican physics teachers who has opinions about the textbook and ideas about public education, politics, society and culture in the Island turned out to be both advantageous and disadvantageous. On one hand, I have the knowledge to understand the educational, social, linguistic, and cultural specificities that a foreign researcher would overlook. However, I might have unavoidably designed the research and analyzed the collected data without the objectivity that a project like this requires. As I said before, researchers with different experiences and knowledge about the Puerto Rican culture, society, politics, and education might develop alternate explanations based on the same data.

Implications

Some of the findings of this dissertation must be interpreted in terms of the theories that informed it. For example, the complex historical and political relationship between Puerto Rico and the United States and its impact on Puerto Rican education stated by researchers such as Solis (1994), Eliza-Colon (1989), and Negron de Montilla (1990) was clearly present throughout this study, especially in its qualitative component. Although my purpose was not to examine the interactions between ideology, politics, and educational decisions, it was evident that they are still present fifty years after the establishment of the Commonwealth and should be studied further.

Also, this study turned out to very consistent with Court's (1972). In both cases, curricular influences from the United States (PSSC materials then, physics textbook now) were introduced without a detailed study of their possible cultural implications. They were just assumed to be good. In addition, current physics teachers and their counterpart from the 1970's were critical of the introduced materials. In Court's study, teachers stated that the translations, where available were literal rather than culturally relevant, that the PSSC curriculum was too difficult for the population they served, and that students became disinterested with the physics class. Similar criticism to the textbook's translation and its level of difficulty, in particular its mathematical approach, was mentioned by a number of the teachers, both in the short answer questions and in the interviews.

In terms of the way Puerto Rican physics teachers presented their understanding of learning contextualization, their ideas were consonant with those on the literature, in particular Georgoudi (1986), and Cole and Griffin (1987). Although some aspects of contextual teaching and learning were evident, such as learning related to meaningful problems and the appreciation of students' diverse life contexts (College of Education, University of Georgia, 2000), other aspects of standard contextual teaching were not observed. For example, the participant's responses suggest a teacher-centered learning structure, which is not consistent with student mental engagement, student active participation, learning in multiple settings, or the use of interdisciplinary knowledge. Contextualization must be carefully engineered for it to have a positive impact on students (Tharp, 1982). In my opinion, what was observed was some teacher-centered attempts at contextualization, used mostly as a pedagogical and motivational tool, but that does not seem to be rooted in current theories of how students learn and does not seem to have a significant impact in student academic achievement.

In this study I observed Puerto Rican teachers teaching mostly Puerto Rican student in Puerto Rico (as opposed to similar situations that might occur in the continental United States). However, the fact that there is a strong influence in education from the United States, in particular the use of a translated version of an American physics textbook, suggests that we have a multicultural situation in science teaching on the Island. Depending on a variety of factors, this might or might not be explicitly recognized by Puerto Ricans. The particular multicultural situation in Puerto Rico is not completely consistent with the perception of multicultural education stated by researchers such as Grant (1994), Nieto (1992) and Banks (1993).

Banks (1993) propose five dimensions of multiculturalism. Of those five, only the use of examples, data, and information from a cultural perspective to present a subject area was apparent in the research data. Other dimension, such as prejudice reduction, equity pedagogy, or implicit cultural assumptions, were not observed. This inconsistency, along with the differences in ethnicity relations between the United States and Puerto Rico and the use of imported curriculum materials, suggest that an aspect of multiculturalism somewhat different from Banks' model is going on in Puerto Rico. Not being an anthropologist, I leave the description and analysis of this apparent importation-induced multiculturalism to future researchers.

Suggestions for Further Research

Given the exploratory nature of this study, many questions were left unanswered. In general, further research should be done to replicate the findings from questions one and two, that is, confirm whether Puerto Rican physics teachers are making their physics content presentation and teaching methodologies contextual and culturally relevant. Special emphasis should be placed on the teachers providing specific, detailed evidence of how and why they make changes in these two areas.

Also, future research might focus on specific cultural aspects of Puerto Rico in the physics class, since the importance and relevance of this component was not completely detailed in this study. A more complex endeavor might be to explore the relationship between the concepts “culture” and context”, and if these concepts are differentiable or not.

This study identified a number of factors that might influence the teachers’ decision of making their physics content and teaching methodology more pertinent. Each one of these factors can be explored in a different study. An abbreviated list of some research questions that include the factors discovered in this study are:

- Specifically why and how the years of experience teaching physics a teacher has influence his/her decision of making their physics content and teaching methodology more pertinent to Puerto Rican students?
- Specifically why and how class size influence the teachers’ decision of making their physics content and teaching methodology more pertinent to Puerto Rican students?
- What other ways can be used to measure the teachers’ academic preparation in physics and how these compared in terms of why and how this variable influences the teachers’ decision of making their physics content and teaching methodology more pertinent to Puerto Rican students?
- Are locally created, culturally based physics textbooks the answer to the students’ lack of interest in physics? Some chapters can be created so that students compare both types of printed media.
- Specifically why and how the teachers’ beliefs of the nature of science influence their decision of making their physics content and teaching methodology more pertinent to Puerto Rican students?

Although I have a personal preference for quantitative studies, I acknowledge that these types of questions might be better informed using case studies or other types of qualitative perspective.

Summary of Seventh Chapter

In the previous chapter each of the research questions that originally informed the study were answered by using data from quantitative and qualitative sources. It was found that Puerto Rican physics teachers do make changes to their physics content presentation and teaching methodology to include context and cultural relevance. Also, a number of factors that might influence teachers in their decision of making or not making contextual and culturally relevant changes were identified. Finally, the limitations of the study, from both quantitative and qualitative standpoints, were considered and some suggestions for further research were proposed.

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APPENDICES

APPENDIX A

HIGH SCHOOL PHYSICS TEACHER'S DEMOGRAPHICS SURVEY (ENGLISH)

Instructions: Please complete the following information about yourself, the school you are working with, the students you have, the physics courses you are teaching, and the textbook you are using.

1. Gender: ( ) male ( ) female

2. Age:
( ) 21-25 years old ( ) 26-30 years old ( ) 31-35 years old
( ) 36-40 years old ( ) 41-45 years old ( ) 46-50 years old
( ) 51-55 years old ( ) 56-60 years old ( ) 61 + years old

3. Years of experience as a teacher:
( ) 1- 5 years ( ) 6-10 years ( ) 11-15 years
( ) 16-20 years ( ) 21-25 years ( ) 26-30 years
( ) 30 + years

4. Years of experience as a PHYSICS teacher:
( ) 1- 5 years ( ) 6-10 years ( ) 11-15 years
( ) 16-20 years ( ) 21-25 years ( ) 26-30 years
( ) 30 + years

5. Number of physics courses taken at the college level (undergraduate and graduate). If you took a year-long physics course, count it as two semester courses (1 course = 1 semester).
( ) 0- 2 courses ( ) 3- 5 courses
( ) 6- 8 courses ( ) 9-11 courses
( ) 12-14 courses ( ) 15-17 courses
( ) 18+ courses

6. School type: ( ) public ( ) private

7. School setting: ( ) urban ( ) suburban ( ) rural

8. School size: ( ) small ( ) medium ( ) large

9. Group size for an average physics course:
( ) 0-10 students ( )11-20 students
( ) 21-30 students ( ) 30 + students

10. How much freedom do you think the school system gives you to decide the physics curriculum?
( ) no freedom at all ( ) some freedom ( ) absolute freedom

11. How much freedom do you think the school system gives you to decide the presentation of the physics content?
( ) no freedom at all ( ) some freedom ( ) absolute freedom

12. Please indicate the high school physics textbook that you are using now:
title and year ______________________________
author(s) ______________________________
publishing co. ______________________________

13. How do you evaluate the quality of the textbook you are using?
( ) excellent ( ) good ( ) average ( ) deficient ( ) poor

14. Taking into consideration your political/ideological beliefs with respect to the relationship between Puerto Rico and the United States, please write an “X” for the statement that best represents your opinion:

_____ Puerto Rico should keep its actual political relationship with the United States

_____ Puerto Rico should become a state of the American Union

_____ Puerto Rico should become an independent country from the American Union

APPENDIX B

HIGH SCHOOL PHYSICS TEACHER'S DEMOGRAPHICS SURVEY (SPANISH)

Instrucciones: Por favor provea la siguiente información sobre usted, la escuela en la que trabaja, los estudiantes que tiene a cargo, los cursos de física que enseña y el libro de texto que usa.

1. Género: ( ) masculino ( ) femenino

2. Edad:
( ) 21-25 años ( ) 26-30 años ( ) 31-35 años
( ) 36-40 años ( ) 41-45 años ( ) 46-50 años
( ) 51-55 años ( ) 56-60 años ( ) 61 + años

3. Años de experiencia como maestro:
( ) 1- 5 años ( ) 6-10 años ( ) 11-15 años
( ) 16-20 años ( ) 21-25 años ( ) 26-30 años
( ) 30 + años

4. Años de experiencia como maestro de FISICA:
( ) 1- 5 años ( ) 6-10 años ( ) 11-15 años
( ) 16-20 años ( ) 21-25 años ( ) 26-30 años
( ) 30 + años

5. Cantidad de cursos semestrales de física acquiridos a nivel postsecundario. Si tomó un año de física, cuéntelo como dos cursos semestrales (1 curso = 1 semestre).
( ) 0- 2 cursos ( ) 3- 5 cursos ( ) 6- 8 cursos
( ) 9-11 cursos ( ) 12-14 cursos ( ) 15-17 cursos
( ) 18+ cursos

6. Tipo de escuela: ( ) pública ( ) privada

7. Ubicación de la escuela: ( ) zona urbana ( ) zona suburbana ( ) zona rural

8. Tamaño de la escuela: ( ) pequeña ( ) mediana ( ) grande

9. Número de estudiantes en una clase promedio de física:
( ) 0-10 estudiantes ( ) 11-20 estudiantes
( ) 21-30 estudiantes ( ) 30 + estudiantes

10. ¿Cuánta libertad para decidir el CURRICULO de física cree usted que el sistema escolar le provee?
( ) ninguna libertad ( ) alguna libertad ( ) libertad total

11. ¿Cuánta libertad para decidir el METODO DE PRESENTACION del currículo de física cree usted que el sistema escolar le provee?
( ) ninguna libertad ( ) alguna libertad ( ) libertad total

12. Por favor, indique qué libro de texto de física usted está utilizando actualmente:
título y año ____
autor(es) ____
casa publicadora ____

13. Como usted evaluaría la calidad del libro de texto que usted esta usando?
( ) excelente ( ) buena ( ) promedio ( ) deficiente ( ) pobre

14. Tomando en consideración sus creencias políticas e ideológicas en cuanto a la relación entre Puerto Rico y los Estados Unidos, por favor escriba una “X” al lado de la alternativa que mejor represente su modo de pensar:

_____ Puerto Rico debe mantener su relación política actual con los Estados Unidos.

_____ Puerto Rico debe convertirse en un estado de la Unión Americana.

_____ Puerto Rico debe convertirse en un país independiente de la Unión Americana.

_____ Otra opción (explique) ____

APPENDIX C

TEXTBOOK RELEVANCE DEGREE-OF-CHANGE INSTRUMENT (ENGLISH)

Instructions: Please indicate the degree to which you modify the physics curriculum of your lessons, based on the main topics of the high school physics textbook, to make them more relevant to your students. Use the scale at the center to indicate that degree of modification by circling the appropriate number. In this scale, "1" refers to no change at all in the textbook's discussion of physics contents and problems, and "5" refers to maximum modification in the textbook's discussion of physics contents and problems to accommodate the needs and particularities of your students. Numbers in between refers to variations between the two extremes. Please circle N/A if you do not teach that topic on your class. In addition, please write on the space available at the right how confident you are in your knowledge about these physics topics. Circle “A” for extremely confident, “B” for very confident, “C” for confident, “D” for not very confident, and “F” for not confident at all.

Topics	**no change**				**complete change**		**degree of confidence**				
Mathematical Relationships	1	2	3	4	5	N/A	A	B	C	D	F
Motion in a Straight Line	1	2	3	4	5	N/A	A	B	C	D	F
Graphical Analysis of Motion	1	2	3	4	5	N/A	A	B	C	D	F
Forces	1	2	3	4	5	N/A	A	B	C	D	F
Vectors	1	2	3	4	5	N/A	A	B	C	D	F
Motion in Two Dimensions	1	2	3	4	5	N/A	A	B	C	D	F
Momentum and its Conservation	1	2	3	4	5	N/A	A	B	C	D	F
Work, Energy, and Simple Machines	1	2	3	4	5	N/A	A	B	C	D	F
Energy and its Conservation	1	2	3	4	5	N/A	A	B	C	D	F
Thermal Energy	1	2	3	4	5	N/A	A	B	C	D	F
Gas Laws	1	2	3	4	5	N/A	A	B	C	D	F
States of Matter	1	2	3	4	5	N/A	A	B	C	D	F
Sound	1	2	3	4	5	N/A	A	B	C	D	F
Light	1	2	3	4	5	N/A	A	B	C	D	F
Reflection and Refraction	1	2	3	4	5	N/A	A	B	C	D	F
Mirrors and Lenses	1	2	3	4	5	N/A	A	B	C	D	F
Static Electricity	1	2	3	4	5	N/A	A	B	C	D	F
Current Electricity	1	2	3	4	5	N/A	A	B	C	D	F
Series and Parallel Circuits	1	2	3	4	5	N/A	A	B	C	D	F
Magnetic Fields	1	2	3	4	5	N/A	A	B	C	D	F

APPENDIX D

TEXTBOOK RELEVANCE DEGREE-OF-CHANGE INSTRUMENT (SPANISH)

Instrucciones: Por favor indique el grado en que usted modifica el currículo de física en sus clases, basado en los principales tópicos cubiertos en el libro de texto, para hacerlos más relevantes a sus estudiantes. Utilice la escala al centro para clasificar dicho grado de modificación y circule el número correspondiente. En esta escala, "1" implica que usted no cambia nada en los conceptos de física discutidos en el texto para acomodar las necesidades y características particulares de sus estudiantes, y "5" implica un máximo grado de modificación en los conceptos de física discutidos en el texto para acomodar las necesidades y características particulares de sus estudiantes. Números intermedios representan diferentes matices dentro de las dos opciones principales. Si usted no cubre en clase alguno de los siguientes temas, favor de circular la opción N/A. Además, utilice la escala a la derecha para indicar cuán seguro está usted de sus conocimientos en la enseñanza de los tópicos presentados. Circule "G" si usted esta completamente seguro, "H" si está parcialmente seguro, "I" si está indeciso, "J" si está parcialmente inseguro, y "K" si esta completamente inseguro.

Tópicos	**no cambio**				**máximo cambio**		**grado de seguridad**				
Relaciones Matemáticas	1	2	3	4	5	N/A	G	H	I	J	K
Movimiento en Línea Recta	1	2	3	4	5	N/A	G	H	I	J	K
Análisis Gráfico de Movimiento	1	2	3	4	5	N/A	G	H	I	J	K
Fuerzas	1	2	3	4	5	N/A	G	H	I	J	K
Vectores	1	2	3	4	5	N/A	G	H	I	J	K
Movimiento en Dos Dimensiones	1	2	3	4	5	N/A	G	H	I	J	K
Momentum y su conservación	1	2	3	4	5	N/A	G	H	I	J	K
Trabajo, Energía y Máquinas Simples	1	2	3	4	5	N/A	G	H	I	J	K
Energía y su Conservación	1	2	3	4	5	N/A	G	H	I	J	K
Energía Termal	1	2	3	4	5	N/A	G	H	I	J	K
Leyes de los Gases	1	2	3	4	5	N/A	G	H	I	J	K
Estados de la Materia	1	2	3	4	5	N/A	G	H	I	J	K
Sonido	1	2	3	4	5	N/A	G	H	I	J	K
Luz	1	2	3	4	5	N/A	G	H	I	J	K
Reflección y Refracción	1	2	3	4	5	N/A	G	H	I	J	K
Espejos y Lentes	1	2	3	4	5	N/A	G	H	I	J	K
Electricidad Estática	1	2	3	4	5	N/A	G	H	I	J	K
Corriente Eléctrica	1	2	3	4	5	N/A	G	H	I	J	K
Circuitos en Serie y en Paralelo	1	2	3	4	5	N/A	G	H	I	J	K
Campos Magnéticos	1	2	3	4	5	N/A	G	H	I	J	K

APPENDIX E

TEACHING METHODOLOGY DEGREE OF CHANGE INSTRUMENT (ENGLISH)

Instructions: Please indicate the degree to which you modify the presentation of the physics concepts to make them more relevant to your students. Use the scale to your right to indicate that degree of modification by circling the appropriate number. In this scale "1" refers to no change at all in your teaching techniques to accommodate the needs, experiences, and particularities of your students, and "9" refers to maximum change in your teaching techniques to accommodate the needs, experiences, and particularities of your students. Numbers in between refers to variations between the two extremes. Please circle N/A if you do not use that particular teaching technique in your class.

Teaching Technique	**no change**				**complete change**	
Audiovisual aids, use of	1	2	3	4	5	N/A
Brainstorming	1	2	3	4	5	N/A
Case study	1	2	3	4	5	N/A
Collaborative learning	1	2	3	4	5	N/A
Creative writing	1	2	3	4	5	N/A
Debate	1	2	3	4	5	N/A
Demonstration	1	2	3	4	5	N/A
Discussion	1	2	3	4	5	N/A
Drill & Practice	1	2	3	4	5	N/A
Group projects	1	2	3	4	5	N/A
Guest speaker	1	2	3	4	5	N/A
Homework	1	2	3	4	5	N/A
Individual projects	1	2	3	4	5	N/A
Inquiry-based teaching	1	2	3	4	5	N/A
Laboratory	1	2	3	4	5	N/A
Lecture	1	2	3	4	5	N/A
Questioning	1	2	3	4	5	N/A
Role play	1	2	3	4	5	N/A
Tutorials	1	2	3	4	5	N/A

APPENDIX F

TEACHING METHODOLOGY DEGREE-OF-CHANGE INSTRUMENT (SPANISH)

Instrucciones: Por favor indique hasta qué grado usted modifica su metodología educativa en la enseñanza de los conceptos de física para hacerla más relevante a sus estudiantes. Utilice la escala de la derecha para clasificar dicho grado de modificación y circule el número correspondiente. En esta escala, "1" implica que usted no cambia su metodología de enseñanza para acomodar las necesidades y características particulares de sus estudiantes, y "5" implica un máximo grado de cambio en su metodología de enseñanza para acomodar las necesidades y características particulares de sus estudiantes. Números intermedios representan diferentes matices dentro de las dos opciones principales. Si usted no utiliza alguna de las siguientes técnicas de enseñanza, favor de circular la opción N/A.

Técnica de Enseñanza	**no cambio**				**máximo cambio**	
Audiovisuales	1	2	3	4	5	N/A
“Brainstorming”	1	2	3	4	5	N/A
Estudio de Casos	1	2	3	4	5	N/A
Aprendizaje Cooperativo	1	2	3	4	5	N/A
Escritura Creativa	1	2	3	4	5	N/A
Debate	1	2	3	4	5	N/A
Demostraciones	1	2	3	4	5	N/A
Discusión	1	2	3	4	5	N/A
Ejercicios y Problemas (en clase)	1	2	3	4	5	N/A
Proyectos en Grupo	1	2	3	4	5	N/A
Conferenciante Invitado	1	2	3	4	5	N/A
Asignaciones	1	2	3	4	5	N/A
Proyectos Individuales	1	2	3	4	5	N/A
Enseñanza por Descubrimiento	1	2	3	4	5	N/A
Laboratorio	1	2	3	4	5	N/A
Conferencia	1	2	3	4	5	N/A
Preguntas	1	2	3	4	5	N/A
Dramatización	1	2	3	4	5	N/A
Tutoriales	1	2	3	4	5	N/A

APPENDIX G

TEXTBOOK RELEVANCE DEGREE-OF-CHANGE QUESTIONNAIRE (ENGLISH)

Instructions: Please read carefully the following paragraphs.

Culturally relevant teaching

Culturally relevant teaching empowers students intellectually, socially, emotionally, and politically by using cultural referents to impart knowledge, skills, and attitudes. Culturally relevant teaching uses school, home, and community culture to counteract not seeing one's history, culture or background represented in the textbook or curriculum.

Culturally relevant teaching not only addresses student achievement but also helps students to accept and affirm their cultural identity and to develop a critical perspective. Culturally relevant teaching must meet three criteria: (a) an ability to develop students academically, (b) a willingness to promote cultural competence, and (c) the development of a sociopolitical consciousness. It is designed to encourage teachers to ask about the nature of the student-teacher relationship, the curriculum, schooling, and society.

Contextual learning

Formal education is an institution that was created in a social, cultural, political and economic context. As a consequence, learning is continually shaped by sociocultural contexts. Context can be defined as "… The events preceding, occurring with, and following the cognitive task; context so conceived includes all factors that might influence the quality of time spent on the task, ranging from the arrangement of a lesson in the curriculum, to the relation of the classroom to the school as a whole, and to the relation of the school to the community of which is part."

Researchers argued that contextual learning works by modifying the cognitive task itself by using "familiar scripts", making available otherwise unused cognitive resources that help students in dealing with a difficult problem or with new material. They also maintained that reorganization of lesson format to attend specifically to linguistic and cultural variations can promote educational excellence.

Based on the information you just read, answer the following questions.

1. Do you think that physics concepts can be taught in a contextual, culturally relevant way for Puerto Rican students? Why or why not?
2. Do you think that teaching physics concepts in a contextual, culturally relevant way can improve Puerto Rican students academic achievement in physics? Why or why not?
3. Do you think that the textbook you are using is appropriate to the context and cultural background of Puerto Rican students? Please explain your answer.
4. How do you incorporate modifications in the physics curriculum to make it contextual to your students? Please provide a few examples.
5. How do you incorporate modifications in the physics curriculum to make it more culturally relevant to your students? Please provide a few examples.
6. How do you modify your teaching strategies and techniques to help your students learn the physics content better?

APPENDIX H

TEXTBOOK RELEVANCE DEGREE-OF-CHANGE QUESTIONNAIRE (SPANISH)

Por favor lea cuidadosamente los siguientes párrafos.

Enseñanza cultural-relevante

La enseñanza cultural-relevante permite a los estudiantes un desarrollo intelectual, social, emocional y político mediante la combinación de las características culturales de los estudiantes y la enseñanza de conocimientos, destrezas y actitudes. La enseñanza cultural-relevante usa la cultura del hogar, la escuela y la comunidad para contrarrestar la ausencia de nuestra historia, cultura y experiencias en algunos libros de texto y el currículo de ciencias.

La enseñanza cultural-relevante no solamente promueve el aprovechamiento académico de los estudiantes, sino que ayuda a los estudiantes a aceptar y afirmar su identidad cultural, a la vez que desarrolla una perspectiva crítica. La enseñanza cultural-relevante esta basada en las siguientes premisas: (a) la habilidad de promover el aprovechamiento académico, (b) la disposición de promover la identidad cultural, y (c) el desarrollo de una conciencia sociopolítica. Este concepto está diseñado para fomentar que los maestros reflexionen acerca de la relación estudiante-alumno, el currículo, el sistema educativo y la sociedad en general.

Aprendizaje contextual

Las instituciones educativas fueron creadas en un contexto social, cultural, político y económico. Como consecuencia, el aprendizaje es moldeado constantemente por estos contextos. "Contexto" se define como "los eventos que anteceden el proceso enseñanza-aprendizaje, que ocurren durante el proceso enseñanza-aprendizaje y que siguen después del proceso enseñanza-aprendizaje. Estos eventos incluyen todos los factores que pueden influenciar la calidad del tiempo que se ocupa en la enseñanza-aprendizaje como, por ejemplo, el arreglo y organización de una lección en el currículo, la relación entre el currículo y la escuela y la relación entre la escuela y la comunidad de la que es parte."

Los investigadores educativos argumentan que el aprendizaje contextual trabaja mediante la modificación de los conceptos presentados en el proceso enseñanza-aprendizaje con situaciones y ejemplos familiares a los estudiantes. Esta modificación promueve el uso de recursos intelectuales adicionales que ayudan al estudiante a comprender nuevos conceptos y conceptos difíciles. Los investigadores educativos también argumentan que la reorganización del formato y presentación de los conceptos con el fin de atender las variaciones culturales y linguísticas de los estudiantes, pueden promover la excelencia educativa.

Basado en la información que acaba de leer, conteste las siguientes preguntas (use papel adicional si necesita proveer mas detalles)

1. ¿Cree usted que los conceptos físicos pueden ser enseñados de una manera contextual y cultural-relevante a los estudiantes puertorriqueños? ¿Por qué o por qué no?
2. ¿Cree usted que si los conceptos físicos se enseñan de una manera contextual y cultural relevante los estudiantes puertorriqueños pueden aumentar su aprovechamiento académico? ¿ Por qué o por qué no?
3. ¿Cree usted que el libro de texto que actualmente usa es apropiado al contexto y la cultura de los estudiantes puertorriqueños? Explique su respuesta.
4. ¿Cómo usted incorporaría cambios a los conceptos físicos para hacerlos afines con el <u>contexto</u> de los estudiantes puertorriqueños? Provea algunos ejemplos.
5. ¿Cómo usted incorporaría cambios a los conceptos físicos para hacerlos afines con la <u>cultura</u> de los estudiantes puertorriqueños? Provea algunos ejemplos.
6. ¿Cómo usted modificaría sus estrategias y técnicas de enseñanza para ayudar a que los estudiantes aprendan mejor los conceptos físicos?