POWER, CURRICULUM MAKING AND ACTOR-NETWORK THEORY: THE CASE OF PHYSICS, TECHNOLOGY AND SOCIETY CURRICULUM IN BAHRAIN

By

Ahmed Mohammed Rafea

B.Sc., McGill University, 1981
Dip. (Educational Technology), McGill University, 1985
M.Ed. (Secondary education), McGill University, 1987

A Thesis Submitted in Partial Fulfillment of the
Requirements for the Degree of
Doctor of Philosophy
in
The Faculty of Graduate Studies
(Department of Curriculum Studies)

July, 1999

We accept this thesis as conforming
to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

July, 1999

In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the head of my department or by his or her representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Department of Curriculum Studies (CUST)

The University of British Columbia
Vancouver, Canada

Date 16-07-1999

DE-6 (2/88)

Abstract

This study is an exploration of power and how it is manifested in curriculum making. More specifically, it examines the responses of actors in the physics curriculum network to a proposal to introduce a Physics, Technology and Society (PTS) version of physics in the secondary schools of Bahrain. The proposal to introduce PTS created a point of entry to explore issues of power in curriculum making and highlight some of the strategies that actors used to maintain or reconstruct power relations. Data collection consisted of three phases during which interviews were conducted with Ministry of Education personnel, university physicists and physics educators, physics teachers, university and secondary students, and industry representatives. Interviews focused on responses to: 1) an example of PTS materials (Phase One); 2) the views of other actors (Phase Two); and 3) the Ministry's decision to proceed with piloting of the PTS materials (Phase Three). From Actor-Network Theory (ANT), the responses of the various actors can be understood in terms of their efforts to maintain or reconstruct the school physics network. Furthermore, the study shows that curriculum making can be seen as a networking process in which the success of the various actors is linked to the size and strength of the networks they are able to mobilize to their position. From this point of view, the Ministry, drawing primarily on local networks, is seen to move cautiously in response to the extensive international network which university physicists maintain and which provides high status pathways for students.

Power relations are network effects, and in exploring them one gains a better appreciation of the network that constructed them. Therefore, this study illuminates aspects of the school physics network, revealing its constituent actors, the strength of the links between some of its actors, and the establishment of the curriculum as an obligatory passage point. Conclusions pertaining to the nature of this network and the strategies employed by actors in constructing and maintaining power relations as they engaged in negotiating the physics curriculum are drawn. Finally, these conclusions have implications for policy in curriculum change and, more specifically, for addressing issues of power and problems that emerge when fundamental changes in secondary science are introduced.

Table of Contents

List of Tables

Acknowledgments

The assistance, support and encouragement I received from many people were indispensable in the preparation of this thesis. Foremost among those whose help I wish to acknowledge is my program and research supervisor, Professor P. James Gaskell, for his endless support, dedication and generosity. He has been a mentor and an inspirer and made my studies at UBC an enjoyable experience. I am also grateful to my other supervisory committee members, Dr. Walter Werner and Dr. Stephen Petrina for their patience, support and valuable criticisms. In particular, I must thank Dr. Werner whose generosity with his time, experience and personal resources were invaluable throughout my program.

I should also express my gratitude to my colleagues and friends in the Ministry of Education in Bahrain, the wonderful students, the physics teachers, and university professors who took part in this study. Without their sincerity, thoughtfulness and enthusiasm this thesis could not have been written. It was an interesting and a rewarding experience for me to engage with them in negotiating school physics. However, I hope that they would find my interpretations plausible and forgive me if I have interpreted some of their ideas in a way they themselves might not have done.

I am deeply indebted to my family and friends in Bahrain whose kindness and support made my journey of studying abroad possible. In particular, I wish to thank my mother who constantly made sacrifices to help me achieve

what I have achieved, and my brother-in-law Mansoor, who has been a father and an extraordinary teacher, and has inspired me since I began to learn. Also, my gratitude to my friend Mohammed Al Zayani is especially great. His encouragement and continuous help while I was away from home made my learning journey possible and smooth.

It is customary in acknowledgment to say a few words about the dedication of one's wife and children. Yet I believe that words may not do justice to convey the debt I owe to my wife Minas, whose support and patience have been very significant in helping me pursue my goals. Her criticisms and insights were also valuable in the preparation of this thesis. This thesis is dedicated to her and to our four daughters, Eman, Amal, Shereen and Merriam, with whom we have been blessed.

Finally, I wish to gratefully acknowledge the financial support I have received from the Ministry of Education in Bahrain and the encouragement that many of its personnel provided throughout my program of study at UBC. They had faith and invested a great deal in me over the years, and I hope to be able to pay them back by helping them achieve the wonderful goals they have set for our children.

CHAPTER 1

INTRODUCTION

Over the last two decades science educators have argued that science education should be redirected, and sometimes redefined, in order to reflect better the rapid changes occurring in society, science and technology (Hart & Robottom, 1990; Hurd, 1986; Rubba, 1987; Solomon & Aikenhead, 1994; Yager & Tamir, 1995). This new direction called for greater emphasis on technology and social issues related to science. As a result, a new kind of science education has emerged, one with a science, technology and society (STS) emphasis. The STS movement has gained momentum over the past decade and, though it originated in England and North America, is well received in many countries over the world. Its success, however, has been more in terms of acknowledgment in the science education literature and support from some policy makers than in terms of putting this innovation into practice. As pointed out by Bybee (1991) and Kummar and Berlin (1993), there has been little progress with respect to implementing STS programs in schools. This is what Bybee refers to as "the policy-practice gap" in STS science education.

The policy-practice gap is evident in the upper secondary level where disciplinary or subject-based curricula dominate schools. Although STS courses have been developed for students at this level, such courses are often intended for non-science students or as a "supplement" to—and not as a

replacement for— existing physics, chemistry and biology courses; for example, Chemistry in Community (CHEMCOM) (Ware, Heikkinen & Lippincott, 1987) and the SATIS project (Hunt, 1988). Fensham (1988b) argued that because so much has been said about STS education and its importance, whereas so little has been achieved in practice, proponents need to "face up to the fact that there are powerful constraints operating in relation to physics and chemistry and STS that need to be understood" (p. 376). These "powerful constraints," Fensham further maintained, are sociological in nature and require sociopolitical resolutions. School politics and power are acute in the school curriculum, particularly in areas "that play a critical role in subsequent levels of education or careers selection" (p. 375).

Sociopolitical analyses of curriculum are inevitably concerned with interests and power (Bush, 1986; Carlson, 1996; Hoyle, 1988). This study explores issues of politics and power in the context of introducing an innovation in the school physics curriculum in Bahrain. The process of innovation was initiated within the existing actor-network by proposing a physics, technology and society (PTS) curriculum as an alternative version of school physics. The PTS innovation was represented by three exemplary units adopted from the Netherlands' PLON project in physics (Eijkelhof & Kortland, 1988; Eijkelhof & Lijnse, 1988), and was proposed by the researcher who is also a member of the ministry of education. Proposing change in the secondary physics curriculum, arguing for it and consulting others who are

concerned are part of my duties as a physics curriculum specialist at the ministry.

One avenue for understanding issues of politics and power in curriculum making is through the writings of Bernstein (1971), Young (1971, 1973) and Goodson (1987, 1988). The contributions of these authors provide a significant starting point to think about school knowledge and curriculum from socio-historical perspectives. In fact, a major change in how school curriculum is perceived and analyzed springs from the sociology of education. In particular, the publication of *Knowledge and Control*, a collection of essays edited by Michael Young (1971), was regarded as providing a 'new' direction in the sociology of knowledge focusing on school curriculum (Whitty, 1985). The main approach taken by the contributors to the volume, says Young in the introductory chapter, is that "they do not 'take' for granted the existing definitions of educational reality, and therefore do 'make' rather than 'take' problems for sociology of education." Moreover, these authors are "inevitably led to consider...'what counts as educational knowledge' as problematic" (p, 3). An important conclusion arising from this sociological research is the notion that school knowledge and subjects (their content and forms) can be viewed as socially and historically constructed (Goodson, 1987, 1988; Englund, 1985) and, therefore, should be considered as problematic rather than given. The sociological account of school knowledge focused on domination and control and, therefore, put the emphasis on the activities of dominant interest groups in society at large.

Goodson (1987) took the sociological perspective developed by Bernstein and Young further by showing that the process of developing and organizing school subjects is more complex than suggested by these and other sociologists. He contended that school subjects are constructed by subject communities, where a subject community is seen as "comprising of shifting network of subgroups, segments or factions" (1987, p. 25). His approach shifted the focus of analysis from domination by external agents to conflicts and interests within a subject community.

The separation between subject community or within-subject groups and society at large (e. g., class, gender, race, economic, etc.) in the analysis of school subjects and curriculum change is unnecessary and, in fact, could be misleading. In other words, there is no need to assume that focusing the analysis on either within-subject groups or larger social factors should necessarily exclude the other. The study of school physics in British Columbia (Rowell & Gaskell, 1987) is an illustrative example of the significance of including groups other than those identified within the subject community to account for curriculum change. The study revealed the possibility of promoting and accepting "alternative versions of school physics," but also illustrated the complexity of the task and the significance of taking into consideration factors at both the macro and micro levels. Rowell and Gaskell showed how a disciplinary school physics was introduced in 1964, and how it declined 15 years later, making way for alternative versions. The authors provided an account of this change in terms of the "tensions" between

secondary school physics teachers and university physicists, on the one hand, and the changing social, economic, educational and scientific climate, on the other. Throughout this period, university physicists maintained their position on the need to preserve the disciplinary nature of school physics and affirmed its purpose as preparatory for further studies in the subject. However, this position was eventually challenged by physics teachers as well as other groups from outside the subject community who, together, responded "to the needs of a diverse clientele, rather than to a need to preserve the 'integrity' of the discipline" (p. 98).

Although Rowell and Gaskell's study was framed within the sociological perspective of the times, it can be seen to question the stability of the power of the dominant group (physicists) and the separation between subject community and other communities. Another approach that accommodates these challenges explicitly in its framing of power as an effect rather than a cause and which dissolves boundaries between micro and macro, inside and outside, is actor-network theory.

Actor-Network Theory (ANT) (Callon, 1986, 1987, 1991; Callon & Law, 1997; Latour, 1986, 1987, 1988, 1991, 1993, 1996, 1997; Law, 1986, 1991,1992, 1994, 1996) provides another way to explore and understand curriculum making and change. It is particularly adaptable to investigate how controversies and conflicts are resolved. ANT was originally developed by researchers within the social studies of science and has achieved a respectable position in that field. However, as Roth and McGinn (1997) point

out, although ANT has been successful within science and technology studies, it has not been widely used in educational research. Nevertheless, some interesting and successful research in education has recently emerged that employs an ANT perspective (Fountain, 1998; Gaskell & Hepburn, 1998; Gaskell, 1994; Hepburn, 1996; Nespor, 1994; Roth, 1996; Roth & McGinn, 1998). Curriculum making or change is an area where, I believe, ANT can provide a useful framework for investigating the fate of innovations as a process of constructing or maintaining networks.

To provide an account of the development of scientific knowledge and technological artefacts, actor-network theorists study science and technology *in the making* as opposed to ready-made science and technology. They follow scientists and engineers as they involve human and non-human elements to establish networks. The present study employs actor-network theory as a framework to explore *curriculum and power in the making.*

1.1 The Study

This study is an exploration of power and how it is enacted and manifested from the perspective of ANT within the context of physics curriculum making in Bahrain. More specifically, this study examines the responses of actors within a school physics network to a proposal to introduce a physics, technology and society (PTS) version of physics in the secondary schools of Bahrain. Data were collected during three phases through interviews with

ministry of education personnel, university physicists and physics educators, physics teachers, university and secondary students, and industry representatives. Interviews focused on responses to: 1) examples of PTS materials (in phase one); 2) the views of other actors (in phase two); and 3) the ministry's decision to proceed with a piloting of some PTS materials (in phase three). The focus of my analysis is on the responses of these actors with the purpose of answering the following questions.

Focus question

How is power manifested in the school physics actor-network in Bahrain?

Research questions

1. What are the elements of the school physics actor-network in Bahrain?
2. How does school physics link the various actors to their goals?
3. How is the PTS innovation negotiated?

The first research question assumes that secondary school physics can be viewed as an actor-network and as such attempts to describe its constituent elements or actors. From the perspective of ANT, these elements are heterogeneous in the sense that they comprise human and non-human actors. Furthermore, in this actor-network, these elements appear as black boxes (Latour, 1987) or simplified networks (Callon, 1986). That is, they are unproblematic and taken for granted by actors who mobilize them in their practice. The challenges brought by the PTS innovation and the negotiation of

its validity by a member of the ministry (myself) disturbed the status quo in school physics and allowed these black boxes to be opened.

The second research question deals with the strengths of the links between actors and the school physics curriculum. By exploring the views of the actors with regards to the PTS innovation and their responses to other actors' views, the relative strength of their links to the physics curriculum can be assessed. No prior assumptions were necessary at this stage regarding these links. The analysis of the responses of these actors determined what aspects (or elements) of the curriculum these actors were linked to and the strengths of these links.

The term "link" refers to a relationship or attachment between actors. A link between actors may be social, physical, or spiritual, it may be strong or weak, and it applies symmetrically to human and non-human actors, just like the term actor itself. To give an example from Latour (1991, p. 108), a key may be attached to a weight by a metal ring just as a hotel manager is attached to his keys and wants the customers to return them to the front desk before they leave the hotel. In this example, the metal ring constitutes the link between the key and the weight where as the manager's desire to keep the keys constitutes his link to the keys. While the former may be called "physical," the latter may be called "emotional" or "financial." Furthermore, both links are considered strong to the extent that they would withstand the test of attempting to break them. In actor-network analysis, the focus is on the strength (and not so much the nature) of the links between actors,

because that would determine the extent to which their relationships and, consequently, the overall performance of the network, will hold when challenged.

The third research question deals with the innovation itself as restructuring the network. The focus here is on the PTS innovation and the decision made by the ministry to pilot some PTS materials. The purpose of this question was to see the extent to which the innovation and the network were modified in the course of the negotiation.

Underneath the description of the network—the elements, the links between the elements, and the modification of the PTS innovation—is a larger, more subtle issue of power relationships. Power is a central issue in all conflicts and controversies over curriculum change. ANT is well suited to the study of the roles played by various actors in constructing and attributing power relations because power is considered as a property of the actor-network rather than as external to it. By following the story of the PTS innovation and answering the three research questions, I also provide an account of the construction and attribution of power in a school physics actor-network.

1.2 Significance and Contributions of the Study

The outcomes of this study have implications for policy formation and theory relating to secondary science curriculum, particularly from a perspective that incorporates the sociology of knowledge and the politics of

curriculum. This study, however, is distinctive in at least two ways. First, it is conducted within a centralized educational system operating in a uniformly religious and authoritarian society. A study of curriculum change, which gives attention to the sociology of knowledge and the politics of curriculum, is rare in such a context, one where the issue of power as a cause or effect becomes particularly significant. In essence, this study represents both a "unique or extreme" and a "revelatory case" (Yin, 1994) in which the researcher had the opportunity to investigate curriculum change in a situation previously inaccessible to investigation. To extend existing theorizing of school subjects and curriculum change, which is largely bound to Western societies, to this unique context is an important contribution of this study. Further, most of the literature on STS education focuses on Western societies and very little research has been conducted in societies similar to Bahrain. The few studies conducted in some parts of the Arab world (e. g., Mattar, 1994; Selim, 1993) were quantitative, focusing on surveys and text-book analyses, and did not explore how STS was conceptualized, or the extent to which it could compete with disciplinary sciences in secondary schools.

Second, the interviews with a variety of participants elicited their views around concrete PTS materials. The introduction of these materials represented a major perturbation in the status quo of the physics curriculum. Using concrete units of study, rather than a general description of PTS, brought a sense of immediacy and 'reality' to the situation that encouraged

respondents to be as critical and forthcoming as possible when expressing their views.

Finally, this study shows ways in which ANT can be used to theorize about curriculum change and issues of power in the curriculum. In particular, by exploring the limits of earlier theorizing about school curriculum and showing ways in which actor-network theory can overcome these limitations, this study makes its own theoretical contribution.

1.3 Organization of the Chapters

Chapter 2 describes the theoretical framework used in analyzing the data, and that underlies the research questions. Chapter 3 presents the research methodology, whereas each of Chapters 4, 5, and 6 deals primarily with one of the research questions. Chapter 4 outlines the elements of the physics actor-network in Bahrain by focusing on the physicists' efforts to maintain the current network; Chapter 5 presents the responses of secondary physics teachers and university students to the PTS innovation, and explores how they are linked to the school physics; Chapter 6 focuses on the ministry's decision regarding the PTS innovation and their efforts to reconstruct the school physics actor-network. Finally, Chapter 7 provides conclusions, implications, and suggestions for further research.

CHAPTER 2

THEORETICAL FRAMEWORK: POWER IN ACTOR-NETWORK THEORY

> Power is surely one of the most contentious and slippery concepts in sociology. Used, re-used and endlessly abused, it is not surprising that there are many who believe that it should be dropped altogether from the vocabulary of the discipline. (Law, 1991, p. 165)

This chapter describes the theoretical framework that I use in the study. It focuses on the issue of power, and introduces the concepts needed to understand and discuss this issue within the context of curriculum making or change. I draw upon actor-network theory, particularly the contributions of Bruno Latour (1986, 1987, 1991, 1993, 1996, 1997), Michel Callon (1986, 1987, 1991, & Law, 1997), and John Law (1986, 1991, 1996). ANT is based on what these theorists call the "sociology of translation" which has been particularly useful in understanding the development of science and technology and the role they play in structuring and constituting power relationships. The same theory, I argue, is helpful in understanding power in curriculum making once the curriculum is seen as an actor-network.

This chapter is organized into four sections. I begin by briefly reviewing and discussing several notions and theories of power. This section highlights some of the major issues pertaining to power, and points out some of the limitations of existing approaches to power. Next, I discuss power in

curriculum making. More specifically, I highlight the significance and limitations of some current understandings of "power" in curriculum making. Third, I discuss ANT's approach to analyzing power, and, finally, conclude by arguing that it is a useful framework for exploring power in curriculum making.

The discussion in the first section, which primarily draws upon selected power theorists in the social sciences (e.g., Barnes, 1988; Fiske, 1993; Foucault, 1977, 1980; Lukes, 1974, 1986; Wartenberg, 1990; 1992b), serves two purposes. First, it provides a context for discussing and analyzing power in curriculum. Scholars who emphasize power in curriculum employ, whether implicitly or explicitly, similar "notions of power" and often "enroll" the same theorists that I discuss in this section. Second, it provides a background against which ANT's approach to power can be contrasted in order to clarify the similarities and differences between ANT and alternative approaches to power.

2.1 Notions of Power

There is an extensive literature pertaining to power in the social sciences (e.g., Barnes, 1988; Boulding, 1989; Dyrberg, 1997; Fiske, 1993; Hindess, 1996; Law, 1986, 1991, 1996; Lukes, 1974, 1986; Olsen, 1970; Rose & Miller, 1992; Wartenberg, 1990, 1992a). However, as soon as one explores selections from this literature, the complexity and ambiguity of the concept of power becomes evident. Analysts have employed a diversity of views to deal

with power. Each view, depending on the assumptions made, chooses to deal with a particular aspect of power. Some authors (e.g., Dahl, 1986; Weber, 1970, 1986) assumed, explicitly or implicitly, conflict and competitiveness and, consequently, focused on questions pertaining to power such as, who can get what? Who can control and affect whom? Others (e.g., Arendt, 1986) assumed cooperation and common goals and, consequently, were concerned with the question of "who can secure the achievement of collective goods?" (Lukes, 1986, p. 12). Indeed, it is not clear, at times, if these theorists are talking about the same phenomenon when they talk about power. In my view they are not, and this, in part, is the reason for the ambiguity and confusion. Currently, there is a disagreement among theorists of power about many fundamental questions, such as whether power is beneficial or harmful, whether it can be possessed and stored, whether it must be seen as intended or both intended and non-intended, and whether it is assigned to individuals or groups. All these issues remain unsettled. In brief, not only do theorists disagree on their analyses of power but, above all, on what power is.

In contemporary discourses of power, it is possible to identify two broad "notions" of power: "power over" and "power to" (Dyrberg, 1997; Hindess, 1996; Law, 1991; Wartenberg, 1990). These notions, however, are not only different approaches to analyze power, they also rest on two meanings for power that many theorists have attempted to keep separate. This separation, in my view, accounts in part for the confusion and ambiguity surrounding many power analyses. The first, "power over," represents one mainstream

meaning of the term power which is used to refer to instances where a particular individual or group exercises power over another in a manner contrary to the interests of the latter (Lukes, 1974, p. 27). This conceptualization of power also lies at the basis of the use of terms like "domination" and "control" by educators. In this context, power (that is, "power over") becomes a means to dominate others. Barnes (1988, p. 6) noted two aspects of this approach to power. First, it is always defined within a context of relationships between individuals; the power attributed to a particular actor is "indeed a property of the social relationships" in which the actor participates. The second aspect of "power over" is that "the power of the individual is manifest in its effects upon others—in their compliance, whether willing or reluctant, with the will of the power-holder." To illustrate, consider the following definition of power given by Dahl (1957, pp. 202-3): "A has power over B to the extent that he can get B to do something that B would not otherwise do" (cited in Barnes, 1988, p. 6). Both the relational aspect of power and its effect were stressed by Dahl (1986, p. 46) when he wrote: "The closest equivalent to the power relation is the causal relation. For the assertion 'C has power over R', one can substitute the causal relation, 'C's behavior causes R's behavior'."

In contrast to this notion of power, note the following three definitions:

> [Power is the] ability to do or act. (The Oxford Dictionary of Current English, 1992, p. 699)

> Social power is the added capacity for action that accrues to individuals through their constituting a distribution of knowledge and thereby a society. (Barnes, 1988, p. 57)

> Power corresponds to the human ability not to act but to act in concert. (Arendt, 1986, p. 64)

The key words in these definitions are "ability" and "capacity," and they are emphasized by authors who subscribe to a second notion of power, namely "power to." Theorists who adopted this notion treated power as a productive, enabling phenomenon and largely as positive (Law, 1991).

Compared to the mainstream notion, "power to" differs in three respects. First, the term power stands for an ability that an actor has independently of whether that ability is used or even realized. Second, this notion of power need not be relational because it is a property of a particular actor. Finally, defined as such, power need not be confined to humans; non-human actors may have the ability to act, or have "power to," although in general social scientists have confined the term to human agents. Interestingly, these aspects are also consistent with our everyday use of the term power as, for example, when we talk about the power of a car or a machine. A car's engine might be considered powerful, and that would remain true even if the car is parked.

Part of the disputes among theorists has been with regards to which of these two notions should be prioritized in social analysis. Wartenberg (1990, pp. 27-28) argued that

> In so far as social theory has as one of its objectives the understanding of the nature of human beings' control over

> another in society as a means of justifying the role or criticizing the role of such control, social theory will have to adopt the concept of power-over as one of its fundamental concepts. There is simply no other concept that is able to subsume the variety of forms of social control and influence under one rubric.

For Wartenberg, "power over" with its emphasis on control and use to describe domination is more appropriate to problematize existing social hierarchical relationships. Similarly, Lukes (1974, p. 31) limited the use of the term power to "power over" when he criticized authors who focused on

> the locution "power to", ignoring 'power over'. Thus power indicates a 'capacity', a 'facility', an 'ability', not a relationship. Accordingly, the conflictual aspect of power— the fact that it is exercised over people— disappears altogether from view.

For the purpose of this study, it is irrelevant to engage in this particular dispute. Rather, with Law (1991), I think there is no need to assume that accepting either notion should necessarily exclude the other. In fact, like Law (1991) and to some extent Barnes (1988), I think both could be used because capacity (emphasized in "power to") and relations (emphasized in "power over") are inseparable. Indeed, power theorists such as Foucault and Arendt, while working within the notion of "power to" still emphasized the significance of relationships in describing power, as I will show shortly. While this analysis suggests that both notions of power entail relationships, Dyrber (1997, p. 8), on the other hand, notes that "all notions of power entail 'ability'." The point, therefore, is not whether we should focus on relationships or the ability to act,

for both ideas will be important in the context of this study and within actor-network theory. The key issue has to do with the overall conceptualization of power itself, particularly in terms of issues like "power storage" and whether power is a cause or an effect. The remainder of this section is devoted to exploring these issues as a lead to ANT's conceptualization of power.

One of the obvious problems with most theories of power, especially within the "power over" mainstream, is their unidirectional characteristic. By focusing on the "dominating" agent, these theories underemphasize the role played by the other "subordinate" agent in giving rise to the power relation. Fay (1987) drew attention to this problem when he argued that "power must be dyadic." He maintained that the existence of a power relation is the responsibility of both the "powerful" and the "powerless," and unless the role of the latter is recognized, little can be done to change that relation.

> Something as crucial in social life as power must involve the activity of those being led or commanded as much as those leading or commanding. *Power must arise out of the interaction of the powerful and powerless*, with both sides contributing something necessary for its existence. Power must be dyadic. (Fay, 1987, p. 120, my emphasis)

Although Fay (1987) began by assuming the existence of a hierarchical power relation between the agents involved in the power relation, his conception recognized power as an outcome of such relation rather than causing it. Furthermore, "interaction" is a key word here, because without it the terms "powerful" and "powerless" become meaningless. This is an

important point and, in fact, is the basis of Latour's (1986, 1987) approach to power elaborated later in this chapter.

Hannah Arendt (1986) also emphasized the role played by actors other than those who are considered "powerful." She did not see power as a commodity possessed by those conceived as "powerful," but as an achievement gained by being able to speak and act on behalf of the collective group. In this respect, we can note that those who speak and act on behalf of the collective group do not do so by virtue of "possessing" power to begin with; rather, being able to represent the collective is what we describe as power in this context. As Arendt (1986, p. 64) put it:

> Power is never the property of an individual; it belongs to a group and remains in existence only so long as the group keeps together. When we say of somebody that he is 'in power' we actually refer to this being empowered by a certain number to act in their name. The moment the group, from which the power originated to begin with...disappears, 'his power' also vanishes.

Arendt's theory of power bears some similarities with ANT. First, the notion of who speaks on behalf of whom is fundamentally crucial in the translation model suggested by Latour and Callon (to be discussed in the next section). However, while Arendt (1986) is only concerned with the (human) actors directly involved in a given relation or discourse, ANT would also include those actors who are not immediately present or directly participating, but nonetheless are represented by the participating actors. Second, her notion that power belongs to the group and remains in existence only as long as the

group stays together also suggests that power is the outcome of the collective group involved in a particular set of relationships. Again, this is also consistent with ANT's claim that power is a result of a (temporarily) stable network. However, ANT extends the population of this group (or network) to include both human and non-human participants and views power relations as an outcome of this collective rather than what holds it together.

Wartenberg's (1992b) theory of "situated power" deserves to be explored in some detail because it offers a significant improvement over the previous conceptions of power. In particular, it includes the role played by actors who are not directly present or involved in the instance being described as a power relation, and therefore it rectifies a shortcoming in the existing approaches to power. To begin with, Wartenberg rejected the notion of "dyadic power" which he noted has been an accepted assumption by many social theorists. He was particularly critical of the "localization of power in a sphere of existence made up of two social agents who constitute the central actors in the power relation itself" (p. 79). Wartenberg correctly noted that the main problem with this theorizing is that it ignored the fact that such power relations exist "as a result of the actions of agents who do not themselves figure in explicitly in the power dyad itself" (p. 80). Therefore, an understanding of a particular power relation is not possible without highlighting the role played by those "external" actors or what he called the "social others" in constituting that relation. Accordingly, Wartenberg proposed the notion of "situated power" which was specifically aimed at emphasizing this role. "Situated power" stresses that a

given power relation is itself situated in a context of other social relations through which it is actually constituted as a power relation.

Wartenberg applied his conception of "situated power" to a specific example: the power relation between a teacher and her student. His analysis, while illuminating, illustrated the shortcomings of his theorizing. In this example, he explored how "situated power" can help us understand the "power of a teacher over" his or her student. He focused on the role that grading plays in the constitution of this relation and asked: "How is a teacher constituted as having power over her students by virtue of the fact that she grades them?" To answer this question, Wartenberg first argued that conventional theories that do not analyze the situation beyond the classroom level fail to account for the power of the teacher over his or her student. He maintained that such power is not the result of the teacher's actions, such as lowering the students' grades or requiring them to do extra work, as traditionally assumed. Alternatively, he suggested:

> According to the situated conception of power, one needs to move beyond the classroom itself in order to gain an adequate understanding of the power of a grade, for the teacher's power over the student is constituted by the actions of social agents peripheral to the central dyad. The question that needs to be clarified is precisely how the actions of these "social others" constitute the relationship between the central actors as a power relationship. (Wartenberg, 1992b, p. 83)

In attending to the last question, he drew attention to the possible actions of parents, school principals, post secondary institutions, and the workplace. The actions of these "agents peripheral" to the teacher-student relation

depend upon the grade that a student receives; for example, because of a low grade, a student may be punished by his or her parents, denied access to a particular university or program, expelled from school, not offered a job in a particular firm, and so forth. In general, then, students' realization of their future plans depends on the actions of these actors, which in turn depends on the grade they receive. Wartenberg then concluded that these familiar facts cannot be accommodated within dyadic conceptions of power which ignored the presence of, and the roles played by, social agents peripheral to the teacher-student power relation. "Situated power," on the other hand,

> acknowledges that power relationships are constituted by the presence of social agents peripheral to the central power dyad and whose treatment of the disempowered agent is regulated by certain features of the empowered agent's relation to that agent. It posits a structure of social mediation that is essential to the constitution of social power relationships, for without the "cooperation" of social others with the "intent" of the teacher's grading, the student would not be harmed by the low grade. (Wartenberg, 1992b, p. 84)

The concept of "situated power" provided some insights into the complexity of power relations, and suggested some improvement by involving actors beyond those 'directly' engaged in a particular relation. It is not, however, without problems. The first is general and is related to how non-human actors are dealt with in the analysis. In the teacher-student relationship, "grade" obviously appears as a significant actor— it is an actor in the sense that it acts in certain ways, such as by influencing the actions and decisions of those "social others." And as such, "grades" shape, in part,

not only the student-teacher relationship but also the relationships of students with other actors beyond the classroom. Wartenberg even seemed to endow grade with power as, for instance, when he referred to the "power of grade" in the earlier quote. In spite of all this, Wartenberg concluded that "it is obvious that the grade, being by nature a sign, does not have an adverse effect on the well-being of the student." Grades, as I show in this study, shape the assessment used in physics classroom, the content of the curriculum emphasized, and the teaching practices.

Another problem with "situated power" is how the relationship between the "central" and the "external" agents is analyzed. In the example cited, this relationship was presented in a manner that downplayed the goals and interests of the students and teacher involved. In fact, as some research conducted within the ANT perspective (e.g., Roth & McGinn, 1998) has shown, the interests of many students have been translated into maintaining the practice of grading; achieving high grades is a route to achieving one's goals. Teachers also have many reasons for maintaining such practice. The point here is that one must involve equally all the actors and explore how consideration of their various interests and goals eventually leads to creating and maintaining a given relationship. In this example, it is not solely, as Wartenberg claimed, "the cooperation of social others with the intent of the teacher's grading" that allowed the teacher to have power over students, for without the cooperation of many actors, including the students, teachers and grades, such a relationship would not exist at all. The insight provided by

Wartenberg by viewing this relation within a broader "social context" will be extended in ANT; in the latter, power relationships will be viewed within a network of interwoven human and non-human actors.

It is important to note that as we moved along from Fay's dyadic conception of power, Arendt's notion of representing a collective group, to Wartenberg's "situated power" we are gradually involving more actors (although so far only humans) and paying more attention to the activities and actions of these various actors. This move, although still limited, enabled us to see power as mobile and dynamic. The limitation, however, still remained of accepting power as a cause for the actions or the maintenance of the relationships among actors involved. In essence, while we saw the significance of exploring the how rather than the what of power, the tension between the two remained. A step towards resolving this tension, however, was offered by Foucault (1977, 1980).

Foucault (1994, p. 291) used the concept of power as an abbreviation for "relations of power." He argued that "power relations" do not refer to "a political structure, a government, a dominant social class, the master and the slave" which often come to people's minds. Power, according to Foucault, exists in all human relations and at all levels. Furthermore, "these power relations are mobile, they can be modified, they are not fixed once and for all" (Foucault 1994, p. 292). Concerning the nature of power itself, Foucault (1980) maintained that power has no essential essence or form; it is not something to be possessed or with which individuals, systems or structures

can be endowed. Accordingly, he argued that power can't be regarded as a casual concept to be conceived in terms of agency and structure. Therefore, instead of focusing on what power is, Foucault analyzed how power is exercised. He maintained that power only exists in action, in its exercise. As he put it:

> [T]he power exercised on the body is conceived not as a property, but as a strategy, that its effects of domination are attributed not to 'appropriation', but to dispositions, manoeuvers, tactics, techniques, functionings; that one should decipher in it a network of relations, constantly in tension, in activity, rather than a privilege that one might possess...In short this power is exercised rather than possessed; it is not the 'privilege', acquired or preserved, of the dominant class, but the overall of its strategic positions. (Foucault, 1977, p. 26)

Foucault's conception of power sets him apart from some authors in two respects: his rejection that power can be possessed and, most importantly, the notion that power is an effect rather than a cause. This is a significant departure from earlier theorizing about power, especially if one notes that "from at least Hobbes onwards power has been equated with cause" (Dyrberg, 1997, p. 238). The implication of Foucault's view for researchers concerned with analyzing power then, is to focus on the "exercising" of power and the "actions" of the actors involved. As we shall see, Latour (1986) takes a similar position and extended this notion to the techniques employed in the study of science and technology. The similarity with Foucault's analysis of power is often acknowledged by ANT theorists (e.g., Latour, 1986; Law, 1992), but they emphasize that ANT "tells empirical stories about processes of

translation" in which human and non-human elements are included as actors (section 2.3 below).

2.2 Power in Curriculum Making

In this section I wish to situate the concept of power within curriculum making. The purpose is not to review all of the literature on curriculum and power; rather, to highlight the significance and limitations of "power" in the discourse of curriculum making and change.

Power is a central concept in all sociopolitical analyses of schools and school subjects (e.g., Bush, 1986; Carlson, 1996; Kincheloe, 1997; Westoby, 1988). In recent years, many curriculum theorists have come to see schools and curricula as political terrain where interests, conflicts, and power intersect to shape what and how students learn (e.g., Apple, 1990, 1996; Beyer & Apple, 1988; Englund, 1986; Giroux, 1983, 1992; Goodson, 1997; McLaren, 1989, 1995; Pinar, 1995):

> In sociopolitical arenas the interests of the decision makers transcend ideas, even when debate often appears to be focused on getting the "best" decisions. The tools of power usually dominate over the rules of discourse.... Becoming players in these [political] arenas creates some troublesome problems for educators. But to become a bystander and to simultaneously expect decisions to be made in the best interests of children and youth and those who teach them in school is to be naive. (Goodlad, 1991, p. 31)

A similar, yet stronger, position is voiced by Kincheloe (1997) when introducing Goodson's (1997) recent book, *The Changing Curriculum*:

> The way school policy and curricular decisions are made is not made on the basis of what's best for children...Such determinations are first and foremost political acts, marked by the power plays of material and ideological interests that may ostensibly have little to do with school or its students. The truth is that such struggles have everything to do with the school and its students and the social roles they play. The power struggle over curriculum shapes our views of ourselves and our visions for a better and more just world. (p. xxii)

This focus on the political aspects of curriculum is inevitable because curriculum making, as Werner (1991a, p. 106) discussed, is not merely a technical act; it is fundamentally characterized by a "value dimension" over which there is struggle. The failure to recognize this dimension often resulted in "evolutionary" (Hodson, 1987) and techno-rational views which oversimplify the complexity of curriculum making and change. But complexity arises primarily because of the kinds of questions raised and decisions that are made during curriculum making. As Werner (1991a, p. 106) further explains:

> Content is selected from a universe of knowledge and beliefs on the basis of what someone deems to be important. Decisions have to be made about what to include and exclude. Central to this activity are value questions: What knowledge is of most worth for students? What should be taught and learned?...What purposes should be pursued? How should it be taught? All curriculum development, whether at the level of policy or materials, is an answer to such questions.

Value questions do not have universal answers. There are often conflicting answers to what may seem to be a simple question, such as what counts as secondary physics education? Or what ought the physics curriculum to emphasize? Although disputes are inevitable, in every educational system in

the world decisions are made and certain views are adopted. Curriculum theorists are particularly interested in exploring how and whose views shape the curriculum in a particular setting; it is here that notions of power are frequently invoked, along with accompanying concepts such as "domination," "status," and "control."

Hodson (1987) noted two "polar opposite" perspectives on curriculum change in school science: evolutionary and decision making. The evolutionary view considers curriculum change as a natural progressive process, though not necessarily a smooth one, driven by advances in our knowledge of science, educational psychology, and philosophy. For example, recent developments in cognitive psychology and findings from constructivist research in science education have resulted in some reconsideration of the way the content of physics is dealt with in textbooks and classrooms. By contrast, the decision making view considers the curriculum as representing "a selection of available knowledge and teaching methods, deriving from decisions and choices made by powerful individuals and interests groups" (Hodson, 1987, p. 529). Hodson argued in favor of this latter view:

> the way in which school science is perceived is not a result of inevitable progress in the disinterested search for 'curriculum truth'. Rather it is socially constructed, being the product of particular sets of choices made by particular groups of people, at a particular time, in furtherance of their interests. (p. 538)

From this point of view, Hodson (1987) recommended that science curriculum proposals should be examined to reveal the underlying sociopolitical

motivation of the interest groups. Important questions to be addressed were: whose views of science, whose interests, and whose view of society are being advanced?

The notion that school science is a social construct, a selection from a wider universe of knowledge and teaching methods, stemmed from a broader view of knowledge emphasized by the sociology of education in the early 1970s, particularly the work of Bernstein (1971) and Young (1971). Focusing on disciplinary and academic curricula, the analyses employed by Bernstein and Young explained the maintenance of such curricula by invoking notions of domination and social control. This is clearly reflected in Bernstein's (1971, p. 47) widely quoted statement that "how a society selects, classifies, distributes, transmits and evaluates the educational knowledge it considers to be public, reflects both the distribution of power and the principle of social control." Similarly, this theme is echoed in Young's (1971, p. 32) assumption that "those in the positions of power will attempt to define what is to be taken as knowledge, how accessible to different groups any knowledge is, and what are the accepted relationships between different knowledge areas and between those who have access to them and make them available." By relating the stratification of knowledge in schools to the stratification of society, these theorists explained the persistence of unequal patterns of schooling and curricula, and provided a starting point for educational theorists to study the content and form of school subjects in relation to issues of power. For instance, Michael Apple (1990, p. 38), a major proponent of the

new sociology of curriculum in the United States, argued that one of the major reasons why disciplinary or subject-based curricula dominate is because schools have become places for "maximizing the production of high status knowledge, [a function which] is closely interrelated with the school's role in the selection of agents to fill economic and social positions in a relatively stratified society."

One of the problems with both Bernstein's and Young's earlier theorizing was that it portrayed subjects as monolithic; their accounts did not emphasize within-subject change (Goodson, 1987; Cooper, 1984) as, for example, within school physics itself. Furthermore, although the concept of power appeared central in their theorizing, the emphasis lay on domination by those "in the position of power" (Young, 1971), and this led to a simplistic view of how power is exercised in curriculum making. As pointed out by Goodson (1988, p. 161), Young neither specified those "powerful or dominant" groups nor did he examine the process whereby they exercised power over other groups. Young's (1976) later work shifted from emphasizing the role played by broad social and economic classes in defining what counts as school knowledge, to universities and their domination of school examination boards, and to teachers who shaped the science curriculum through their classroom practices and their assumptions about "high status" knowledge.

Contemporary proponents of the new sociology of education (e.g., Apple, 1990, 1993, 1996; Giroux, 1981, 1983, 1992; McLaren, 1989, 1995; Torres,

1998; Whitty, 1985), also known as radical or critical curriculum theorists (Englund, 1997; Schrag, 1992; Pinar, 1995), continue to problematize the content of school knowledge and emphasize political aspects of curriculum. However, like the new sociology of education which never was a precisely defined movement (Morrow & Torres, 1995; Whitty, 1985), the body of scholarship produced by critical curriculum theorists is also far from uniform; there are many differences and disagreement among them, even with regards to central concepts like hegemony and resistance (Pinar, 1995). In addition, the work of these theorists is concerned less with particular school subjects and more with education and schooling at large. Thus, a detailed analysis of this scholarship is beyond the scope of this chapter. Instead, what is important in terms of this thesis is to review the significance of power and how it is conceptualized in relation to curriculum making from the point of view of these authors. In doing so, I show that both notions of power, namely "power to" and "power over" discussed earlier, are advocated by critical curriculum theorists. In addition, I show that although power is invoked by these theorists as a *cause* to account for the emergence and persistence of certain patterns of schooling, their analyses also give rise to power as an *effect*. This point is significant, because it brings the theorizing about power from the point of view of these scholars close to that in ANT.

Critical educational theorists continue to focus on understanding how schools function within the larger society (Schrag, 1992) and "re-emphasize the centrality of power and politics" (McLaren, 1995, p. 29). Earlier attempts

to understand the relationship between schooling and society in general and the construction of curricula in particular involved the concept of reproduction or correspondence (Pinar, 1995, p. 244). However, many theorists now recognize that this relationship is complex and more dynamic than portrayed by earlier theorizing where the legitimate knowledge was seen as simply imposed by dominant or privileged groups. For instance, Apple (1996) argued that:

> [S]chooling never was simply an imposition on supposedly politically/culturally inept people. Rather, as I have demonstrated elsewhere, educational policies and practices were and are the result of struggles and compromises over what count as legitimate knowledge, pedagogy, goals, and criteria for determining effectiveness. (p. xvi)

Frequently, power is invoked as a *cause* that determines the outcome of the "struggle and compromises" over curriculum and to suggest whose knowledge becomes legitimate. This can be seen, for example, in Apple's (1993, p. 10) assertion that "those in dominance almost always have more power to define what counts as a need or a problem and what an appropriate response to it should be." In a later volume, Apple (1996, p. 22) also argued that "the decision to define some groups' knowledge as the most legitimate, as official knowledge, while other groups' knowledge hardly sees the light of the day, says something extremely important about who has power in society." Such statements, which remind us of those made by Bernstein and Young years ago, depict power both as a commodity (something with which certain groups can be endowed) and as a cause. Yet, in their analyses of the

struggle over curriculum and schooling in general, Apple and colleagues recognize the relational aspect of power as well in that power relations are contentious and never stable. Therefore, to better understand how power operates in the context of curriculum and schooling, another major concept is employed: hegemony.

For Apple, Giroux and McLaren, the struggle between dominant and subordinate groups to define what counts as legitimate knowledge is viewed within a process of hegemony; a concept which is closely linked to power. According to Apple (1996, p. 14), hegemony "is an essential tool in uncovering some of the ways in which differential power is circulated and used in education and the larger society." Apple (1996, p. 15) further clarified this link by suggesting that hegemony "refers to a process in which dominant groups in society come together to form a bloc and sustain leadership over subordinate groups." Furthermore, sustaining leadership need not rely on "physical force" or coercive power; rather, it is achieved through "a struggle to win the consent of subordinated groups to the existing social order" (Giroux, 1992, p. 186). In this sense, hegemony becomes a form of power "obtained by moral and intellectual persuasion rather than through control by the military, police, or the coercive power of the law" (Morrow & Torres, 1995, p. 253). The reliance on hegemony to explain domination and the emphasis on persuasion and obtaining consent was further elaborated by McLaren (1989, p. 173) when he wrote:

> The dominant culture is able to exercise domination over subordinate classes or groups through a process known as hegemony. Hegemony refers to the maintenance of domination not by the sheer exercise of force *but primarily through consensual social practices, social forms, and social structures produced in specific sites such as the church, the state, the school, the mass media, the political system, and the family....*Hegemony is a struggle in which the powerful win the consent of those who are oppressed, with the oppressed unknowingly participating in their own oppression.

Three points can be made with regards to hegemony and its use in the context of curriculum and schooling. First, given the way it is defined, hegemony is better seen as "power over," because it focuses on the process whereby dominant groups achieve leadership and exercise domination over others. Second, hegemony, as "power over," is employed by critical theorists *to explain* domination, the persistence of certain curricula and, more generally as in the definition given by Giroux (1992, p. 186), the maintenance of an "existing social order." Yet the way these authors talk about and analyze hegemony suggests that it is better seen as an effect, or a product, of a given "social order" rather than a cause for it. This is implied in the use of terms like "obtained" and "achieved," but it is more evident when hegemony is referred to as a noun; for example, in phrases like "hegemonic knowledge" and "constructing hegemony" which are frequently found in the writings of critical educators. Alternatively, an argument can be made that without achieving leadership, without succeeding in making one's knowledge being accepted by others, or without establishing and maintaining a given "social order" there is no dominant hegemony to begin with or to be invoked as a

causal concept. For this reason, hegemony itself needs to be explained rather than used to explain the situation in hand. To simultaneously do both in a given situation, in my view, is contradictory and misleading. However, invoking hegemony as a *cause* can be justified only as long as one deals with the end result of the struggle and compromises; for instance, when certain groups succeed in obtaining leadership or when a particular form of knowledge becomes dominant and taken for granted. In such a case, hegemony becomes part of the so called "social order or structure" being explored, or, from the point of view of ANT, hegemony is an outcome of a relatively stable heterogeneous network. When applied to curriculum, this will be the case when a particular school subject, or a version of it, becomes accepted by many actors including teachers, students, parents, ministry officials, and academics as given. But even then, as critical theorists know well, a dominant hegemony is not achieved once and for all; it needs to be constantly negotiated and maintained. As Apple and Weis (1983, p. 28) stated, "hegemony is not and cannot be fully secure."

The third point (which is also related to the previous one) has to do with viewing hegemony as a process or a struggle to achieve domination, obtain consensus and sustain leadership. Naturally, this suggests a focus on practice and techniques. In other words, if hegemony is a process, and if it is constantly being negotiated, then what becomes important is understanding *how* certain groups achieve leadership and obtain victory for their hegemonic values and knowledge. To do so, one needs to explore the negotiation process

and the techniques and strategies employed by the various actors involved. Here, as I show shortly, ANT provides both a language and an appropriate method for exploring these activities. From the point of view of ANT, hegemonic struggle can be understood as a networking process; that is, a process of translating interests which at the end produces a particular form of curriculum or a given "social order or structure" which includes the identities, roles and values accepted by many participating actors. In this respect, I believe, the concerns of critical scholars intersect with those of ANT.

Substituting hegemonic struggle for broad domination and control opens doors for possibilities to achieve change within education and in society at large through education. Exploring ways to achieve change in society is considered vital because the specific objective sought by critical educators is "to empower the powerless and transform existing social inequalities and injustice" (McLaren, 1989, p. 160). Here, in the context of defining their primary goal, critical educators adopt another notion of power; this time "power to."

McLaren (1989, p. 186) used the term empowerment to mean both "self-confirmation" and "social transformation" while Giroux (1992, p. 11) defined it as "the ability to think and act critically." This is also consistent with Kinchloe's (1997, p. xxvii) notion of power which he defined as "the ability and capacity for...moral judgment and action." The reliance on such a notion of power is significant not so much to explain domination and control, as was the case with hegemony, but rather to emphasize the possibility to achieve

change— more specifically, it emphasizes the ability of individuals to resist a given hegemony and construct an alternative one. Therefore, power theorists like Foucault, Wartenberg and Fiske who emphasize "ability" as well as "relational" aspects of power are often cited by critical curriculum scholars (see, for instance, Giroux, 1992; Kincheloe, 1997, McLaren (with Giroux), 1995; Torres, 1998). As an illustration, consider how Kincheloe (1997, p. xxvii) used Fiske's (1993) concepts of "imperializing power" and "localizing power" to describe the significance of "power theory in...critical curriculum scholars' attempt to understand the social construction of curriculum." Fiske used the term imperializing power to describe strong, top-down forms of power and localizing power to refer to bottom-up forms of power. The former is usually associated with dominant groups whereas the latter is often used in relation to the subordinate groups. According to Fiske (1993), imperializing power attempts to spread its influence as far as possible. Localizing power, by contrast, tries to control immediate space around it, including the individual's thoughts, feelings, identity, and interpersonal relationships. Fiske's imperializing power and localizing power can be regarded as loosely corresponding to "power over" and "power to" respectively. Using these notions, Kincheloe (1997, p. xxvii) then argued that in the context of school subjects the imperializing power of the subject discipline attempts to colonize the localizing power of secondary teachers and their students to make the subject relevant to their everyday lives. Localizing power, in response, "challenges the influence of the power wielders and produces alternative

spaces for self-production" by drawing upon racial, gender, or class based counter-knowledge.

What then do critical educational theorists offer us in terms of understanding and analyzing power in curriculum making? First, we note that both notions of power (i.e., "power over" and "power to") are central, and in fact necessary, to talk about struggle and change. In particular, hegemony appeared central to understand domination and how dominant ideas are sustained, whereas "power to" provided a means to resist a prevailing hegemony and construct a counter hegemony.

The second point has to do with key players or actors involved in constructing a counter hegemony. In arguing about reforming public education, critical curriculum theorists, especially Apple (1990, 1993), Giroux, (1981, 1983, 1992) and McLaren (1989, 1995), see teachers as key change agents whose task is to build a counter hegemony. One problem with this view, according to Morrow and Torres (1995, p. 336), is that "the larger society, including students, parents, politicians, and business, is treated analytically mostly as a residual element, while the teacher is placed at the center stage in the process of transformation and struggle." Englund (1997, pp. 216-217) also noted that "American critical curriculum theorists" mainly regarded change as "a matter of transforming the consciousness of classroom actors" whom they saw as a primary change agent "separated from an analysis of the state and its role."

Another problem with relying primarily on teachers as key agents to achieve change, especially the kind of change advocated by critical educators, is that it views teachers as opponents of the "dominant social groups" and, consequently, assumes that most teachers are willing to change and that such a change is in their interest. In my opinion, such a view still celebrates the "domination model" emphasized by earlier sociological approaches. In contrast to this view, research on school subjects revealed that teachers often play a major role in promoting academic subjects and maintaining disciplinary practices in furtherance of their interests. For example, in his study of the development of Geography in Britain, Goodson (1988) showed that it was primarily "considerations of teachers' material self-interest in their working lives" that accelerated Geography to its academic position (p. 180). In science education, Gaskell (1992, p. 269) also showed that academic science (as opposed to other versions) was highly supported by science teachers with an interest in maintaining it. The study in hand confirms these findings and further reveals the kinds of interests teachers have in maintaining an "academic" version (Goodson, 1987) of school physics.

Finally, one needs to keep in mind that teachers are but one source of influence in science curriculum. Other sources, such as academic scientists, parents, business, industry, philosophical ideas about science and science education, economic and political situations are also important and, at times, could significantly influence the science curriculum (Fensham, 1988b, 1993; Gaskell 1992; Gaskell & Hepburn, 1998; Hodson, 1987; Rowell & Gaskell,

1987; Woolnough, 1988). While it is reasonable to expect teachers to play a crucial role in shaping the science curriculum, these other sources should not be ignored. More importantly, and as I show in this study, to involve teachers as change agents requires translating their interests (see next section). But that too is not enough to achieve a significant change in curriculum unless many other actors are involved in the process. Teachers do not define their roles and identities independently, but in relation to the subject they teach (Werner, 1991b), students and parents, among others. More specifically, teachers can be seen as members of actor-networks and their roles and identities are defined accordingly. The redefinition of these entails a construction of an actor-network in which "transforming the consciousness" of teachers is but a step towards such a project.

Unlike many critical educators, Goodson (1987, 1988, 1997) focused on the development of school subjects. His research, also inspired by the research program set by Bernstein and Young, led to a view of this process which was more complex than that suggested by these and other sociologists where the emphasis was put on the "activities of the dominant interest groups, particularly the universities" (Goodson 1987, p. 10). Goodson (1987) argued that school subjects are constructed by subject communities, "seen as comprising of shifting network of groups, segments and factions" (p. 25). Furthermore, within a subject community, conflicts among subgroups arise primarily over the aims and nature of school curricula which, in turn, influence the boundaries and priorities of the subject. From this perspective, Goodson

(1987) recognized three curricular styles or traditions: the utilitarian, the pedagogic, and the academic. Furthermore, he argued that "in the process of establishing a school subject (and university discipline) base groups tend to move from promoting pedagogic and utilitarian traditions towards the academic tradition" (Goodson, 1987, p. 3). There is a sense of evolution in these traditions; the "academic" represents a stage at which the subject is seen as fully developed and is warranted a high status.

Unlike other sociological accounts that focused on domination and control, Goodson's analysis focused on the activities within the subject community and the conflicts and interests of the various subgroups within it. In other words, Goodson focused on the micropolitics of curriculum making, in which coalitions, strategies and interests are chief elements and the focus of analysis (Hoyle, 1988). This is an important departure, because by highlighting the roles played by groups other than those "dominant" in the society (e.g., social or economic classes), he showed that curriculum making is more dynamic than traditionally perceived. Within this approach, power is not merely held by those who are privileged in the society, and who use it in a top-down manner. By focusing on the struggle and alliances within groups, power itself becomes mobile and shifting.

Finally, Cooper's (1984, 1985) research on change in school mathematics bears some similarity with the present study because both deal with the redefinition of a particular subject. Like Goodson (1987, 1997), Cooper began by rejecting the notion that school subjects are monolithic, and

perceived school mathematics "as a set of segments, or social movements, with distinctive missions, or perspectives and material interests" (p. 60). The significance of this assumption is that it allowed for the possibility of conflicts within the subject community itself and consequently the possibility of change emerging from "within" rather than being imposed from the top by dominant groups. The specific question of interest for Cooper (1984, p. 54) was "why it was that some segments appeared more powerful (in relation to achieving their missions against actual and potential opposition) than others." Drawing on Archor (1979), Cooper argued that power must be conceptualized in terms of the resources available to actors engaged in conflict over redefining the mathematics subject. He further argued that "if we are to explain change sociologically, these resources must be seen as differentially (and not randomly) distributed to actors by virtue of their location in various sets of structural social relationships. To map out the distribution of resources available to actors within and outside the mathematics community, Cooper (1984, p. 55) adopted "a broad definition of resource" which included:

> [A]cademic and general status (reflected in degree of self-confidence and, for example, ease of access to media and political arenas), access to time for proselytization, access to financial resources, access to particular social networks and organizations, control over entry to institutions and positions, previous access to 'valued' definitions of mathematics, and the degree of fit potentially available between segment's mission and those of other 'powerful' groups.

Cooper's research is particularly enlightening in terms of suggesting the need to 1) consider a spectrum of actors in accounting for the development and possibility of change within a particular subject, and 2) articulate a theory of power in order to discuss and assess the conflict among the various actors. While Cooper's suggestion to conceptualize power in terms of resources and the broad definition of resources he adopted are both useful, he seemed to equate power with these resources. This, in my view, makes his theory of power somewhat limited and static, especially since he took the unequal distribution of resources for granted to begin with. In addition, equating power to resources downplays the strategies of utilizing these resources in the discourse of conflict. If these strategies are ignored, then power itself as a concept becomes meaningless since what we are left with is merely a variety of resources. Moreover, this approach to power also leads to a focus on the "powerful" groups and marginalizes other significant actors like students and their parents in constructing power relations. As I will show in this study, these actors play a significant role in shaping the curriculum. Again Rowell and Gaskell's (1987) study mentioned in the previous chapter included some insights into this issue. In this study, the conflict between university physicists and secondary physics teachers revolved around the need to maintain the integrity of the subject (physics) as opposed to the needs of diverse students. The achieved change responded to the needs of the students although the key actors identified in achieving this change were the teachers. The point here is

that the *alignment of students' and teachers' interests* was crucial in determining the outcome of the struggle over the nature of school physics.

In this overview I attempted to situate the concept of power within curriculum making. Power appeared to be a central concept in the discourse of curriculum making/change, although theories of power are rarely articulated. Theorists invoke power primarily as a cause to account for the resolution of conflict, the emergence of certain views, or the persistence of certain curricula. Theorists conceptualize power in terms of resources, status, privilege, and authority, to name some; if power is any or all these terms, then the term power becomes redundant, and other questions need to be addressed; for example, how did certain people come to "own" power in the first place?

ANT takes a different perspective on power by rejecting the notion that it is a cause, rather than an effect.

2.3 Power in ANT

Before discussing how power is conceptualized by actor-network scholars, it is necessary to describe some features of ANT. It is a theory of constructing heterogeneous networks that combine the material and non-material, the human and non-human. Law (1986), for instance, used the term "heterogeneous engineering" to describe the technologists' efforts to build a successful artifact. These technologists combine raw materials, skills, scientific and social knowledge, and capital in a stable network that will hold

these diverse elements together to perform as one. Similarly, in describing how scientists and engineers work, Latour (1987, 1988, 1996) observed that they are actively involved in enrolling elements of the material world, money, established (black boxed) knowledge, people, laboratory equipment, inscriptions, and so forth, in order to construct networks. For instance, Latour (1988) showed that Pasteur's network consisted of many actors: farmers, sheep, domesticated strains of bacteria, journalists, notebooks, statistics, laboratory equipment, the public, and so forth. Pasteur's greatest achievement was to combine and negotiate with all these actors. From the point of view of ANT, the success of any project depends on linking as many heterogeneous elements as possible such that they perform in harmony. Latour (1996, p. 58) captured the difficulty of this task in *Aramis*, in which he described the development of a new guided transportation system in Paris:

> The full difficulty of innovation becomes apparent when we recognize that it brings together, in one place, on a joint undertaking, a number of interested people, a good half of whom are prepared to jump ship, and an array of things, most of which are about to break down. These aren't two parallel series that could each be evaluated independently, but two mixed series; if the "onboard logical systems" fizzle out at the crucial moment, then the journalists won't see a thing, won't write any articles, won't interest consumers, and no money or support will get to the Orly site to allow the engineers to rethink the onboard logical systems.

These heterogeneous elements (actors or actants) and their associations (the manner in which they are linked or related) is what Callon and Latour refer to as an actor-network. Although both terms, actors and networks, are

commonly used by people in everyday practice, the notion of an actor-network suggests more than a combination or a mixture of the two. As Callon (1987, p. 93) put it:

> The actor-network is reducible neither to an actor alone nor to a network. Like networks it is composed of a series of heterogeneous elements, animate and inanimate, that have been linked to one another for a certain period of time....An actor-network is simultaneously an actor whose activity is networking heterogeneous elements and a network that is able to define and transform what it is made of.

Both Callon (1987) and Latour (1997) caution against confusing the notion of actor-network with the common use of the term 'network' as often associated with technical networks, such as telephone or train systems, that link perfectly defined and stable elements whose behavior is normally predictable. This need not be the case with actor-networks and indeed is rare. On the contrary, actors in an actor-network could at any time "redefine their identities and their mutual relationships in some new way and bring new elements into the network" (Latour, 1997, p. 6). In ANT, actors are not conceived as fixed elements and their definitions, stability and continuity are constantly negotiated and obtained by other actions.

Networks are constructed as scientists and engineers involve and link many actors to establish facts (scientific knowledge) and artefacts. ANT focuses on the process of constructing and maintaining such networks. Any scientific claim begins as a fragile or weak assertion made by an individual or a small group. It is weak in the sense that it is perceived as personal and

local. In order for a weak claim to become stronger and eventually become accepted as truth, it must enroll enough allies and enlist sufficient resources to establish a large network. Of course, not all claims successfully link themselves to an encompassing network; those claims that are able to insinuate themselves into the activities and rhetoric of other actors become established truth, objectified knowledge, or "black boxed."

A "black box" is a term that Latour (1987) used to refer to claims and artefacts in science and technology that are no longer contested but generally accepted and used with little or no modification. Callon (1987) also used the term "simplified networks" to describe elements of an actor-network that are black boxed; this term captures the hidden complexity of the elements constituting an actor-network. By their nature, these elements are complex, but in an actor-network they are related to each other as uncontested, simplified networks.

Latour (1993) observed that a fundamental characteristic of modernity is the maintenance of dichotomies: between human and non-humans, society and nature. Scientists, both social and natural alike, accept these dichotomies when they privilege either nature or society to account for the development of facts and artefacts in science and technology. Latour saw no fundamental difference between social scientists who take society for granted and seek to explain events and knowledge in terms of social causes, and the natural scientists who take nature for granted; to take society (or nature) for granted is to assume that it does not need to be explained, and therefore can be used

in explanations. As Latour (1993, p. 80) put it: "in the modern perspective, Nature and Society allow explanation because they themselves do not have to be explained." He was particularly critical of scientific realism's privileging of a natural order of things and social realism's emphasis on social causation. In rejecting these approaches to knowledge, Latour (1993) suggested an approach that constructs nature and society as twin results of another activity that he calls "networking." The question for Latour (1993, p. 88) is not how some natural or social structure affects the ordering of things, but how the sorting is achieved, how things are stabilized, purified and assigned to the poles of nature or society. Thus, the divide between nature and society exists only as "a delayed result of stabilization"; both are the result of settling controversies, of establishing order in the world.

Like society, power is treated as an effect or a consequence rather than a cause of actions. Power, Latour (1986) argued, is not something that is provided by the prior existence of society, in which case it does not need to be explained; rather, it is obtained by enrolling many actors. Power is an achievement and, hence, needs to be explained rather than used to explain the existence of the order of things.

In this approach to power, Latour (1986) introduced the notion of a "token": a claim, an artifact, an innovation, an order given by a "powerful" leader, or, as in this research, the PTS innovation. He explored two approaches to the analysis of power; one is the standard "diffusion model" and the other a "translation model" employed by actor-network theorists.

Latour (1986) considered writers who treat power as a cause to be adopting a diffusion model: a token is endowed with an inner force or "inertia" in a manner similar to that in physics. According to the principle of inertia in physics, once a mass is set in motion it will continue to move with a constant velocity unless it encounters resistance (friction, for example); once a token is put in motion it will continue to spread in space and time unless it is met by resistance (lack of communication, ill-will, opposition from interest groups, indifference) which slows or stops the token from spreading. In this model, society is a medium which consists of groups with interests and through which ideas and artefacts travel (Latour, 1987, p. 136). In the diffusion model the path of a token and its spread in space and time is determined by three elements: the initial force that triggers the motion of the token (e.g., the power of the individual or the group originating the idea or the innovation), the inertia that conserves this force or energy, and the medium through which the token circulates. Power is used here *as a cause* to explain the actions of others:

> In [the diffusion] model when we see an order given by a manager has been executed by two hundred people we conclude that the force that displaced the latter should be placed in the hands of the manager. To be sure, the order as it is executed is not quite the order that was given, but such distortions may be attributed to frictions and resistances which deflected and slowed down the pace of the original force. The advantage of such a model is that everything may be explained either by talking about the initial force or by pointing to the resisting medium: When an order is faithfully executed, one simply says that the masters had a lot of power; when it is not, one merely says that the masters' power met with a lot of resistance. (Latour, 1986, p. 267)

Latour (1986, 1987) contrasted the "diffusion" model with a "translation" model in which a token has no inertia to keep it in motion; that is, to spread it in space and time. Rather, the spread of any token depends on the actions of the people who actively may appropriate, deflect, modify, or reject it. As such, the medium is not passive; it consists of active actors who do not simply resist the spread of the token or transmit it as in the diffusion model, but shape it according to their own projects and interests. Because tokens, whether claims, orders, innovations, or artefacts, are constantly shaped by all actors, the faithful transmission of a particular token becomes but a rare possibility that requires explanation.

How can we understand power in terms of the translation model? Latour (1986, p. 268) asks, and answers:

> The obedience to an order given by someone would require the alignment of all the people concerned by it, who would all assent to it faithfully, without adding or subtracting anything. Such a situation is highly improbable. The chances are that the order has been modified and composed by many different people who slowly turned it into something completely different as they sought to achieve *their* own goals... Power is always the illusion people get when they are obeyed; thinking in terms of the diffusion model, they imagine that others behave because of the masters' clout without ever suspecting that many different reasons others have for obeying and doing something else; more exactly, people who are 'obeyed' discover what their power is really made of when they start to lose it. They realize, but too late, that it was 'made of' the wills of all the others.

The shift from diffusion to translation specifically entails a shift from "principle to practice" in how power is conceptualized. Powerful individuals and groups, Latour (1986, p. 273) argued "are not those who 'hold' power in principle, but those who practically define or redefine what 'holds' everyone together."

An immediate implication of Latour's perspective for analyzing power is to focus on the activities of (all) the actors involved in a given project to see how they are held together, what holds them together, how they are defined, and how they see the project in terms of their own goals. Callon's (1986) description of networking—or translation process— is particularly helpful in terms of attending to these questions and hence analyzing power relations.

Like Latour, Callon (1986) argued that power is not something that an agent or actor can possess and is better seen as a consequence of actors' actions. Power relationships, as Callon illustrated, are produced in the process of networking which he described in terms of four "moments." These moments constitute the different stages of a general process called translation, during which the identity of actors, the possibility of interaction, and the margin of maneuver are negotiated and delimited (p. 202). These moments are not sequential stages in the networking process, but overlapping aspects of the strategies and tactics of network builders. The four phases are problematization, interessement, enrolment, and mobilization. Problematization refers to the process of identifying (relevant) actors and defining their allowable identities and interests in relation to a particular

problem. As such, the formulation of the problem during the problematization phase becomes crucial for it allows the network builders not only to identify who and what the relevant actors are, but also those that are not. Actors may be drawn from the social, natural, or spiritual world; they may be humans (students, teachers, parents) or non-humans (textbooks, physics problems, assessment, dictionary, God). An important aspect of the problematization is the definition of an obligatory passage point (OPP). An OPP could be a question, a program, or a particular curriculum that converges the interests of the various actors. It is a point along the path leading to the goals of the various actors defined in the problematization phase. For instance, in his study of an undergraduate physics program, Nespor (1994) noted that the only appropriate identity allowed for a student in the physics program was "physicist-in-the-making" along a path leading to a career in research. As such, the (physics) program had been defined as an OPP along this trajectory.

Interessement, the second moment in the networking process, is the group of actions by which an actor (the network builder) attempts to impose and stabilize the identity of the actors it defines through its problematization. The essence of the interessement process is to create barriers between the actors being defined in the problematization "and all other entities [actors] who want to define their identities otherwise" (Callon, 1986, p. 208). The strategies for creating barriers between an actor and others vary depending on the situation and the actors being "interested." In certain cases, rhetorical barriers (explanation, persuasion) might work well, whereas in others, as Nespor

(1994) showed, these may be material barriers and material organizations of space and time that restrict contact with others. A successful interessement thus would result in dissociating or weakening the relationships between a particular actor and certain actors while strengthening relationships with others. Therefore, while the problematization phase might tentatively describe the system of alliances between the relevant actors by defining their allowable identities and interests, interessement strengthens these alliances by stabilizing the identities of these actors.

The third moment, enrolment, designates the device by which a set of interrelated roles is defined and attributed to actors who accept them. Enrolment and interessement are thus related because unless the actors being networked accept the roles and identities defined in the problematization and negotiated in the interessement phase, enrolment is not achieved. Accordingly, a successful interessement is necessary to achieve enrolment.

Finally, mobilization is the process by which certain actors are seen as representatives or spokespeople for the various relevant collectives that are not directly participating in the process. For example, do I (as an actor interested in promoting a PTS version of physics) represent the Ministry of Education in Bahrain in this particular discourse? Do the four Bahraini university physicists who participated in this study represent physicists (and physics) in other distant universities? Similar questions can be asked regarding the existing physics curriculum and the three units I used in the

study. For instance, which particular version of school physics stands for and represents (the discipline of) physics? What do the three units represent? Do they represent STS as well as PTS? Can they represent physics however it is defined? The task for the network builders is to ensure that actors enrolled are able to represent the larger collectives they belong to and are not betrayed by the latter. This becomes significant for the network builders who ultimately become designated spokespeople for whole collectives.

If the translation is successful, an actor-network is constructed. The result of these translation activities, according to Callon (1986, p. 224), is a situation in which certain actors control others.

> Understanding what sociologists generally call power relationships means describing the way in which actors are defined, associated, and simultaneously obliged to remain faithful to their alliances. The repertoire of translation.... also permits an explanation of how a few obtain the right to express and to represent the many silent actors of the social and natural worlds they have mobilized.

It should be noted that a successful actor-network would simultaneously produce the social and the natural world. This is evident in the previous account since neither the social world, defined in terms of its constituent humans and their relations, nor the natural world, defined in terms of its non-human elements and laws, were assumed to be fixed or used to explain the actions of the (human and non-human) actors involved in the translation and networking process. Elements of both worlds need to be negotiated, defined and related throughout the process. Only when controversies are settled—

when claims become facts, and innovations are accepted and used—do we begin to see natural and social elements distinctly defined and separated.

Law (1986, 1991, 1996) explored power within established networks. His research supported Latour and Callon's view that power is an effect. For instance, Law (1996) tells a story of Andrew, a "powerful Director/ manager" who "sits on the top" of a large European scientific laboratory, has many responsibilities, makes decisions, exercises discretion, and whose commands are respected. In all, Andrew is a "powerful manager." To understand the "powers of the powerful manager," Law (1996) wondered how he would perform in the particular situation explored if his materials (e.g., computers, furniture, telephones, fax machines, archives, calculators) and assistants (e.g., secretary, postman, driver, engineers, fellow managers) were to be taken away. Law argued that in such a case the manager would not be able to calculate, decide, command, exercise discretion, or even remember. In other words, we would not see him as a "powerful manager." The lesson from this, Law (1996, p. 4) argued, is that the "powers of the manager... are extended. Spread out. Distributed." He further explained:

> They are distributed through the arrangements of the organisation. They arise from those arrangements. The people who do the work of subordinating themselves. Secretaries. The tiers of under-managers. The clerks. The technicians. All those people. But not just the people. For the powers of the powerful manager lie also in the papers. The texts that fix the commands. That map the organisations, its financial health, its credibility ...And in the technologies which remember. Which calculate. Which write. Which talk to the other end of the world. (p. 4)

Finally, Law (1996, p. 4) concluded that "power resides elsewhere. It is always deferred. It is always a product. It is always an effect."

The above analysis also revealed that Andrew was more complex and, indeed, more interesting than if perceived simply as a "powerful" manager whose powers were viewed and explained within the "social" sphere. This is because Andrew is not simply a social entity, but a combination of heterogeneous elements which includes people, texts, money and machines, and which produce Andrew-the-powerful-manager. In short, Andrew himself is a network. This point is generalized by ANT's theorists by suggesting that all entities, whether they are people, devices, or texts, are networks (Callon & Law, 1997; Law, 1992).

To conclude, the translation model described by Latour (1986; 1987) and Callon (1986) depict power as a dynamic process of continuous activities. It is precisely on these activities depicted by Callon's four "moments" that we need to focus if we are to understand how certain projects become accepted as "truth" while others fail. To take power as a starting point to explain this process is methodologically unacceptable. For example, to say that a particular group or individual shapes or defines a physics curriculum because they are powerful does not tell us much about the situation at hand, nor does it explain that power. Rather, it assumes that these individuals are "powerful" and, consequently, they are able to define the curriculum against the will of others who wish to define it otherwise. If one challenges this analysis or probes it further, one finds resources, authority, prestige and expertise

employed as forms of power. But again, these terms do not touch the heart of the issue. To say that a particular group or individual has power because they control resources or by virtue of being an authority is redundant and does not add to our knowledge about the nature of power itself, unless one equates these terms with power, in which case the term loses meaning. There is no such "thing" as power to cause actions; to start with power is to confuse the effect with the cause, as Latour (1986) charged.

Therefore, the issue for researchers is not whether we should confine ourselves to either "power to" or "power over," but rather to treat both as an effect, a consequence of the intensive activities of networking. With an established network comes the power of those whom we consider "powerful." In this respect, no individual is powerful by him or herself; rather, as Law (1991, 1996) showed, their powers lie in the network which combines both the human and non-human actors. As long as we maintain this perspective, as Law (1991) argued, both notions of power can be useful; if power relations are treated as effects of established networks, then power remains only as long as these networks remain stable.

2.4 A Framework For Exploring Power in Curriculum Making/ Change

ANT is a useful framework to explore curriculum in the making and issues of power in curriculum. It is particularly adaptable to investigate how controversies are resolved, and consequently can help us understand an innovation as a process of constructing and maintaining networks. This

requires that a researcher pays attention to changes in both the innovation and its context. From the perspective of ANT, one does not follow a particular innovation through a context, rather one needs to follow the simultaneous construction of both; the innovation and the context co-evolve (Latour, 1991, 1996). In this process, power is a significant notion, and is defined in terms of the activities that actors engage in as they build networks and pursue their goals when a particular project or innovation is put forward. The task of a network builder is to engage other actors in spreading the token in space and time. This is achieved as their interests are translated into the project. "Interests," according to Latour (1987, p. 109), "are what lie in between actors and their goals, thus creating tensions that will make actors select only what, in their eyes, helps them reach their goals among many possibilities." Actors involved in a particular project need not all have the same goal, but the task of a network builder is to make them see the realization of their goals through that particular project. With the construction of an actor-network, power relations evolve as part of that network. Thus to explore power one needs to pay attention to the activities of the actors as they define each other, establish obligatory passage points, forge alliances, and enroll and mobilize other human and non-human actors. Power and power relations are the results of all these activities and will remain as long as the network itself remains in place.

Through ANT our conceptualization of curriculum change and methodology for investigating it are both enhanced in several ways. First, it

provides the concepts (e.g., actors, translation, mobilization, enrollment, interessement, network and network construction) that allow the researcher to describe and discuss the process of curriculum change and decision making by following the actions of the various individuals and groups and examining the strength of their arguments. These analytical concepts are useful for understanding the roles played by different actors in constructing power relations as they engage in a given project.

Second, ANT extends the set of actors enrolled in the networking process to include both human and non-human actors. Non-human actors are artefacts, texts and processes that are utilized in the network in some way. For example, in this study, physics, physics problems, student assessment, textbooks, curriculum goals and decision making processes were some of the actors that are part of a network to either promote the PTS innovation or maintain the status quo in physics education.

Third, compared to ANT, social construction perspectives (e.g., Apple, 1993, Cooper, 1985, Goodson, 1997) on school subjects, however appealing they may seem, remain asymmetric because they privilege social explanation (e.g., social groups, power, interests, beliefs) in the establishment of knowledge and school subjects. While these perspectives take knowledge and school subjects as problematic, they do not equally treat "society" as problematic. This asymmetry also holds for the traditional techno-rationale perspective which dominated the field of curriculum until the early 1970s (Pinar, 1995). In this view, science is considered the outcome of an objective

search for knowledge in which nature is considered the final arbiter. Consequently, this view not only portrayed school knowledge (particularly in science) as objective and unproblematic, but also argued for a similar (scientific) approach to develop curriculum. ANT, in contrast, treats both society and nature symmetrically, eliminating divides between the human and non-human, social and natural, policy makers and implementers, and external and internal forces or agents. In this respect, ANT also bridges the gap between classical sociology of education with its emphasis on domination and external forces, and Goodson's socio-historical evolutionary model with its emphasis on subject communities. And it does so by including all human and non-human elements as actors in a network that defines them and is being defined by them; a school subject/curriculum is a heterogeneous construct rather than a social construct. Therefore, it is not useful to insist that "only by examining education as a fully *social* process...can we begin to make sense of what is possible in educational reform" (Apple, 1998, p. 423). Unless, of course, one keeps in mind that the social is no longer pure, but, as Callon and Law (1997) maintained, is materially heterogeneous. That is, materials are more than mere resources to be utilized by humans; they are active and not passive actants. If the notion that the curriculum is an actor-network is accepted, then curriculum making or change can be explored using the translation model.

Summary

This chapter focused on the issue of power. It began by discussing several notions and theories of power. This, in turn, provided a context for reviewing and discussing power in curriculum making and in ANT. Scholars who view curriculum from sociopolitical perspectives considered power to be central in their analyses, although theories of power are rarely articulated. Nevertheless, power was invoked by theorists primarily as a *cause* to account for the resolution of conflict or the persistence of certain curricula. Theorists conceptualized power in terms of resources, status, privilege, and authority, to name some. The discussion of power in ANT suggested that these elements are important, but only if considered within a broader, more complex arrangement; i.e., as actors or elements in an actor-network. The construction of an actor-network entails the definition of actors, their identities, roles and relationships. It also entails the translation of interests and the establishment of OPPs. Finally, ANT treats power as an *effect* of a network and the activities in which actors are engaged, rather than a cause. Therefore, it is well suited to analyze *power in the making* and is used as a framework in this study. Several concepts were introduced for discussing power as an effect of activities: translation, token, actor-network, problematization, interessement, enrolment, and mobilization. These concepts are used in the data analysis chapters.

The following chapter describes the overall design of the study in terms of actor-network theory, and presents a description of the participants and the procedures of data collection.

CHAPTER 3

RESEARCH METHODOLOGY

This chapter describes the methodology used to explore how power is manifested within the context of physics curriculum making in Bahrain. I begin with a brief description of the setting, Bahrain. Some background information concerning Bahrain, its educational system and school physics is given. Next, I discuss the research design, including a description of the participants involved in the study, and methods of data collection and analysis. This section also includes a description of the PTS innovation. Finally, I situate myself in the context of the study both as a researcher and an insider; I show how aspects of my role as a researcher coincided with, or related to, my role as an insider in a manner that enhanced both roles.

3.1 The Setting: Bahrain and School Physics

Bahrain is an Islamic and Arab state that consists of an archipelago of 36 islands with a total area of about 707 square km. It is located at the center of the Arabian Gulf, about 22 km off the eastern coast of Saudi Arabia. The largest and most important island is called Bahrain from which the state derives its name and where Manama, the capital, is situated. The island of Bahrain represents about 85% of the total land area of the state. The population of Bahrain has increased considerably over the past two decades or so and was estimated to be 598623 in 1996 (Directorate of Statistics,

1996). Given its area and population, Bahrain is among the most crowded countries in the Arab world.

Prior to the discovery of oil in 1932 which resulted in an oil-based economy, pearl-diving, fishing, dhow-building, agriculture and handicraft were the main economic activities. However, and due to the limited oil reserve, the government was encouraged to diversify and establish non-oil based industries such as aluminum, natural gas, ship repairing, and petrochemical. The increased industrial development also created a need for an expanded banking, commercial, hotel, investment and insurance services.

Historically, the teaching of the Holy Quran was the only form of education available in the period preceding the establishment of the modern educational system in Bahrain in 1919. The Quranic schools (Kuttab) were run by local Mullas in their houses, in shop corners, and in Bazzar lanes in summer (Jain, 1986, p. 13). These schools were mostly coeducational and their programs consisted basically of memorizing Quranic texts and to some extent reading, writing and arithmetic.

In 1919, the first modern public school for boys was opened, followed by another school for girls nine years later. During the 1940s the basic foundation of the whole educational system was laid. The school program, then, was based mainly on the Egyptian model which influenced the content of each subject as well as the teaching methods and the examination policies (Al-Hamer, 1968). This, however, continued until 1981 when the Ministry of Education in Bahrain initiated reform in the educational structure as well as

the school curriculum. The result of this reform was new curricula and textbooks developed locally.

"The Ministry of Education is responsible for administration of the public education system in Bahrain in all levels. It is the official authority responsible for executing the State's educational policy [and] directing the educational system at all levels" (The Educational Documentation Section, 1996, p. 36). The Directorate of Curricula at the ministry assumes full responsibility for planning, developing and implementing curricula and preparing textbooks and other materials. The curriculum specialists at the ministry participate in this process along with teachers and school principals. When needed, experts outside the ministry are also sought for advice and consultation. The process is usually carried out through committees appointed by the ministry (The Educational Documentation Section, 1996, p. 43).

Formal education in Bahrain represents a highly centralized system where the Ministry of Education possesses the legal and administrative instruments for control. For example, the Department of Secondary Science Education is responsible for initiating innovations and for finalizing curricula and teaching materials; members of this department (i.e., physics, chemistry and biology curriculum specialists) then work closely with teachers to provide support and supervision and to ensure proper implementation.

At the present, the educational structure in Bahrain follows a 9-3 pattern for basic and secondary education respectively. The basic education combines primary and intermediate education. The secondary education consists of

three study years (grades 10, 11, and 12) divided into six semesters. Entry is conditioned by obtaining the Intermediate School Certificate or its equivalent. The secondary education is divided into different streams: general (science and literary), commercial, technical, and applied. Arabic language is taught in all grades and is the medium of instruction in all subjects. English as a second language is also taught starting in grade 4.

During the academic year 1990/ 1991 the credit hour system was adapted in the general (science and humanity) and commercial secondary education, and was generalized in the year 1994/1995. A total of 156 credit hours is required to graduate for all streams, except the technical stream where 180 credit hours are required. At the end of the secondary level, students are awarded the General Secondary School Certificate.

The present physics curriculum was the result of the recent change which accompanied the adaptation of the credit hour system in 1991. This "structural" change created an opportunity for the science curriculum specialists at the ministry to update curricula, textbooks and laboratory manuals. Throughout the three years of secondary cycle the physics curriculum is organized into ten courses. Each course is taught over a period of one semester (i. e., 15 weeks) and is allotted either 2 or 4 credits. (One credit is roughly equivalent to 15 periods of instruction, 50 minutes each.) The physics courses are listed below, along with the credits allotted per course.

1. Physical Quantities and Heat [2].

2. Fundamentals in Mechanics [2].
3. Fundamentals in Electricity [2].
4. The Spectra [2].
5. Waves [4].
6. Force and Motion [4].
7. Electromagnetism [4].
8. Alternating Current and Electronics [4].
9. Nuclear Energy [2].
10. Energy and Machines [4].

Students in the science stream of the general secondary education are required to successfully complete the first seven courses of the above list. Students may also select an additional one or two of the remaining courses as electives depending on their interest. Of the above list, Physical Quantities and Heat is the only *required* physics course for *all* secondary students. In Bahrain, a significant number of students opt for the science stream at the secondary level, where biology, chemistry, and physics constitute a major part of the curriculum. However, of these students only a small proportion continue to specialize in science and science related areas, such as engineering and medicine.

The goals of physics education, the content of each course and, when appropriate, the laboratory work, are all specified in detail by the Ministry of Education. Students' textbooks and laboratory manuals are written jointly by physics teachers, university physicists, and the ministry's physics curriculum specialists according to the prescribed curriculum. All textbooks and laboratory manuals are published by the ministry and distributed to schools. The ministry also provides schools with laboratory equipment and

apparatuses. The sequence and depth of the physics content taught closely match that of the textbooks. Within each school, students are evaluated by their teachers and although a variety of assessment methods are advocated and encouraged by the ministry, written exams are still the most commonly used techniques. This is not surprising, partly because the marking scheme specified by the Assessment and Examination Policy places emphasis on exams (50% of the total mark is to be obtained from the final exam and 20% from the mid-term exam), and partly because the teachers themselves, and for a variety of reasons, are reluctant to use other methods. For example, practical assessment is encouraged and mandated by the ministry and allotted 30% of the final exam's mark, but teachers consider it to be time consuming and an easy means to obtain high grades for the less able students. Even when practical assessment is conducted, it is rarely well prepared and quite often the tasks are mere repetitions of earlier experiments or practical exercises (Rafea, 1987).

Public schools in Bahrain are not coeducational, and girls are taught by female teachers whereas boys (except in grades 1 through 3) are taught by male teachers. All female and most male physics teachers are Bahraini. Moreover, the ministry requires that all teachers obtain an undergraduate degree in their specialized subjects with a minor or a diploma in education to be eligible for teaching at the secondary level. Like other schools elsewhere, teachers are organized within their school by departments (Siskin, 1994); the physics teachers belong to the science department. The number of physics

teachers in each department generally ranges from 2 to 4 depending on the number of students in the school. At the time of the study, there were sixteen secondary schools offering a science stream where a full physics curriculum was taught.

Over a period of 25 years, I have had direct experience with three different physics curricula in Bahrain: as a secondary school student when I learned the Egyptian physics curriculum, as a physics teacher who taught the courses that were later on locally developed and, finally, since 1984, as a member of the science education department in the ministry that is responsible for the development and implementation of the current physics curriculum. These curricula do not escape most of the criticisms commonly found in the science education literature, such as abstractness, remoteness from real life experience, authoritative and didactic teaching style, and emphasis on factual information (e.g., Eckert, 1990; Lave, 1990; Martin & Brouwer, 1991). While there have been some changes over the years— better textbooks, new topics, and more applications of physics— the "curricular emphasis" or "companion meaning," in Roberts' (1988, 1998) term, did not change; all courses continued to reflect the structure of the physics discipline, and emphasized the development of a solid foundation for the next level of education, be it the next secondary year or post secondary education. Also, the prevailing practice in physics classrooms, as I have witnessed over the years, has been the emphasis on physics problem solving; this refers to the mathematical manipulation of variables and formulas and involves numeric calculations.

With such prevailing practice, it is not surprising that school physics has become, as Treagust et al. (1990) described, a formula-applying process bearing little relation to the real world. For many students, this is perhaps the most frustrating and discouraging aspect of physics courses.

3.2 The Study

This study utilized a qualitative approach to explore issues of power in the context of physics curriculum making in Bahrain. Disciplinary school subjects are relatively stable networks, or black boxes. The problem with studying established black boxes is that they hide the networks that constructed them and the tensions involved in their construction. When a black box is formed it appears as if it has always existed on it is own. Therefore, a problem with exploring power relationships in an established curriculum is that the process whereby these relationships were created remains out of sight. For this reason, it is appropriate to explore power relations in a context of change where the actor-network, including the power relations, are destabilized; by exploring curriculum in the making, we can learn about power in the making. The proposal to introduce a PTS innovation in secondary school physics in Bahrain created an opportunity, or a point of entry, to explore the issue of power in curriculum making.

Latour (1987, 1988, 1996) and Callon (1986, 1987) followed scientists and engineers to understand how facts and artefacts were produced. These "tokens" simultaneously shaped and were being shaped as they moved among

the various actors involved in the networking. Similarly, in this study, I followed the PTS innovation as it was negotiated by many actors who were interested in it. In following the story of the PTS innovation, I paid specific attention to how power was manifested and enacted through the network. But in distinction from previous uses of ANT, I acted as a networker in problematizing and enrolling actors into this PTS network (section 3.3).

3.2.1 The PTS Innovation: Links with STS and the PLON Project

In science education, STS courses attempt to integrate the disciplinary science areas (i. e., physics, chemistry and biology) and to contextualize them in technology and social issues. Given the flexibility of the boundaries defining the STS movement and the broadness of its goals, it is not surprising that, in practice, STS education has been interpreted in many different ways (e.g., Cheek, 1991; Fensham, 1988; Layton, 1994, Rosenthal, 1989; Ziman, 1994). Aikenhead's (1994, pp. 33-56) "Categories of STS Science" provides a useful scheme to situate the variety of STS curricula and courses. The scheme consists of eight categories and expresses the relative importance given to STS content compared to traditional science content. However, at the secondary level a major constraint, imposed by the educational structure that divides school science into individual subjects, is the need to retain the boundaries of each subject. As such most STS courses designed for the secondary level are either optional or offered to non-science students. Therefore, instead of integrating science courses in general with technology

and society issues (and talk about STS), it is more feasible in secondary schools to integrate a particular disciplinary science subject, say physics, with technology and society issues (and talk about PTS). Aikenhead's scheme can then be adapted to provide descriptive "Categories of PTS Physics" that define variations in PTS content in the curriculum. These categories are described in Table 2 below.

Table 1: Categories of PTS Physics
(Adapted from Aikenhead, 1994, pp. 55-56)

1. MOTIVATION BY PTS CONTENT
Traditional school physics, plus a mention of PTS content in order to make a lesson more interesting. Students are not assessed on the PTS content.

2. CASUAL INFUSION OF PTS CONTENT
Traditional school physics, plus a short study of PTS content attached onto the physics topic. The PTS content does not follow cohesive themes. Students are assessed mostly on pure physics content and usually only superficially (such as memory work) on the PTS content (for instance, 5% PTS, 95% physics).

3. PURPOSEFUL INFUSION OF PTS CONTENT
Traditional school physics, plus a series of short studies of PTS content integrated into physics topics, in order to systematically explore the PTS content. Students are assessed to some degree on their understanding of the PTS content (for instance, 10% PTS, 90% physics).

4. PHYSICS THROUGH PTS CONTENT
PTS content serves as an organizer for the physics content and its sequence. Students are assessed on their understanding of the PTS content (for instance, 20% PTS, 80% physics).

5. PHYSICS ALONG WITH PTS CONTENT
PTS content is the focus of instruction. Relative physics content enriches this learning. Students are assessed about equally on the PTS and pure physics content.

Table 1 (Continued)

6. INFUSION OF PHYSICS INTO PTS CONTENT
PTS content is the focus of instruction. Relevant physics is mentioned, but not systematically taught. Emphasis may be given to broad physical principles. Students are primarily assessed on the PTS content, and only partially on pure physics content (for example, 70% PTS, 30% physics).

7. PTS CONTENT
A major technology or social issue is studied. Physics content is mentioned but only to indicate an existing link to physics. Students are not assessed on pure physics content to an appreciable degree.

In this research, three units were used as exemplars for discussing the PTS innovation: Water For Tanzania (WFT) (PLON project group, 1983), Ionizing Radiation (IR) (PLON project group, 1984), and Light Sources (LS) (PLON project group, 1984). The units were adopted from the Netherlands' PLON project for physics (Eijkelhof, 1983; Eijkelhof & Lijnse, 1988). The units vary in their emphasis on either technology or social issues related to physics and technology, and also include content that can be described as 'pure' physics. A brief description of the PLON project and these units is given below.

The physics curriculum development project (PLON) was initiated in 1972 with the purpose of modernizing and updating secondary school physics in the Netherlands. The project ended officially in 1986, but the project developers have continued to evaluate and modify the materials based on the research findings. Because the PLON curriculum was meant to replace the "traditional" physics courses, it was necessary to create a balance in the

curriculum between preparing students for further studies in science and preparing them for life (Eijkelhof & Lijnse, 1988). The PLON curriculum consisted of about forty units, of which students would normally study five or six units each year throughout their five years of secondary education. Examples of units developed are: traffic and safety, energy and quality, nuclear weapons and/or security, ionizing radiation, water for Tanzania, light sources, and matter. Each unit is built around a question or theme that is generally relevant to students. For instance, in the unit ionizing radiation the central question is "how acceptable is the risk of radiation" to students, while the unit nuclear weapons and/or security develops around the theme of security through deterrence versus security through disarmament (Eijkelhof, 1983).

The two most important features of the PLON curriculum, according to Wierstra (1984), are: "context-learning" and "inquiry-learning by pupils." The first feature is reflected in the titles of the units and signifies the importance of understanding the applications of physics concepts and models in a variety of social, technological and scientific settings. By adopting such a feature, the PLON curriculum made a significant departure from traditional school physics, a departure that was described as a "change of emphasis from academic physics to applications, systems, functions and skills which are relevant for living in a highly technological society" (Eijkelhof & Kortland, 1982, p. 4).

Finally, research conducted by PLON developers regarding the effects of this curriculum on students in domains like cognitive achievements, affective and attitudinal outcomes, and the learning environment in the classroom has produced favorable results (Eijkelhof, 1994; Eijkelhof & Lijnse, 1988; van der Valk, 1989; Wierstra, 1984).

Water For Tanzania (WFT)

This unit deals with the problem of water and pumping techniques in a developing country like Tanzania. The role of students in this unit of study was described in the introduction:

> You and your classmates are on the staff of the (imaginary) Technical Advisory Bureau of Africa (TABA) for the duration of the theme. This firm of consulting engineers has been asked by the Department of Development Cooperation to advise on a pump to be installed in the village of Kisima in Tanzania. Four working groups of TABA are each going to *study a separate pump, build a model of it and express their opinion on its suitability*. Each group will demonstrate its pump to other TABA staff members (in other words classmates) and say what they think about it. The whole 'office' will then decide which of the four pumps they will advise the Department to install. You are going to play a role game— the meeting of TABA in which this decision is taken (p. 6).

The students in this study are engaged in solving a real problem, which provides a genuine purpose for learning and makes the activities meaningful. Students work as groups, share opinions, and contrast alternatives as they actively participate in devising solutions to the problem posed. They explore

four types of pumps: the displacement pump, the hose-and-bucket pump, the suction pump, and the rope pump. Students study how each pump works, determine what criteria specified by the Department are met by the pump, and give arguments for and against its use. In the process, students become aware of the significance of understanding the social, economic and environmental contexts in which the pump will be installed. Preliminary information concerning the life in the village, availability and quality of groundwater, and climate is provided in the unit, but students are referred to other references and encouraged to consult people for more information as deemed necessary. The unit does not focus on the physical concepts as much as on the technology (design, effects, use) of the pumps. In the section on "how the pumps work" the students examine more closely how each pump works. Scientific explanations are offered mostly in a qualitative manner.

Ionizing Radiation (IR)

Ionizing Radiation exemplifies a unit of study that, according to Fensham (1992, p. 813), is "STS in character" compared to earlier materials developed by the PLON which were "STS-influenced." This unit emphasizes acceptability and risks involved in the applications of ionizing radiation. Although scientific knowledge is not ignored, the unit emphasizes the use of this knowledge to help students gain insights and "contribute to the economic, political, medical and social debates" pertaining to radiation (p. 4). The main questions sought in this unit are: Where does radiation come from, what are the properties of

ionizing radiation, how do we measure these radiation, what are the effects of these radiation on the human body, for what particular applications is radiation useful, and how is protection possible?(p. 4).

The unit begins by introducing numerous everyday situations in which ionizing radiation is involved, and leads to the nature of "risk" as a concept. Examples of these situations include: a nurse taking X-ray photographs, or using radiation on patients, a technical medical worker in a hospital who is responsible for the cleaning and disposal of radioactive waste, an activist campaigning against nuclear energy, and a resident of a city in which a nuclear power station is situated. The next part discusses some basic scientific knowledge concerning properties, effects, and sources of ionizing radiation (chapters 2-4). Physical concepts covered include: radioactive decay, activity, half-life, energy of radiation, nuclear fission and fusion, etc. Students then explore areas of applications including nuclear energy, nuclear weapons, and health. Concepts relevant to risk assessment, such as radiation dose and somatic and generic damage, are introduced along with the relevant physics concepts. Finally, the unit deals with the issue of acceptability and risk associated with ionizing radiation. Collecting information from literature and interviewing people are central activities in which students are engaged as they learn the content, making the unit particularly unique in terms of its approach to secondary physics teaching. Contextualizing scientific content into society and technology allows students to engage in controversial issues whereby they may develop decision-making and critical thinking skills. The

following activities and exercises are illustrative of the approach used extensively in the unit.

(1) *Types of nuclear weapons:*
In articles on nuclear weapons one encounters terms such as light and heavy weapons, and clean and dirty weapons. Try to determine the meanings of these terms from the literature. Use physical concepts to illustrate the meaning of these terms (p. 50).

(2) *Nuclear shelters*:
Opinions about the effectiveness of nuclear shelters are sharply divided.

- Collect a few of those opinions and write down the arguments which support them.

- Try to develop a shared point of view in your group, and formulate this point of view in the form of a thesis. Ensure that you are able to defend this thesis in a debate or discussion with others (p. 57).

(3) *Radiation load:*
Medical applications of ionizing radiation make a significant contribution to the average radiation load of a citizen of the Netherlands (see the table on page 16). Consistent with the ALARA [As Low As Reasonably Achievable] and the justification principles, it is attempted to keep this dose to the minimum. Some people believe that concern about x-ray photos is largely unwarranted. As they put it: "The dose for a chest X-ray is about equal to the dose received in a few week's winter sport at an altitude of 2000 m, and nobody is concerned about that."

- Find out what the dose is for a number of common treatments. Convert this dose to a body equivalent and compare this with the dose received during a few week's skiing at an altitude of 2000 m.

- Is a concern about radiation doses in X-rays realistic or is it an exaggeration? Why? What is your view?

- Are patients informed, as a rule, about the size of the radiation dose? Are there instances in which the size of the dose could be regarded as a reason to cancel the treatment or to replace it by another type of treatment? (p. 62)

Light Sources

This unit deals with social, scientific and technological aspects of light. It is an example of a unit of study where the scientific content traditionally found in physics textbooks is maintained, but thoroughly dealt with in a social and technical context making it both useful and meaningful to students. The topics covered in the unit include: illumination, measurements of light, incandescent lamps, gas discharge lamps, light and atoms, and modern light sources. The specific scientific content includes: reflection, interference, diffraction, atomic spectra, energy levels, and flux. The introductory chapter summarizes the social, scientific, and technical questions that the unit deals with. These are:

- For what purposes are we using the different kinds of light sources? What requirements do we have for illumination of the home, the street, etc.? What does it cost us? How much energy is involved? How can we reduce lighting expenses? (Social questions).

- What happens when a material gives off light? What is light? What are the laws and processes which govern the type and the amount of emissions from the various kinds of light sources? (Scientific questions).

- How are all of these different kinds of lamps constructed? How do we use physical laws and the processes in the development of modern light sources? When there are

conflicts in the requirements specified for light, how can we select the best solution? (Technical questions). (p. 1-6)

Light Sources includes many hands-on activities that involve using prisms, lenses, and ripple tanks to investigate and measure certain properties of light. In addition, graphs, tables and, to some extent, formulas (e.g., $\lambda = d \cdot \sin \alpha$, $c = \lambda \cdot f$, $\Delta E = h\nu$) are extensively utilized, and students are encouraged to use them both in the traditional sense to calculate physical quantities as well as to contrast ideas and draw conclusions for specific practical situations. For instance, consider the following exercises given on the section on illumination.

(i) Calculate η of the two types of fluorescent lamps (white and deluxe white), using data from the tables. Put the results in a table including the η of a 75 Watt incandescent lamps.

(ii) Using your table of ηs, find out which method of lighting uses the least amount of energy: incandescent lamps, fluorescent lamps or economizer lamps?

(iii) What other factors play a role in choosing whether to use incandescent lamps, fluorescent lamps, or economizer lamp? (p. 2-6).

In another investigation, students were given the following tasks:

(a) Compare your conclusions with the following quotation from the article "To Save on Lighting" from the February 1984 edition of *Consumentengids*.[The quotation was then shown below].

(b) Calculate the percentage of energy saved in a house if you replace all incandescent lamps by fluorescent lamps (with

total light output remaining the same). Do the same for economizer lamps.

(c) What are the cost savings? .... Can you criticize the conclusion from the article in the *Consumentengids*?

A combination of these or similar units represents what I refer to as the PTS innovation; a version of a PTS curriculum that fits within Category 6 in the scheme described above. Therefore, these units do not stand for the PLON curriculum because the latter fits Category 4 (Singular discipline through STS content) in Aikenhead's (1994) as well as the modified scheme. I should emphasize, however, that the innovation was not presented as merely three units; rather these units were exemplars for other units that could be developed in Bahrain for grades 10, 11 and 12, and collectively described as category 6 in the PTS physics continuum. As such, the proposed innovation suggested that a complete curriculum be designed with PTS content being the focus of instruction and comprising about 70% of the curriculum content. The remaining would be devoted to 'pure' physics content. Currently, the time allotted for physics at the secondary level allows for about 12 units to be developed and taught to all science students. The idea of using units was also suitable in the Bahraini situation because the curriculum is organized by (mini) courses, where each course corresponds to 30 or 60 periods of instruction. This is equivalent to the amount of time needed to cover each exemplary unit in classroom teaching.

3.2.2 Sources of data: Actors in the school physics network

Data were collected from two sources: a series of interviews with actors, and my own reflective notes. The latter included my thoughts, analyses and dilemmas as they emerged throughout the inquiry, as well as summaries of and thoughts about conversations pertaining to the inquiry that were unplanned but occasionally took place between myself and other participants, especially the ministry personnel. As for the interviews, certain actors could be identified beforehand because the network already existed; identifying all actors was neither possible nor necessary to begin with, as some actors would lead to other actors. Being involved with physics education in Bahrain over the past seventeen years, I was an established actor myself and, therefore, could identify initial actors; furthermore, the secondary science education department at the ministry, physics textbooks, and the consultation committee for science curricula were sources for identifying some of the actors in the school physics network. When I looked at the established network, some actors initially "appeared" more important than others and certain actors were not even seen as part of the network. As change was proposed for the curriculum, the stability of the actor-network was challenged; in fact, it was no longer the same network. In this circumstances, I expected new actors to emerge, and that those who previously were considered peripheral could move to the center, and so on.

In brief, then, given the history of the network some "key" actors, or actors who were centrally involved in physics curriculum making, could initially be

identified, and in the ensuing controversy I expected to find what other actors they called upon. For the purpose of this study I believe enough actors were identified and interviewed to provide an account of the complexity of the school physics actor-network; in particular, to give sufficient data to understand the heterogeneity of the network and answer the research questions. However, if I were to follow the network through to its closure, that is, until the controversy is settled, then it would be necessary to provide an account of the views and roles of actors such as parents who emerged in the controversy and appeared to be significant in the network, but nonetheless were not interviewed.

Before describing the actors interviewed, a point regarding the extent to which they "represent" other actors needs to be made. As stated in the previous chapter when discussing ANT and the Translation Model, this issue is related to "mobilization." The absence of "official" organizations (e.g., unions, associations) representing the actors involved in this controversy proved to be a constraint when selecting teachers and students for interviews. This constraint was less relevant in the case of other actors such as university physicists and ministry personnel (because of their small numbers), but nevertheless the issue of representation may be significant for following the settlement of the controversy.

1. *Ministry of Education personnel*

Within the ministry group, the physics curriculum specialists and the head of the secondary science education department were most directly involved with physics curriculum development. Initially, there were two physics curriculum specialists, but during the course of this inquiry one of them left the ministry and was not replaced. The Director of the Curriculum Development Department, though not directly involved, was nonetheless identified by myself and other ministry members as someone who could play a significant role in curriculum decision making and the promotion of the PTS innovation. In all, three members of the ministry group were interviewed: a physics curriculum specialist, the head of the secondary science education department, and the Director of the Curriculum Development Department.

2. *Secondary physics teachers*

Initially all physics teachers were informed about the study and invited to participate. Invitation letters were given to the senior science teachers (i.e., the heads of the science departments in 16 schools) during their meeting with the secondary science curriculum specialists. The head of the ministry's secondary science education department chaired the meeting. In this meeting, I emphasized that the study was related to a proposal to introduce change in the physics curriculum and that participation was voluntary. Although the meeting was not primarily held for the purpose of discussing my research or the proposal for change, its being on the agenda conveyed the seriousness of the proposal for change. This was particularly true after the

chair commented that the ministry was considering this proposal, and urged the senior teachers to encourage all their physics teachers to participate in giving their opinions regarding the matter.

Surprisingly, not as many teachers as I expected were interested in participating. Later on, I found that many were uncomfortable with the idea of being recorded and that my request to obtain a written consent from participants worried some teachers and made them suspicious. In his book, *Knowledge and Authority in the Arab Society*, Saboor (1992) noted a similar phenomenon among the Arab academics whom he studied. In his account of this observation, Saboor (1992, p. 210) argued that this type of research was still not well established in the Arab world and, more importantly, that the data collection techniques involving recorded interviews are often associated with police interrogation, especially when a conversation involves sociological and ideological issues.

In spite of this, 27 teachers volunteered, which was more than needed to provide a "maximum range" of views concerning the introduction of PTS in secondary schools. I had a conversation with each of them for two purposes. First, to ensure that they were wanting to participate voluntarily and that they were not pressured directly or indirectly by the heads of their department or someone else, including myself. Second, that they had a purpose for participating other than "helping me" or "doing me a favor." Based on these criteria, I selected nine teachers (four males and five females) whose experience ranged from four to twenty-four years in teaching physics at the

secondary level. Among them were teachers who had a wide reputation and established credibility among their colleagues, as well as having co-authored some of the previous and currently used physics textbooks. The group also included teachers who felt that such a major change in curriculum should not be carried out without their involvement. Therefore, although the selected group did not "represent" all the physics teachers, the diversity of their views represented the diversity of views among teachers. Further, throughout the data collection stage, I was sensitive to any comment or observation, especially from teachers, suggesting that certain teachers should specifically be consulted. This happened once; a teacher called and recommended that I interview and consult a specific teacher who happened to be among the selected group. No other names were mentioned. In addition, as I found later on, some of the teachers talked among themselves about the interviews and the PTS units and have commented positively on the teachers I selected for the interviews[1]. In any case, whether some of these teachers were able to speak on behalf of other teachers cannot be known at this point, but will be an important issue in settling the controversy.

The nine selected teachers were interviewed individually or as a group, according to their wish. The focus group consisted of four teachers; three females and one male.

---

[1] I have maintained the confidentiality of teachers and at no time revealed their names to any one. But, as it turned out, they talked among themselves and revealed their identities to each other.

3. *University physicists*

Historically, in Bahrain, the Ministry of Education invited and encouraged physicists, especially who were Bahraini nationals, to participate in curriculum development and textbook preparation. Needless to say, they had a vested interest in physics education and sought to influence it in a variety of ways. The number of Bahraini physicists who work in the university is not large; during the data collection phase of this study it was seven. Of these, four, including the head of the physics department, were selected to participate. Two of the physicists had been involved previously in curriculum development and textbook preparation for schools. All of them had experience in teaching physics to first year university students and two of them were currently teaching first year physics to science and engineering students. These physicists had direct experience with students in their very early stage of university education, and had concerns about the kind of preparation that the students received in secondary schools.

The physicists took the project very seriously. In my first visit with the head of the physics department and after discussing my research with him, we went to the lounge for coffee. While we were there, the Dean of the Faculty of Engineering joined us for a short time. The head of the physics department introduced us and informed him that I would be conducting a study and would need to interview some university professors and students. The Dean commented that "university professors are very busy with their academic work and research and usually do not have time to participate in such [educational]

research." Interestingly, the head of the physics department interrupted by saying: "no, but this is a very important matter. And above all, physicists must participate and must be consulted before making any significant changes" (Reflective notes #5). I was pleased to hear this because it meant that he was taking my proposal for change seriously, and not just to help me with my thesis.

4. *Students*

Students are, by and large, the acknowledged stakeholders in any school curriculum. Yet their views are rarely sought and they are almost never consulted in curriculum decision making (Blades, 1994; Fullan, 1991). However, as this study shows, students were referred to by many other actors and in different ways. As such, it was reasonable to include them as participants in negotiating the proposed curriculum change. They were drawn from four populations:

1. Grade 12 science students (boys).
2. Grade 12 science students (girls).
3. First year university science students.
4. First year university engineering students.

In each group, students were selected from a typical classroom. After explaining the purpose of the study, I asked for volunteers; however, most (especially among university students) were not interested in participating and apologized for not having the time to spend on reading the PTS materials and to participate in the interviews. For each of the four populations, only 5 or 6

students volunteered and they were interviewed as groups. It was assumed that, as a group, students would speak more openly and be better able to express their views. The secondary students who volunteered were all, except two, enthusiastic about entering post-secondary education in medicine, engineering, sciences, and mathematics. A total of twenty-two students participated.

5. *Industry representatives*

Industry is a good example of a non-traditional actor in the school physics network. Industry had been recognized as a "key" actor in vocational (technical) education, but ignored in the academic school physics curriculum. In Bahrain this was evident by the presence of representatives from industry on vocational curriculum committees and their total absence from all committees pertaining to academic (general) education. Elsewhere, researchers (Gaskell & Hepburn, 1998) have shown the significant role that industry could play in support of less academically and more vocationally oriented science courses, such as applied physics. I included industry in the negotiation process on the belief that they could play a role in the promotion of the PTS curriculum.

Three individuals representing two of the largest oil and non-oil based industries were interviewed. An electrical engineer with a position as power and utility superintendent represented one large company. A director of training and his assistant engineer represented the other major company.

6. *University physics educators*

Like university physicists, physics educators sat on curriculum committees and participated in textbook preparation. Only one person had a background in physics and therefore had an interest in participating.

Table 2 summarizes the participating groups, the number of actors in each group, and the type of interviews conducted (i.e., individually or as a group). It also includes the codes I used for referencing each participant; these codes, rather than pseudonyms, better maintain anonymity.

Table 2: Summary of participants and symbol codes used for referencing.

Groups/ Participants	Number of participants	Symbol Codes	Type of interview
University physicists	4	Uph#1, Uph#2, Uph#3, Uph#4	Individual
Physics teachers	9	T1, T2, T3, T4, T5 T6, T7, T8, T9	Individual Group
Ministry of Education	3	MEP#1, MEP#2, MEP#3	Individual
Secondary students/ Boys	6	SB1, SB2, SB3, SB4, SB5, SB6	Group
Secondary students/ Girls	6	SG1, SG2, SG3, SG4, SG5, SG6	Group
First year university science students	4	USS#1, USS#2, USS#3, USS#4	Group
First year university engineering students	6	UES#1, UES#2, UES#3, UES#4, UES#5, UES#6	Group
Industry representatives	3	INR#1, INR#2A, INR#2B	Individual
University physics educators	1	UPE	individual

3.2.3 Data collection

Data were collected in three phases. The first two phases were accomplished during the period between 15 September 1996 and 8 February 1997. The third phase, while partly begun towards the end of this period, was primarily conducted during September 1997. In Phase One, the interviews focused on the participants' responses to the three PTS units (see the section above for details on the innovation) which were given to them at least a week before the interview date. Participants were asked to review the three units and to think about the possibility of adopting these or similar units in the physics curriculum. Discussion during the interviews also involved participants' views concerning using the PTS emphasis in general to redesign the secondary physics curriculum. The interviews were semi-structured and I used a prepared but flexible interview protocol (Appendices A &B). I used the same general framework for all participants but maintained flexibility to follow new ideas suggested by the participants. In Phase Two, the interviews focused on the participants' responses to the views of other participants which were elicited in Phase One (Appendix C). Ideas and views were discussed but no names were mentioned; for example, physicists were asked to comment and react to certain claims, arguments, or suggestions made by a university educator, a ministry official, or a student. The participants were also told whether there was uniformity or variation in the views of the actors within the groups. The discussion with actors also involved the views of others within their groups. Actors were also told when others held similar and supporting

views. The data in this phase were helpful in exploring the extent to which the actors held to their initial ideas once they were challenged by other actors' views (including myself), and the type of modification, if any, they suggested. During each of the two phases, interviews were completed with participants from a given group before moving to the next group. Finally, in Phase Three, a decision was made by the ministry to proceed with piloting some PTS materials. According to the ministry, the pilot is a step towards developing and implementing a particular version of PTS curriculum, namely Category 5 (physics along with PTS content). That decision was negotiated between myself and other members of the ministry and in the light of the views elicited in the previous phases. That decision was then discussed in interviews with university physicists, secondary physics teachers and the university physics educators (Appendix D). The interviews in this stage were conducted with the purpose of probing for actors' reactions and anticipated actions in response to the ministry's decision. It should be emphasized that the ministry's decision was, in fact, a result of an ongoing negotiation throughout the inquiry process, although it was officially formulated in the third phase. The nature of this decision will be discussed in the analysis chapters.

Most interviews extended beyond one hour, and were audio-recorded and transcribed verbatim. Interviews were conducted in Arabic, except for the industry people who spoke mostly in English. Each participant was provided with transcripts of his or her interviews for comments and clarification. They were allowed enough time (about a week) to review the transcripts before the

follow-up or the next interviews were conducted. This served as a member check and a means to obtain confirmation from the participants on their comments which were to be used for analysis and quotation. While this was a relatively quick procedure in the second and third phases, it involved lengthy discussions in Phase One; indeed, these follow-up interviews for Phase One lasted between 30 to 60 minutes and provided useful data.

In the analysis chapters, the following notations are used to identify which of the four interviews was the source of a quotation:

- The letter A indicates interviews conducted in Phase One.
- The letter B indicates Phase One follow-up interviews.
- The letter C indicates interviews conducted in Phase Two.
- The letter D indicates interviews conducted in Phase Three.

Table 3 summarizes the interviews conducted throughout the three phases of the data collection and the participants in each phase.

Table 3: Interview phases and participants in each phase.

Groups/ Participants	Phase 1 interview (A)	Follow-up interview (B)	Phase 2 interview (C)	Phase 3 interview (D)
University Physicists: Uph1, Uph2, Uph3, Uph4.	✓	✓	✓	✓
Physics Teachers. Individuals: T1, T2, T3, T4 & T5.	✓	✓	✓	✓
Focus group: T6, T7, T8 & T9	✓	✓	✓	✓
Ministry of Education Personnel MEP#1, MEP#2 & MEP#3.	✓	✓	✓	✓
Secondary Science Students				
Focus Group (Boys): SB1,SB2, SSB3, SB4, SSB5 &SB6	✓	✓	✓	x
Focus Group (Girls): SG1, SG2, SS3, SS4, SG5 &SG6.	✓	✓	✓	x
University Physics Educator: UPE#1	✓	✓	✓	✓
Industry Representatives: INR#1, INR#2A, INR#2B.	✓	✓	✓	x
First Year University Science Students: Focus Group: USS#1, USS#2, USS#3, USS#4.	✓	✓	✓	x
First Year University Engineering Students: Focus Group: UES#1, UES#2 UES#3, UES#4 & UES#5.	✓	✓	✓	x

3.2.4 Data Analysis

In this study data analysis refers to the process of moving from raw data towards an account of the school physics actor-network and the issue of power in curriculum making. This process was accomplished through several steps of data transformation and reduction. The raw data consisted of interview transcripts (in Arabic) as well as my reflective notes and summaries. Initially, the data corresponding to each group of actors were organized chronologically; that is, according to the three phases.

Following the suggestion from McMillan and Schumacher (1993) and Merriam (1988) for data analysis I began by reading through all the data several times "to gain a sense of the whole" story. Two broad categories were identified: maintaining and restructuring the school physics network. Guided by the conceptual framework (ANT), the research questions, and the problem under study, each category was divided into smaller subcategories. Examples of these included: defining the role of students, the role of PTS in school physics, mobilizing human and non-human allies, linking school physics to university physicists, defining the goals of physics education, linking school physics to high status jobs, maintaining assessment as a black box, redefining assessment, mobilizing extended network, interessement strategies, enrolling actors, translating interests, who counts, structural change in curriculum making, modifying the innovation, and redefining groups. Data segments that captured each subcategory were highlighted, assigned a number, translated

into English, and stored in the computer for easy access and comparisons. The Categories and subcategories, together with my reflective notes and the literature that informed the study, formed the basis for the story told in this thesis.

3.3 The Researcher: An Actor and Networker

Janesick (1998, p. 72) asserts that in any given research project, analysis and interpretation must include "a serious description of the researcher's role in the entire history of the project." Although qualitative researchers generally agree with this statement, it does not follow that all would agree on what is meant by "researcher's role." As a concept, it encompasses several aspects that relate to the researcher him- or herself throughout the course of conducting and reporting research. First, it could refer to the desirable characteristics and qualities that researchers are expected to possess during the inquiry process. Such qualities may include sensitivity to context and people, tolerance for ambiguity, and good communication skills (Merriam, 1988). Second, the term "researcher's role" may also refer to the stance that a researcher adopts during the inquiry, especially during the data collection phase (McMillan & Schumacher, 1993): observer, participant observer, or participant. Finally, the term refers to the position of a researcher within a group that is under study, as well as his or her relationship with the participants. In the following account of my role in this inquiry, I am mainly concerned with the second and third aspects. I begin, however, with a brief

personal reflection in order to situate myself within the context of this research and to provide a sense of its development.

Within the streaming system in Bahrain, many students (both male and female) opt for the science stream and hence study physics over a three-year cycle. A lot of effort (and money) is put into preparing textbooks and other curriculum materials and in providing schools with laboratory equipment and apparatus. Regrettably though, it is my belief that most students neither enjoy learning physics the way it is presented and taught nor do they get much understanding out of it. This is not a recent discovery for me; however, like some of the participants in this study, I assumed that it was "natural" for most students not to find physics interesting and that not many can "actually understand it, and that all that we could do was to teach it in a "better" way, say, by doing more laboratory activities, producing more "colorful" textbooks, and making sure that teachers know their physics well.

Prior to 1993, the state-wide final exams for grade 12 students was the important occasion in the academic year. These "high school leaving exams" were prepared by the ministry's curriculum specialists. In physics, the percentage of students who passed this exam rarely exceeded 70%, with many of these students barely obtaining a passing grade. As a member and head of the committee that corrected and marked students' papers for several years I was struck with how poorly most students performed. Blaming teachers for not teaching properly and students for not putting in enough effort were the main reasons I frequently encountered and even used myself

to explain the fact that most secondary students didn't actually "get the physics right" or do well in the exams. And when these reasons were not satisfactory, we (ministry curriculum specialist and teachers) reasoned that that is how physics "was," and that we should not expect most students to understand it to an appreciable degree, let alone enjoy learning it. But there is a big difference between saying that most students don't find physics interesting and meaningful and saying that the physics curriculum is not interesting and does not make sense to most students. In the first case, the blame is on the students or teachers, while in the second the subject itself is questioned. Eisner (1990, p. 524) once wrote: "No matter how well something is taught, if it is not worth teaching it is not worth teaching well." Nowhere, I believe, does this statement need to be kept in mind more than in physics education. The literature is replete with how to teach, demonstrate, and accurately present to students almost every single topic in physics, but rarely, if ever, are the content, the wide coverage, the in-depth analysis of theories and laws, and the level of abstraction found in almost all secondary physics curricula criticized or questioned. My point here is not that physics itself is not worth teaching. Physics, Woolnough (1988, p. 1) asserted, "is, at one and the same time, a vocational and an educational project, it is both useful and cultural" and hence there is little question about its place in the curriculum. But the question is whether school physics with its present content and form is worth teaching, especially when the usefulness of this content and its

relation to students' society are neither part of that content nor experienced by students.

I had developed an interest in the STS literature and was intrigued by its overall goals. While in the Master's program, I even thought about writing my thesis around some science, technology and society topics to be included in the physics curriculum. But my supervisor suggested then that this was not a very interesting subject since it did not bear much on physics. Besides, all my course work was directed towards improving the current school physics curriculum so that it would better reflect the mother subject as known to practicing physicists. Because of my disciplinary view, it was not surprising that no matter how appealing the STS courses seemed to me, I did not consider them a suitable replacement for the disciplinary courses in secondary schools.

Then, during my doctoral program at UBC, I was introduced to some of the literature which dealt with curriculum from sociological and socio-historical perspectives (e.g., Apple, 1990; Bernstein, 1971; Goodson, 1987, 1988; Hodson, 1988; Rowell and Gaskell, 1987; Woolnough, 1988; Young, 1971, 1976). What struck me most was the idea that school physics could differ in content and organization from what I had known for many years. The notion that school science was a social construct was initially shocking to me, but eventually became a fascinating revelation. School physics, after all, did not have to be the way it was; relieved of the idea that the disciplinary oriented

curriculum represented the only legitimate version of physics curriculum, I began to seriously consider other options.

The sociopolitical approach to curriculum and curriculum making suggested an interesting avenue for researching the possibility of bringing about change in the physics curriculum, particularly towards incorporating more STS materials. Initially what motivated me most to pursue research in this area was the possibility of introducing this kind of change in the physics curriculum in Bahrain, and to identify constraining factors. Given my previous experience with curriculum development and the central role played by the ministry of education, I did not expect the task of introducing such a change to be difficult, but I thought the exploration would be worthwhile in order to shed light on the views of the various actors, and to explore how they correspond with Western curriculum theorizing.

Through reading the literature on STS and curriculum change, and as I begun to collect the data for this research, I became more committed to the task of bringing about change in the physics curriculum, although I was gaining a new appreciation of the difficulty of the task. Speaking of developing countries in general, and middle eastern countries in particular, George Za'rour (1987, p. 733) argued that:

> In centralized systems, government officials in the Ministry of Education have to be convinced about the change and, once they and their superiors are convinced, the innovation is likely to be sweeping, covering a whole country.

Markee (1997, p. 63) made a similar point about curriculum change in centralized systems whether in developing or developed countries such as France and Japan. Markee described this as a top-down approach or "center-periphery model" and argued that:

> In these countries, the power to promote educational change rests with a small number of senior ministry of education officials who are at the center of the decision-making process. Teachers, who are on the periphery of this decision-making process, merely implement the decisions that are handed down to them.

Given my previous experience with curriculum development in Bahrain, Za'rour and Markee's argument made a lot of sense, but did not quite fit the curriculum making process I was exploring. "Power," at least in this curriculum case, was more complex than portrayed by Za'rour and Markee, and was more than a "thing" possessed by the ministry or any particular actor. Power became the central theme of interest to me and it was here that I found ANT helpful.

My role as a physics curriculum specialist in the ministry is to propose change in the physics curriculum, argue for it, consult people interested in the matter, and participate in the decision making process. My task as a researcher, though, is to understand how power is manifested and enacted in this situation. My research design combined—and depended upon—both roles. It was because of my insider's role that I had access to this natural setting. In my role as a ministry curriculum specialist, I proposed change in the physics curriculum and carried out the negotiation with various actors.

Being an insider added 'reality' to the whole process, and allowed for an inside view of the network. Some writers (e.g., Glesne & Peshkin, 1992; Andeson et al., 1994) cautioned that when a researcher already has an established role within the setting it may be difficult for respondents to dissociate this role from his or her role as a researcher and, in turn, this could lead to some confusion for them. However, for the participants involved in this study, the more they perceived the researcher as a participant actor the better it was in terms of providing an accurate account of their efforts in maintaining or constructing networks. As the study progressed into the second phase, it became clear that participants took seriously the issues discussed, thereby furthering my understanding of how the various actors constructed power relations in the context of this curriculum change.

However, this raises certain issues. For example, according to Anderson et al. (1994), the researcher as participant "makes it hard... to step back and take a dispassionate look at the setting" (p. 54), "to see the taken for granted aspects of their practice from an outsider's perspective" (p. 28). While this is an important issue, it is of less concern in this research because making problematic many of the taken for granted assumptions regarding physics teaching and curriculum practices was the purpose of this study.

In summary, I engaged in this inquiry both as a researcher and a full participant or actor. As an inside-actor interested in promoting an innovation in the secondary physics curriculum in Bahrain, I carried my role in the usually expected manner, as allowed by my position in the ministry and my

established relations in the school physics network. The design of this research combined the roles of insider and researcher. The task of the insider was to initiate curriculum change or, to put it in ANT's language, to restructure the school physics network, whereas the task of the researcher was to understand how power was enacted or constructed in this actual situation.

Summary

In this chapter I described the overall design of the study. Details about the participants and procedures for data collection and analysis were presented, as well as some background information concerning the context of the study. The PTS innovation was described using "Categories of PTS Physics" that define variations in PTS content in the curriculum. The scheme was adapted from Aikenhead's (1994) "Categories of STS Science." Three units, Water for Tanzania, Ionizing Radiation and Light Sources, were described as exemplars for PTS. These units were adopted from the physics curriculum development project (PLON) in the Netherlands. Finally, I discussed my role both as a researcher and an insider and showed how both were related and enhanced each other. The design of this study combined both roles. The task of the insider was to initiate and gain support for the curriculum change. The task of the researcher was to provide an account of the school physics network in Bahrain and to understand how power was enacted and constructed in this actual situation.

CHAPTER 4

THE SCHOOL PHYSICS ACTOR-NETWORK: OPENING A FEW BLACK BOXES

This chapter maps the various elements that constitute the existing school physics actor-network. These elements are heterogeneous in the sense that they include both human and non-human actors that are linked together to form an actor-network. As such, this chapter also illustrates the heterogeneity of the school physics actor-network. I identify these elements by exploring the views and reactions of the various actors who, in response to the challenges brought by the PTS proposal and members of the ministry, strive to maintain the basic features of the existing actor-network. The key actors in this category are university physicists[1], and their views and strategies in mobilizing support for the school physics network will be the focus in this chapter.

4.1 Fundamental Features of the Physics Curriculum Content

The challenge to the existing school physics actor-network by the PTS materials and members of the ministry highlighted several contested elements of curriculum making, including the content of the curriculum, the goals of secondary physics education, the nature of exams and assessment techniques, and students' and teachers' roles and identities. This network and

these elements had been previously black boxed or stable and without need of further justification. The first aspect of the PTS materials that university physicists were prompt in noticing and reacting to was their "descriptive" or "non-mathematical" nature. For these actors, the content of a physics curriculum must, above all, be mathematical and emphasize problem solving.

> **Uph#3:**
> I have read through everything written in this unit, Light Sources, and found general information, not specialized. That is to say, the unit can't stand on its own as a physics unit, because it doesn't cover the topics adequately, but rather gives some general information. Also, many topics are briefly mentioned in this unit and, by the way, *these topics are dealt with in a non- mathematical manner. Totally non-mathematical.* **[A, 2, 6-10]**[2]
>
> **Ahmed:** Is that a problem? **[A, 2, 11].**
>
> **Uph#3:** Of course that is a problem.
>
> ---
>
> **Uph#4:**
> When we emphasize problems and problem solving that means mathematics; formulas and equations. I don't think you can separate math from physics. This is not an opinion; it is a fact.... Math is the language physicists use to tackle problems in physics. That is why teaching physics in secondary school should be based heavily on math. This is a fundamental criterion of a physics curriculum. Next to that we have the content coverage or what topics to include. **[A, 3, 1-2, 6-11].**

In the last excerpt, the claim to emphasize mathematics in a physics curriculum is strengthened by associating it with other entities, "math is the

---

[1] The attribution of this status to university physicists was not an a priori decision. Rather it is an outcome of the analysis in Chapters 4, 5, and 6.

language physicists use," and by detaching it from any personal or subjective source, "this is not an opinion, it is a fact."

The mathematical aspect was so strongly held by all physicists and most university students whom I met that it was a main criterion upon which the PTS units were rejected. Even when a particular unit was considered "good" in that it contained interesting and useful knowledge that is worth including in a physics curriculum, the absence or minimal use of mathematical equations and formulas made it unacceptable.

> **Ahmed:**
> It seems to me that you liked the topics in this unit [IR] more than the other two.
>
> **Uph#2:**
> Yes. Overall, this unit is good. I only want to include the physics that has been omitted and to include more math. In fact, I do not see any numeric questions and problems.... No equations to calculate the energy, the wavelength, binding energy, that kinds of stuff. Without all that, I can't accept it as a physics unit. **[A, 9, 25-26; 10, 2-4].**

Another taken for granted feature of a physics curriculum is related to the "content coverage." In the context of school subjects, this feature is sometimes referred to as "specialization" or "scope" (Young, 1971b; Stodolsky & Grossman, 1995). In fact, defining the curriculum along this dimension was an important strategy deployed by physicists in negotiating what counts as a physics curriculum. For example, a physics curriculum

---

[2] The numbers following the letter correspond to the page and lines in the transcript from which the excerpts are extracted. A semicolon would be used to separate different pages.

should include a restricted area of knowledge that students are expected to cover. In secondary school physics, this "specific content coverage" is derived from the discipline of physics and encompasses areas like mechanics, electricity, magnetism, light and optics, and modern physics that are usually covered in traditional school physics.

> **Uph#2:**
> Of course, we can't cover all areas or fields of physics in a curriculum. However, we can start with some introductory topics like physical quantities and vectors. Then we teach motion in a straight line and in a plane. *It is the same with our present physics curriculum, and probably it is the same everywhere else. As long as we cover the fundamentals in mechanics, electricity, magnetism, light and optics.* It is also preferable to have an optional course on modern physics; nuclear physics, X-rays and those things, for those who are interested in further physics. **[A, 15, 7-13].**

> **Uph#4:**
> The most important area that should be covered well in the physics curriculum is mechanics because, after all, by definition, and you may consult any dictionary for that, physics is the study of motion and energy and their interactions. Naturally, this is a simplified definition but it provides us with basic ideas as to what to include in a curriculum and how to judge the units you are proposing. **[A, 3, 13-17].**
>
> So, first of all, students should study mechanics thoroughly and strongly over the three years of secondary schooling. Then comes electricity and magnetism, both are important areas and could be covered over a span of two years. Also we have waves and light, although less important than the other topics but nonetheless should be covered to some extent. And, of course, the curriculum should include something about heat and electronics. **[A, 3, 20-27].**

The issue here is not whether physicists are right or wrong in their claims to maintain the content of a physics curriculum, but the nature of their argument and the elements they tie to their claim. In insisting on this specific content coverage, physicists mobilize other elements, such as the definition of physics, the dictionary, and the worldwide acceptance of this content. The array of heterogeneous (human and non-human) allies makes the task of challenging such a claim quite difficult. Therefore, it is not surprising to see physicists taking a strong position regarding what a physics curriculum ought to include (and exclude), leaving little or no room for negotiation or compromise, while mobilizing these elements to further support the school physics network. The following excerpts, taken from a later interview with one of the university physicists, make the case clearly.

> **Uph#3:**
> When you ask me to consider changing the content of the physics curriculum I say no. I can't change it. Why? Because it covers the areas that I talked about, that are implied by the definition of physics- the science of the physical world. It is concerned with, and that is what students need to know: how things move? What makes them move? What are these things? What is the use of that movement? .... So, we have objects, fluids, photons, electrons, and all that leads to mechanics, electricity, magnetism, light, fluids. That is physics. **[C, 9, 10-16].**
>
> So, yes the secondary physics curriculum has a given perspective or format, and this is not set by me, as you know. *It is a universal one. Whether in Bahrain or the Arab World, Europe or America. Everywhere.* **[C, 9, 23-26].**

The appeal to a "universal" view of a physics curriculum is particularly significant because it shows the extended nature of the network which

physicists are able to mobilize. In essence, to contest the physics curriculum in Bahrain one has to confront and challenge not only a few localized actors (for instance, physicists in their department in Bahrain), but many actors (physicists and others) in other distant places as well. Indeed, understanding the nature of this extended network would, as we shall see, shape the ministry's decision in a fundamental way. We will also see how physicists were able to utilize this strategy to maintain the physics network once confronted with the ministry's decision to adopt a PTS version of curriculum.

There are two sides to discussing the content of a physics curriculum. The first is what key actors, who want to maintain the existing network, insist on including in a curriculum. The other has to do with content that ought to be excluded from, or at least marginalized in, the curriculum. This means that, in the existing secondary school physics actor-network, the boundaries around the physics curriculum are sharply defined, making it a "closed" (Young, 1971) or "strongly classified" curriculum (Bernstein, 1971). The proposed (PTS) units, and particularly the unit Water for Tanzania, expanded the boundaries around school physics far enough to have caused considerable disturbance to many actors. The following excerpts capture this point rather clearly.

> **Uph#3:**
> They [the authors of the unit] talk about how people live and work, how they eat, etc. Then how to make water pumps, and I see a picture of someone holding a bucket....what is this? To cut the story short, I do not know why you give me this unit [Water For Tanzania] in the first place. I scanned through it and didn't see anything that relates to physics.

> That is all what I want to say. I don't want to comment any further. **[A, 7, 15-18]**
>
> **Uph#3:**
> [with anger] Has nothing to do with physics. It has to do with society, with technology. Would you tell me where is the physics in this unit? As physicists we discuss about fluids, about flow, how the pressure and velocity change, the energy. We talk about the physics of fluids in a scientific manner. But the applications of that, how it is used in Tanzania, all that has nothing to do with physics. It has to do with something else, perhaps technology or engineering, whatever. **[A, 8, 20-25]**
>
> **Uph#4:**
> I am against teaching about appliances or instruments per se. What is important to me is to teach the science itself. To discuss lamps or other appliances will be kind of specialized, very specialized topics. **[A, 11, 8-10]**

The above excerpts also illustrate "interessement." The essence of interessement, it is to be recalled, is to create barriers between an actor and other actors, or to weaken its relationships (links) with certain actors while strengthening those with others. In the above quotes we observe that the physicists attempt to dissociate or weaken the links between the school physics and certain other actants, like society, people, applications and technology, while strengthening its link with disciplinary knowledge of physics and its practice. The strategies employed in this process include discussion, persuasion, and the mobilization of one's expertise and authority. This act of interessement would also serve to weaken the links between the physics curriculum and other actors, such as industry representatives, university science educators, and even ministry officials, who might wish to

affiliate themselves in a central way with a revised physics curriculum. Defining the curriculum in terms of the disciplinary knowledge and practice of physics thus enhanced the physicists' position as spokespersons of the school physics network.

Deciding on a given definition of physics has direct implications for physics education. Yet this is not a simple task. The definition of physics adopted by university physicists certainly captures certain aspects of physics but, at the same time, it ignores other aspects. It is, as one of the participants admitted, "a simplified definition." This provides an example of Callon's (1987) discussion of the durability of an actor-network in terms of the durability of the enrolled elements as simplified networks. For example, the complexity of science (that is, academic science) is illustrated by Ziman (1984) who argued that each of the "metascientific disciplines"—the history of science, the philosophy of science, and the sociology of science, among other fields—will define science in different ways and emphasize certain aspects of science. Ziman (1984), however, contends that:

> In truth, science is all these things [emphasized by the various disciplines], and more. It is indeed the product of research; it does employ characteristic methods; it is a body of organized knowledge; it is a means of solving problems. It is also a social institution; it needs material facilities; it is an educational theme; it is a cultural resource; it is required to be managed; it is a major factor in human affairs. (p. 2)

The central point to be made is that the durability or maintenance of the secondary school physics actor-network depends, among other things, on the

durability of elements (actants) such as physics and physics curriculum as *simplified networks*. For instance, physics can obviously be seen as a complex collection of human and non-human elements; in other words, physics itself is an actor-network. Nevertheless, in the school physics network, physics itself is simplified, enrolled and mobilized as a black box; in the excerpt from Uph#3, a simplified definition of physics "as the science of the physical world," implied specific content coverage to be learned by students. The following excerpt from another physicist provides another example that illustrates the point further.

> **Uph#4:**
> Let me summarize what I see as problems with this [PTS] approach. First, the simple definition of physics is that: it is the study of motion and energy and the interactions of the two. And to achieve that, to understand the physical phenomena we isolate nature from the observer. *Other aspects or social and economic details are not part of that definition and don't fall in the realm of physics.* **[A, 16, 8-11].**
>
> **Ahmed:**
> Are you saying that consequently they should not be included in a secondary physics curriculum? **[A, 16, 12].**
>
> **Uph#4:**
> Yes. Otherwise you may call that [curriculum] anything else, some other names, but not a physics curriculum. And I don't support that. **[A, 16, 13-14].**

4.2 Defending Networks Against Networks

In defining the content of school physics, the above physicist also attacked what he conceived as a move towards a "utilitarian tradition" that a

PTS curriculum might emphasize, while at the same time arguing to maintain an "academic tradition" (Goodson, 1987).

> **Uph#4:**
> The philosophy underlying these [PTS] units can be clearly seen from the start. In the unit Light Sources, they talk about the importance of light sources to people and society. That is the starting point. Then after some historical introduction, the unit put forward several questions.... you note that they ask the social questions first and leave the scientific questions to the end. This is a general approach in these units. The social, technical, or economic questions are tackled first and later on the scientific questions. **[A, 6, 3-15s].**

> **Uph#4:**
> I don't [approve such utilitarian approach] because there is more to science than mere utilitarian. I don't want to give students the idea that the main purpose of science is to serve us, that science simply is something useful to us. No, I philosophically object to that. We should not select from science what is useful to us and say that something else is not useful....God created us and bestowed upon us the ability to think and find out, so that ultimately we become believers, to ultimately have faith in God. **[A, 8, 17-18, 20-23].**

Invoking God to defend an academic approach to science or physics education might seem a little ironic. However, if one situates this invocation within the Islamic context where the study is conducted it seems like a 'wise' strategy. After all, who would oppose encouraging people to become true believers and to base their faith on scientific evidence? In fact, one of the goals of secondary science education in general and physics education in particular, as stated by the Ministry of Education in Bahrain, is to help students acquire a strong faith in God and develop positive attitudes towards

Islamic religion and values. The attempt was to associate a particular version of school physics (the academic version) to a larger issue (belief in God) such that threatening the former could be seen as tantamount to threatening the latter.

Although in one way or another, all physicists were concerned with maintaining an academic tradition in secondary physics curriculum, this particular physicist was more articulate in expressing that concern. He saw the main problem being the way these PTS units were designed and in the approach itself, and he considered "this to be an even bigger problem than the lack or shortage of scientific content" that his colleagues stressed (C, 1, 18-21). As such, it is not surprising that in taking a stronger position against a PTS emphasis he also invoked a variety of strategies to deconstruct others' alternative views and to support his rejection of the proposed curriculum. Besides invoking God for his network's support, he noted that he was defending against ideology in the PTS network. According to Fuchs and Ward (1994), this is a powerful "strategy to deconstruct or generalize suspicions about a statement's trustworthiness" (p. 490).

> **Uph#4:**
> This, I believe, ultimately promotes a materialistic point of view. This curriculum is written by people for students functioning in a capitalist society and its purpose is to promote capitalist ideology....We live in a different kind of society, we are governed by religious and moral values, not materialistic. **[A, 9, 13-24]**

Given the Islamic context in which the curriculum is expected to function, associating the PTS units with a capitalist or materialistic school of thought could, if taken seriously, have a strong impact. In a later interview, and when presented with views that supported a PTS approach, this particular physicist also hinted at the existence of a "Western conspiracy" or "bad intention."

> **Uph#4:**
> This is a new approach, and it aims at something larger than we can see. There is a broader goal. This is not simply a new method to teach physics. *No. The goal is broader.* Perhaps [pause]. Frankly, what can I tell you? [Why] to give such a narrow view of physics, and why do we want to reduce the number of people who may learn physics properly? Maybe, I am unable to express myself here. **[C, 1, 18-25]**

Although no specific agent or source was targeted as responsible for such a plot, there were implicit indications that a foreign country might export such ideas to us. During the last interview with the above physicist, and when presented with the ministry's decision to pilot a PTS curriculum, he inquired whether a PTS curriculum was actually proposed by me (the researcher) and whether I was personally convinced by it, or "was the curriculum suggested to the ministry by a foreign country?" Another physicist made a similar point by recommending that we should not import innovations in science education from Western countries like the United States, England and the Netherlands. He argued that these countries already have numerous problems with school science and math education and that their students were not performing well in international competitions. It is interesting to note that when it comes to

choosing a disciplinary model for school physics, Western physics is considered good and empowering, while if it is a contesting network, say PTS, then Western ideas become harmful. What is worth noting is how the "West" can be mobilized differently, and in a contradictory manner, by the same actors, in this case physicists (Reflective Notes #16).

These actors, thus, conflated the PTS materials with a larger network. This network was identified to consist of "utilitarian" and "ideological" actors such as industry and capitalism. In contrast, moral values, Islamic religion and God were linked to, and mobilized to support the maintenance of, the existing school physics network.

Further support for the above thoughts can be found in an early remark made by a member of the ministry's curriculum department when this actor cautioned against the possibility of internal opposition to a PTS (and generally STS) emphasis in secondary science education.

> **MEP#2:**
> Even within our department [in the ministry], some people [science curriculum specialists] think that this kind of science education will jeopardize the scientific subject matter. They consider the move towards more STS emphasis to be a backward movement, as if we are giving up on our present strategy. *Some even believe that the West exports these ideas to make us retract and weaken our curricula, when, in fact, our society needs more scientists and more specialized people.* **[B, 12, 10-14]**
>
> **Ahmed:**
> You are referring to people in our science education department?
>
> **MEP#2:**
> Yes. Within our department. Perhaps they don't always

> speak out loud, but I know that. For example, Dr. ... and Dr. ... are against STS. They don't always say that so clearly, but they are. They believe that we need to maintain the disciplinary emphasis and rigor, because our society needs more scientists, and this [PTS or STS] approach will not help us achieve that. **[B, 12, 16-19].**

Although the individuals referred to were not participants in the study they were, nevertheless, aware of it. They were also engaged, within our department, in discussions about STS science education, which began to emerge before, and intensified during, the conduct of this research. Although I did not participate in all these discussions, the colleague I quoted above informed me of them.

4.3 Assessment, Goals and Students' Roles: More Black Boxes

In accordance with the premises of Actor-Network Theory we should expect that contesting the content of the physics curriculum by no longer accepting its simplified or taken for granted nature, would also threaten the stability of other elements within the curriculum and network at large. Indeed, as the nature of the existing network began to unfold, other black boxes were (temporarily) opened. One of these was evaluation or assessment. In fact, all the physicists were quite disturbed to recognize that a PTS version of physics would require different methods (other than, or in addition to, the problem solving type known in physics) for evaluating students' achievement.

> **Uph#4:**
> This unit, Water for Tanzania, is the worst because it does not contain one single equation. You look for yourself, there is no mathematical analysis whatsoever, it is all descriptive. *So, I would expect that the exams will solely test memorization.* I became truly depressed when I read this unit. **[A, 15, 17-21].**

> **Uph#1:**
> The assessment techniques (particularly test questions) will be different if the PTS topics are heavily incorporated into the physics curriculum. Examinations' questions will be more of the types requiring students to describe and discuss certain problems. **[A, 9, 27-29].**

Assessment illustrates another instance of how complex entities are defined, simplified and eventually enrolled as actants in interwoven relationships within a network. As discussed in Chapter 6, a variety of techniques for assessing students' understanding and achievement in science and physics education were suggested by other actors. Nevertheless, in the school physics actor-network, assessment was remarkably simplified to mean written tests and further reduced to testing students' ability to solve standard physics problems.

> **Uph#4:**
> Then we come to evaluation, I mean exams. Exams should focus on problems. The mathematical type physics problems.... Not entirely, but say 80% (of the questions). **[A, 4, 16-17, 19]**

> **Uph#1:**
> As for this [PTS] curriculum, I say it is good, and our physics curriculum should deal with or cover some of these issues or topics. *But, they should not be emphasized in our tests and examinations. The exams should focus on problems.* **[A, 3, 11-14]**

The fact that current practice in physics education is ineffective in helping students acquire the concepts of physics and understand the scientific view of the world is well documented by science educators from all over the world (Arons, 1990; Clement, 1982; Driver et al. 1985; Osborne & Fryberg, 1985, White, 1983). Moreover, the findings of this research are not unique to secondary students as many of the everyday (i.e., common sense or "non-scientific") concepts of physics are even found to persist among college students who have taken physics courses (Eylan & Linn, 1988). The point of these research findings is that students may recall definitions, write formulas, and even successfully solve numeric and symbolic problems without actually understanding the concepts of physics as intended by the scientific community. With all this in mind, one is led to wonder about the reasons for the emphasis in school physics on mathematics and problem solving. A common justification provided by physicists was that such practice "promotes and develops critical, analytical and logical thinking" in students. However, when the researcher suggested that the presumed descriptive questions to be found in PTS units require students to engage in this kind of thinking another set of relations within the actor-network emerged and two more black boxes were opened: goals of physics education, and students' identities and roles.

> **Ahmed:**
> But these questions [found in the PTS units] will also be of the kinds requiring students to think and discuss issues critically.

> **Uph#1:**
> That is true. But is this physics? Do I measure or test students' achievement and skills in physics through the description and discussion of such problems and issues? *And is this the physics needed to prepare students for entering the university? No.* **[A, 9, 24-29].**

Challenging the significance of the problem solving practice consequently revealed how the goals of physics education and the identities of secondary students were defined in the network. In daily life, secondary students can, and indeed do, assume multiple identities and have different roles, and are members of multiple networks. A student may be a brother or a sister, a son or a daughter, a role model, an athlete, and a learner of many things. Each of these identities carries with it certain roles and duties. Yet in the secondary school physics network, students' identities are simplified or reduced to mean "physicists or scientists in the making," whose role in the network is to learn physics the way deemed appropriate by physicists, including the extensive use of mathematical expressions and problem solving techniques. The significance of this simplified role is problematic for many science educators who support a more active role for students in learning science and see the need for the content of the curriculum to be more interesting and socially and technologically relevant. Yet the significance of engaging students in learning the laws of physics, practicing problem solving and manipulating mathematical expressions cannot be overlooked by physicists. The mathematical equations, problems, and the laws of physics are, as Nespor (1994) demonstrates, "representational technologies" that mobilize or

transport "the real world of physics practice" to the physics education program. Nespor further contends that "to be a physicist means becoming proficient in the use of these technologies...to the point of being able to move through and work upon spaces and times that are not accessible to people outside the discipline" (p. 20). The following excerpt captures this point rather nicely. It shows how students' practice in secondary physics is associated not so much with critical and analytical thinking as often claimed, but rather with being efficient in using the techniques of mobilizing those representations.

> **Uph#4:**
> As long as a student has practiced and learned how to solve these problems and knows how to do that in the exams, then that's good. However, a distinguished student who earns 100% must also be distinguished in his ability to apply these equations and formulas to new situations that require thinking skills. Such items, however, will only constitute about 20% of the exam. *That means, there are certain ways or certain techniques that students must memorize and know how to apply routinely. They don't have to think about it every time.* Of course, this is not always the case and that is where the 20% of the mark should be allotted. **[B, 2, 6-15]**

The content of a physics curriculum and teaching practice are both well synchronized with the role prescribed for students in the network. In addition to extensively incorporating "mobile elements" (e.g., equations, formulas, laws of physics) which Nespor (1994) talks about, the content of a physics curriculum (and its organization) leave little or no room for students to become active learners or engage in genuine discussions. Teaching methods reflecting inquiry and stressing the importance of learners as active explorers

are often advocated by policy documents and teachers, but rarely practiced in classrooms. On the contrary, lectures or 'chalk and talk' dominate physics classes. Even when teachers believe themselves to be using "discussion techniques" in their teaching, they often seem to refer to a sort of question-and-answer dialogue between the teacher and student, where the latter either knows or doesn't know the 'correct' answers. My point, however, is not to blame teachers for such practice but to show that it fits well with the physics content to be taught and the way students are expected to learn in the existing school physics actor-network. The following reactions from one of the university physicists to some of the claims made by ministry and university science educators in favor of the PTS units illustrate the situation I described above.

> **Uph#3:**
> Well, I don't know how can science educators say that or who, in particular, raised that point. But there is a problem of misunderstanding. The student may engage in discussion, for example, when we tackle the applications of physics in society. Yes, the student can discuss and give opinions, and there is plenty of room for that. But, we are concerned with the principles of physics, we talk about the natural laws and students can't change these laws. Therefore, when educators claim that this [PTS] orientation is the right one because it allows students to discuss freely, *discuss what? I want to teach the principles and laws of nature, which are created by God.* These are.... Do I want to change them? No. I want students to learn and understand them. Educators are interested in engaging students in critical discussion, fine. But not in the basics of science. These we need to learn and understand. What is in there to discuss? **[C, 2, 25-28; 3, 1-11].**
>
> I give learners the freedom to ask questions and discuss about things that they don't understand to understand the

subject, *not to change it or give an opinion about it.* **[C, 4, 27-28].**

The role prescribed to physics teachers clearly contributes to the authoritarian style commonly found in science, but especially physics, classrooms (Eckert, 1990, Lave, 1990, Roth & McGinn, 1998) because teachers are expected to be the center of attention. More specifically, teachers are expected to deliver to students, and help them assimilate, the knowledge that is mostly prescribed in the textbook. The centrality of teachers is, therefore, derived from them being "gatekeepers" (Roth & McGinn, 1998) to that knowledge. Beyond this role, in fact, very little is expected from teachers to overcome complaints raised about the content of the curriculum and the problems that students face in learning it.

> **Uph#3:**
> I would also add that, students might not see the importance or usefulness of the physics they study in schools, and that is not their fault nor the fault of the subject. It is the fault of the textbook and the teacher who teaches.... And that problem can be taken care of in the introduction of each topic and before going into the details. A brief introduction, a quick application will solve that problem. **[C, 10, 13-16]**

> **Uph#4:**
> I believe a good teacher can always find the time and techniques to make the subject interesting. This is particularly hard to achieve in physics teaching because, as I said before, the subject of physics is dry for many people. **[C, 4, 6-9]**

> Physics is a very difficult subject. A good physics teacher, however, will try to soften it a bit and make it likable to students. This is natural. Certain things are difficult, others are easy. And we should not try to change the nature of

> something that is difficult because we find it such. We should teach it as it is and the student who will accept that will actually get attracted to physics. It will be impossible for most students to like physics because it is difficult, it is very abstract. That is the problem with physics. Only that person who has the ability to understand and apprehend that abstraction will like it. **[D, 6, 3-11]**

Obviously physicists do not consider the fact that many students find school physics difficult and neither interesting nor useful to be a "serious" problem. In addition, one should not take the blame on teachers (and textbooks) seriously either; in fact, the solutions suggested by physicists—to add "a brief introduction" or a "quick application"—neither require teachers to change their roles in the classroom nor do they solve the problems that are actually related to the nature of the content itself and its organization.

Teachers' role and practice in the existing physics network will be dealt with again in the next chapter as I explore the views of teachers themselves. Then it will be possible to see how they conceptualize their role with what is expected from them by other actors.

Within a school physics network students' identities and roles are also in harmony with the goals of physics teaching as seen within the network, which again are simplified or reduced to "preparing future scientists." If students' identities are considered problematic and/or the goals of physics education become contested, the stability of the network is at risk. It is not surprising, therefore, to note that certain participants were disturbed once they realized

that the introduction of a PTS curriculum might require a redefinition of goals and students' roles.

> **Uph#4:**
> What is the goal? Once again we come back to this point. The goal of physics at this level of education in the science stream is to help students prepare for their university studies. To me, this is an important point. The students whom we are talking about will not be satisfied with a high school certificate and then go and open a shop or be a worker in a company or a factory. **[D, 3, 4-9].**

In associating the existing school physics network with a "preparatory goal," the above participant also performed an act of interessement in which he excludes the possibility of alternative goals by invoking the professional future of students. The situation is framed in an 'either/ or' format to suggest that students who would not follow the established curriculum would be those who wish to opt for a low status jobs—"to open a shop or be a worker in a company or a factory." In the following chapters, I explore this further as I discuss how presenting conventional school physics as a high status pathway for students becomes a powerful strategy to enroll them and their parents and translate their interests in the existing network. At this point, I should emphasize that there was consistency in the responses of all physicists regarding the maintenance of a "preparatory goal" as the main function of secondary physics education. All the problems associated with an academic version of physics curriculum, such as abstractness and remoteness from daily life experience, seemed well justified for the sake of this goal. Indeed, it

gave physicists a great sense of relief to know that most of the university students also emphasized problem solving and mathematics and associated that with the preparatory goal.

> **Uph#3:**
> Did you notice the difference now. This is what we have been talking about over and over. How to prepare students for university. That is why we distinguish between those students who will continue their education in a university and those who will not. Those who will must live and go through the approach we described.... They must struggle with it. **[C, 14, 10-14, 16].**

When it comes to maintaining the school physics network no other goals besides the above could be accommodated without change to the network's basic structure. The significance of this was realized by actors who became interested in establishing a PTS curriculum. For them to change the physics curriculum towards a PTS emphasis ultimately implies a new network with its constituent elements defined and related in different ways. It is this restructuring of the network that counts as a change in curriculum, and not whether new materials are used.

The network described so far combined a variety of human, non-human and spiritual actors. These included, physicists, students, teachers, problems, mathematics, dictionary, goals of physics teaching, assessment, curricula in other places, God, moral values in Bahrain, etc. These actors are complex entities, but in the existing school physics actor-network they were defined, enrolled and eventually mobilized as black boxes or simplified networks. Finally, these actors come together to construct a physics curriculum with

certain features, such as abstractness, emphasis on theoretical knowledge and written presentation, and unrelatedness to real life which curriculum theorists like Bernstein (1971), Young (1971), Goodson (1987) and Apple (1990) had identified with academic or disciplinary curricula. For this reason, these features and the curriculum in general are better seen as heterogeneous constructs; that is, these are not merely social constructs. As we have seen, appeal to social elements was never enough to strengthen the claims made by physicists to maintain the status quo in physics education. Actors from other spheres were no less important.

Implicit (and at times explicit) in the definitions and simplifications of the various actors or elements were also attributions of goals and purposes to these actors. For example, students want to be employed in "good" or "high status" jobs and teachers want to prepare students for post secondary education and/or help them understand the laws of nature (created by God), etc. And the definition of the curriculum and its basic features was such that these actors can achieve these goals. But what about physicists? What were their goals and what is it that they wanted? That too was sometimes explicitly stated:

> **Uph#4:**
> The discipline of physics, as you know, has become so deep and wide that eventually we have to set priorities and settle on certain topics and areas to be taught to students in university. One of the consequences is that we don't *have a lot of time to help students fully develop their thinking and reasoning skills for dealing with [physics] problems.* We expect them to acquire that during their first and second years while in the physics program and, hence, we assume that

> similar practice has been followed in secondary *school as an initial preparation.* **[A, 2, 18-26]**

Problematization, as discussed in the previous chapter, refers to the process of identifying relevant actors and defining their allowable identities and goals in relation to a particular formulation of a problem. Therefore, in a controversy, the formulation of the problem, say in a form of a question that becomes an OPP, is crucial; such a question can be regarded as an OPP if it successfully converges the goals of the various actors involved in the controversy such that they see the need to pursue the negotiation through answering that question. As we have seen, physicists downplayed the concerns and issues that other actors raised regarding the existing school physics, ignored the positive qualities of the PTS materials they identified and, instead, framed the problem in terms of student's preparation for post-secondary education in science. For example, the main question that needs to be addressed, according to one physicist, was: "is this [PTS] the physics needed to prepare students for entering the university?" (Uph #1, A, 9, 29). By focusing on preparing students for post-secondary education and helping them understand the laws of physics created by God, physicists were able to identify and define relevant actors (physics, God, dictionary, inspired students, etc.) and their goals, as well as to suggest possible relationships among the identified actors in order to achieve their goals. It is in this sense

that we understand the definitions, simplifications and attributions of goals and roles that we have seen so far as a problematization in Callon's terms.

4.4 Enrolling PTS in the School Physics Actor-Network

In exploring curriculum making or change from the perspective of ANT and the Translation Model elaborated by Latour (1986, 1987) one should not separate an 'innovation' in curriculum from the context (e.g., the groups who are involved, the decision making process, the relationships among actors) in which it is to function. At the same time both (the innovation and the context) should be seen as fluid and capable of being reshaped. When faced with an innovation that disturbs the existing order of things one can, in principle, reestablish stability by modifying either the innovation or the context or both. The implication of this view for understanding the reactions of the various actors in the school physics network to the PTS innovation is significant. It becomes fruitful to focus not so much on which groups/actors resist or accept the innovation, rather on how they (attempt to) modify the innovation and/or the context in order to convince others and translate their interests. The choice to introduce change along either dimension, however, depends on one's stance and goals. For example, actors who were interested in maintaining the fundamental features of the existing network chose to modify the PTS as much as possible. That is, they interpreted the PTS emphasis in such a way that it could be incorporated into the existing network so that the latter retains most of its traditional features. By contrast, others chose to

maintain as much of the PTS features as possible and consequently maneuvered to reshape other parts of the network. Eliminating the divide between the curriculum and its context implies that, in practice, change will occur simultaneously along both dimensions. It is in this sense that both the curriculum and the context (be it social, spiritual or natural) become co-constructed, forming an actor-network.

The position assumed by physicists reflected their attempts to maintain the existing physics network. However, this position should not be understood as implying a total rejection of the PTS units. Although a PTS emphasis is rejected as a legitimate approach to a physics curriculum, some physicists were interested in enrolling the PTS topics in the existing network. In the process, these actors modified the proposed approach and shaped it to their interests. Within the existing actor-network, PTS units or topics could serve a specific purpose and be defined in a way different than that intended by their advocates. The shift in position from total rejection to enrolling PTS and the assigning of a specific role to it are captured in the following excerpts.

> **Uph#1:**
> These units attempt to bridge the gap between pure or theoretical physics and its technological and social aspects and applications.... They are good in that respect. My initial reaction towards these units was rather bad or negative. When I first saw them I asked myself: are these going to be adopted as physics courses for us? So, initially I said to myself: No, I don't accept these at all, because I didn't see them covering the basics. No formulas, no physics problems. But, as a supplementary component, I think they are good. **[A, 4, 3-11].**

> **Uph#1:**
> [The PTS units] will encourage students to learn and study physics. Many students, physics students currently worry and wonder what kind of jobs they can get if they specialize in physics. It is a real problem. What should they do with [a] physics [degree]. It is a problem for students. That is why if students explore some of the social and technological issues and applications that relate physics to real life, then they can see that physics is involved in everything. It is not just formulas, not just solving equations and problems. **[A, 3, 22-28].**

The PTS units, from what we have seen so far, clearly couldn't be incorporated into the existing network without disturbing the links between the various black boxed elements and their functions in the overall network. This is not the case, however, if the PTS were redefined, if its role and purposes were reshaped in the manner suggested by physicists (and others, as discussed in the next chapter). In fact, it is reasonable to conclude that if the redefinition of the PTS is successful, its inclusion into the existing network will contribute to extending the latter and enhancing its stability. By enrolling PTS as intended by physicists, the interests of more students would be translated into specializing in physics leading to an enhancement of the existing actor-network. Furthermore, the addition of some PTS topics to the existing physics curriculum will help maintain and strengthen school physics as an obligatory passage point (OPP) (Callon, 1986) for a wider population of students, not just the university-bound science students. This is particularly important since it was recognized that most secondary science students in Bahrain do not go to a university or specialize in science.

> **Uph#2:**
> I am happy with our physics curriculum. Maybe we need to add some applications or applied topics relevant to our society. Because not all science students will join universities, many will graduate from secondary school and work, and we want them to benefit from what they learn in school physics. **[A, 2, 20-24].**

It is important that physicists' interests in modifying and enrolling the PTS units be interpreted in terms of enhancing the overall existing network, rather than as reflecting a compromised solution resulting from an hierarchical power relationship between the ministry and university physicists. The evidence for this is twofold. First, such interest emerged rather early in the negotiation process and when no decision was actually made by the ministry to advocate or pilot an alternative version of physics. In fact, at this stage physicists didn't seem to believe that the ministry was very serious about implementing such an approach (Reflective Notes #16). Second, although a PTS curriculum would be modified considerably, by defining it as "the applications of physics in technology and society" and regarding it as "a supplementary part to the core physics," physicists gave serious consideration to fully enrolling this modified version. One way to achieve this was by "including one or two questions about that part [PTS] in tests to ensure that students will actually read that part" (Uph#1). The following conversation with another member of the university physics department further shows how serious he was in enrolling aspects of PTS in the curriculum.

> **Ahmed:**
> What about the social aspects of physics and the technological applications and issues? You didn't include them in your descriptions [of a good physics curriculum].
>
> **Uph#2:**
> Well, what shall I say. Most foreign physics textbooks do not include that, especially the social aspects. Perhaps adding that to our physics textbooks would be an advantage, a good thing to do. And whether we add that as essays at the end of chapters or within the body of the text, it is acceptable. **[A, 15, 22-23].**
> In fact, I prefer if we leave it [PTS topics] within the body of the text, because once you append it to the end of a chapter, students ignore it. They will not read it, and I feel sorry about that. **[A, 16, 6-9].**

In the next chapters, I discuss how physicists managed to establish their version of physics as an obligatory passage point and also examine some of their anticipated actions to maintain it as such if a PTS curriculum was to be implemented. However, at this point it suffices to note that enrolling allies, such as aspects of PTS, non-science bound secondary students, and parents, from outside the narrow academic network implies that the conventional school physics network be extended and reestablished.

4.5 Why Physicists? Some Concluding Remarks

Compared to other actors, physicists were able to speak more forcefully and with greater authority when it came to defining the physics curriculum and deciding on who should actually do so. In making their arguments, physicists showed a great tendency to increase control over the curriculum, leaving little or no margin for negotiation.

> **Uph#1:**
> So, between you and I, the final say has to come from physicists...because we are talking about the student who will specialize in physics. So, we have the final say and we see how we can compromise. I don't care about educators, industry, students or others. **[C, 13, 11-15].**

> **Uph#1:**
> I hope you can understand me on that. Whatever ideas come, they have to be all put together and then we, as physicists, can decide and see what could be done, what compromises we can make, so that the final curriculum becomes adequate and clear. We, the physicists, have to approve that curriculum. It is not for the industry, or educators, or anybody else to have the final say on that. **[C, 14, 4-9].**

Certain physicists, however, appeared to be more sensitive to the views and interests of other actors which they saw as contradictory to their own. They used a softer tone in reacting and even saw the possibility of negotiating the curriculum. Nevertheless, the margin of negotiation suggested was still very thin such that the centrality of physicists in the decision making was maintained. This was done by taking for granted the existing physics curriculum.

> **Uph#2:**
> You got university physicists, and we expect students to reach a certain level, to master certain concepts and to cover some important topics. You also got industry, and perhaps they are more interested in high school graduates and not necessarily university students, and they want students to acquire certain skills or knowledge from the curriculum. You also have others. So, we have to be comprehensive in how we would approach the physics curriculum. We can all sit together, discuss all views and negotiate. Of course, you can't satisfy every one; to satisfy

> the industry, university, students, and so on. It is not possible to satisfy all of them. **[C, 11, 19-23; 12, 1-3].**
>
> **Ahmed:**
> Then, how do you see us reaching a common ground? Do you think that we can come to some consensus on the curriculum through discussion and negotiation? **[C, 12, 9].**
>
> **Uph#2:**
> Of course, as long as, and as I have said before, we start from the existing physics curriculum and work towards adding the technology and applications. **[C, 12, 10-12].**

Interestingly, physicists identified certain actors whom they moved to the center of the decision making process. For example, secondary physics teachers were considered important actors in the sense that their views count most compared to other actors. The justification for this privileged position was provided in terms of the link these actors have with disciplinary knowledge of physics and its teaching.

> **Uph#4:**
> You will find the opinions of the physics teachers and physics professors to be more strict than others because they are closely attached to the subject. They have learned the subject and truly understand it more than anyone else. They are specialists and know the nature of the subject and how to teach it, teach physics. Therefore, I believe their opinions should have more weight than others from the industry or ministry.... So, the opinions of the industry people and secondary students are considered secondary or marginal and, I believe, the priority in deciding issues about the [physics] curriculum should be given to [university] physics professors and [secondary] physics teachers. **[C, 10, 11-18, 26-29].**

Many physics teachers, as shown in the next chapter, accepted either directly or indirectly the position taken by physicists with little or no discussion.

The focus of the discussion so far has been on the responses and views of university physicists. I identified physicists as key actors in maintaining the school physics network. Yet, as shown in the next chapter, university science and engineering students and most of the physics teachers also took a similar stance, but provided different rationales. Identifying certain individuals or groups as key actors was not (and indeed, should not be) an a priori decision; rather, it was an outcome of my analysis of the links that unite the various (human and non-human) actors in the network. The secondary physics curriculum is strongly linked with disciplinary knowledge of physics and at the same time dissociated from or weakly related to other contexts and areas of knowledge, such as society and technology. Moreover, by speaking on behalf of the disciplinary knowledge of physics, physicists associated themselves with school physics in a central way. From their perspective, the identities of other actors, such as students, teachers and the curriculum, were defined and roles designated within the school physics network. Defining the identities and roles of the various actors was crucial in maintaining the hierarchy of power within the network. While this was only partly touched upon in this chapter, it will become more evident in the next chapters.

Summary

To summarize, I discussed several black boxes within the school physics actor-network that were opened as physicists argued to maintain the basic

structure of the network. These included the content and form of the physics curriculum, goals of physics teaching, assessment techniques, students' roles and identities, and teachers' roles. This network and these elements had been black boxed or stable such that the stability of the former depends upon the durability of the latter as simplified networks or black boxes. Nevertheless, the contested nature of these black boxes becomes more evident as we explore other actors' views.

In opening these black boxes, I was able to identify other actors that physicists mobilized to strengthen their arguments and stance. These included, curricula in other places, dictionary, moral values of Bahrain, God, mathematics, and physics problems. The particular set of human, non-human, and spiritual actors come together to construct the features of school physics—a simplification.

Although we may understand the basic features of an actor-network by analyzing the views of particular actors or group of actors, the performance and stability of that network are determined collectively by all actors. Thus while university physicists may define a physics curriculum in a certain way, specify a particular goal for the curriculum, and designate particular roles to themselves, students and teachers, the overall situation depends on whether or not the various actors accept these definitions and roles and perform accordingly. The following two chapters explore this point as I map and test the links among the various actors. The focus of the next chapter is on secondary physics teachers and university students.

CHAPTER 5

THE SCHOOL PHYSICS ACTOR-NETWORK: MAPPING AND TESTING THE LINKS

This chapter explores how the school physics links the physics teachers and university students to their various goals and, in particular, shows how it is established as an obligatory passage point. These actors share a common interest with physicists in terms of maintaining the existing school physics network. Secondary physics teachers play a significant role in any school physics actor-network, whether in its present or restructured shape. Their importance is recognized by other actors who, although in different terms, paid particular attention to the teachers. The main argument for this point of view is that how physics teachers work out the curriculum in their classrooms—what they emphasize or marginalize, and how they teach—is what ultimately counts. But, what the physics teachers do in the classrooms is determined by their own interests, and their role and relationships with other actors in the network. Therefore, it is important to explore their views to see where they stand with respect to a proposal to introduce a PTS curriculum and, most importantly, to what extent they accept, modify, or reject the simplifications and definitions we encountered in the previous chapter. This will help us understand their goals, and the extent to which their interests can be translated in alternative networks. In doing so, I shall be able to map the links that tie the physics teachers with the various actors (e.g., students, ministry, curriculum, and university) and test their strength.

Although university students are not generally acknowledged as relevant actors in the school physics actor-network, their direct and indirect presence can't be underestimated. To say the least, most of the claims made by other actors to maintain the status quo in physics curriculum involved the future education of secondary students. Some of today's secondary science students are tomorrow's university students. Costca (1995) refers to them as "potential scientists," and I may add potential engineers since many of our secondary science students actually continue in the fields of engineering. When thinking in terms of recruiting allies to support the views and efforts of those wishing to maintain the network, potential scientists and engineers may constitute a small proportion of secondary students. But that proportion can be extended considerably by adding university students, parents and, not less important, their future careers; hence, this chapter focuses on the views of university students as well, revealing their goals and the strength of their links with the curriculum and, in addition, providing a test for some of the claims made by university physicists and physics teachers.

5.1 Physics Teachers and Features of Physics Curriculum

During the first stage of the study (negotiation), many physics teachers showed considerable support for PTS, but as it turned out, they were particularly attending to, and interested in, only aspects of the units and not the PTS approach as a whole. When these teachers gave a positive response to the PTS units and the possibility of adopting this curriculum emphasis in

Bahrain, they actually meant that certain activities, examples or topics could be incorporated into the existing curriculum because they were interesting and could be used to motivate students to learn the physics content better.

> **T4:**
> I really liked this unit—Ionizing Radiation.... What attracted me most though was the many applications it covers. Because the applications bring life into the physics. Therefore, if after each chapter [in the textbook] we devote 2-3 pages for the applications, and such that one of these applications would require the students to perform some calculations using the related formulas and laws.... All this will be exciting to students and will encourage them to study physics. **[A, 8, 23-25; 9, 1-3].**

While this particular teacher explicitly revealed his conceptualization of the PTS in an early stage of the discussion, the views of other physics teachers became clear only at a later stage. As the following excerpt illustrates, follow-up and Phase 2 interviews were especially helpful in clarifying teachers' views.

> **Ahmed:**
> Let me clarify a few points for myself here. On page 4 [of the interview transcript] you said that you support the idea of rewriting the physics curriculum with a PTS emphasis, which is illustrated by the three [PLON] units. So, what changes would you expect to see in the curriculum as a result of such a move towards the PTS? **[B, 1, 3-7].**
>
> **T1:**
> The curriculum itself in terms of its content, as scientific concepts, principles and laws, will remain the same even if the curriculum is redesigned as a PTS. What I want to include is some technological applications that are common in our daily life and are related to these concepts and laws. Even if they are included as general knowledge. **[B, 1, 8-12].**

Another example is found when a physics teacher strongly criticized the existing curriculum during a group interview. He presented what could be interpreted as support for a PTS emphasis by arguing that the physics curriculum should reflect the technologically advanced environment that students live in. In particular, he suggested that the physics curriculum should explore local and environmental problems and help students see how technology can be used to solve them. However, in a later interview, he explained that:

> **T8:**
> What I mean is that in learning physics, secondary students should be exposed to the latest technologies, know about these modern devices like solar cells, color TV, transistors, etc..... To understand how they work, for example, how does a solar cell function and how can it be used to collect solar energy. How is the color picture produced in the TV. That kind of things. So, my focus is on the scientific principles of these modern technologies. **[B, 2, 3-5, 12-14].**

These excerpts illustrate that physics teachers conceptualized or redefined the PTS emphasis to mean the applications of physics. The focus was on the technological applications for motivational purposes and as a means to aid in learning physics.

In the previous chapter I discussed several aspects of a physics curriculum as well as certain definitions, roles and identities which physicists strove to maintain as black boxes. Of course, what makes these appear as black boxes is the fact the they are taken for granted by most, if not all, network actors. Indeed, this was true for all physics teachers and, in fact,

continued as such for most of them through the course of negotiation. The excerpt from T1 above depicts one such black box—the content coverage.

Another teacher gave a more precise definition of the content of the physics curriculum that captures the taken for granted nature of several aspects discussed earlier. In making a point about the lack of mathematical manipulations and problems in the unit Ionizing Radiation, she asserted:

> **T9:**
> In physics, we have a phenomenon, a physical law or an equation to describe that phenomenon, and then we apply that law to solve problems. *That is how it should be. That is how it has always been.* To ignore the formulas, the mathematical manipulations and the problems would be to change the nature of the physics curriculum very drastically. **[A, 15, 1-3].**

What is remarkable about this excerpt is not just the simplicity with which a physics curriculum is defined, but how it captures it as a black box (in the full sense of the concept) and in relation to other entities (Latour 1986; Callon, 1987; Callon & Law, 1997). First, we observe that the content of a physics curriculum and its organization, going from a phenomenon to a physical law or an equation and then applying the law and formulas to solve numeric problems, appear dissociated from any sense of history and ownership. Or, in the words of the above teacher, "that is how it should be," and "has always been." Second, this conceptualization of a physics curriculum is implicitly based on a definition of physics that is similar to that provided by university physicists. This serves a dual purpose of strengthening

the teacher's claim for such a simplified conception of a curriculum while enhancing the academic physicists' views. Finally, with this simplification, the mathematical or non-descriptive feature of a physics curriculum becomes "natural."

While physics teachers generally emphasized problem solving and mathematics, the rationale for this did not always follow the manner described above. Rather, to justify the emphasis on mathematics in the curriculum, physics teachers invoked a variety of other reasons including personal preference, teacher's identity, students' motivation, and simplified content. In other words, the goals and motives for maintaining the curriculum were different than those provided by physicists. For instance, one of the teachers justified the use of mathematics in terms of simplifying the content and making it more interesting to students.

> **T1:**
> When learning physics, it is necessary to study the laws and formulas of physics because these more or less summarize the scientific content for us. Also, if students are given only descriptive kind materials, you know [things like] explanation and a lot of writings, then they will get bored sometimes. I have noticed that, for example, when I teach the photoelectric effect. **[A, 3, 20-23]**

Other teachers made similar points but, in addition, we find that this emphasis in the curriculum seems to reflect, or at least is in harmony with, teachers' personal preferences and how they define themselves in the network. The two examples below capture these points rather clearly.

T4:
I normally don't like descriptive stuff. That is my nature as a teacher. I like mathematical manipulations, using formulas and equations. That is when I feel that I can be creative. I use concepts and apply formulas to calculate physical quantities. That kind of thing. **[A, 6, 5-7]**

T5:
As a teacher, too, I get bored with the descriptive style. I hate it. Sometimes, where there is a lot of descriptive stuff and discussion [in the text] and I don't find a way to simplify things to students, I get frustrated. **[A, 17, 8-9]**

Ahmed: You mean quantitative? **[A, 17, 10].**

T5:
Yes, an equation or a formula. After all, this is what *distinguishes us as science teachers from other teachers in humanities.* **[A, 17, 11-12].**

These arguments illustrate some of the links between the physics teachers and the traditional physics curriculum and their relative strength, compared to those linking teachers with the PTS units. While teachers initially found aspects of the PTS units attractive, these were not as strongly held as the traditional physics. But there is more, and this is clear in the last remark made by T5 when he referred to the use of formulas and equations as something that distinguishes science (but especially physics) teachers as a community from other communities (teachers). A PTS curriculum would somewhat break these boundaries, creating some overlap between physics teachers and other communities. However, for the physics teachers, or some of them at least, to move away from formulas and equations is to give up numbers, calculations and even experiments with all the consistency and

satisfaction that come with them. In effect, it is to move from "knowledge" to "rhetoric" and "speculations." As one of the teachers explained:

> **T4:**
> For example, what makes me certain or confident of my explanation of a given phenomenon or event? Through *the laws of physics and calculations. A [physical] law that does not change, that gives the same result every time you apply it. We don't want to turn school physics into mere description or speculations* that are not and can't be supported by experimentation, equations or calculations. That will not be physics.**[C, 2, 1-5]**

One criterion employed by physics teachers in deciding whether certain content was acceptable as physics and worthy of being included in the curriculum was related to the difficulty level or accessibility of that content to students. In practice, this criterion essentially meant that the content or knowledge which is worthy of inclusion in the curriculum is, by and large, that which "students can't understand or acquire on their own" by reading the textbook or via general or informal resources. The implication of this is twofold. First, the pure disciplinary physics becomes the primary source from which curriculum knowledge is selected and, second, teachers assume authority roles and become primary agents through which students can access that knowledge.

> **T1:**
> These things [i. e., PTS topics], or this kind of information can be acquired by students through external readings or by watching TV. Such knowledge can be found in many resources and should not be forced into the physics textbook. There are numerous resources where students can learn about technology and the effects of physics, *but the*

physics itself can't be learned and acquired from other or general resources. **[C, 10, 15-18]**

T7:
I realize that we are talking about some interesting topics here. These are good topics. But this is not physics. These topics are not actually physics. In this unit [IR], *certain topics or content must be taught and explained by the teacher, whereas many other topics could be left to students. They [students] can read and understand these topics on their own.* **[A, 11, 11-14]**

T8:
The class time will be devoted to the discussion of physics—the X-ray tube, the metal target used to produce the rays and their characteristics. *Left on their own, the students can't understand these things. I will teach them all that. The rest [i.e., applications and safety issues] they can acquire on their own.* **[B, 5, 20-21].**

To some extent we are now able to trace how school physics becomes conceptualized as a difficult subject, at least at the classroom level. It is the result of a process that excludes from the curriculum and classroom teaching "other" knowledge that does not lend itself to the teaching style normally found in physics, no matter how related to physics and interesting and useful to students that knowledge may be. This was certainly true of the PTS topics that the above teachers wished to de-emphasize or exclude. Besides being judged by teachers as "significant and useful to students," these topics included thought-provoking discussions and debates that aimed at raising students' awareness and fostering decision making skills. In fact, when asked to compare the PTS topics with the traditional physics content in terms of the significance and usefulness of each to students, most physics teachers

argued either in favor of PTS topics, or considered both to be equally important and useful. As these teachers put it when discussing the unit Ionizing Radiation:

> **T6:**
> The latter depend on the former. They are both important to students, but before discussing the latter, the applications and that kind of things, students must know the basic physics of X-rays and the X-rays Tube. **[B, 5, 7-8].**
>
> **T8:**
> In my opinion, the applications of X-rays in health, agriculture, etc., are important things and it is useful to students to know about all that. *In fact, in practical life, this knowledge will be more important and more useful to students than knowledge about the X-ray tube, the target used, and how to produce X-rays*. Although that too is important and students should know that scientific knowledge. **[B, 5, 9-13].**

Physicists' saw that assessment was an important element in the school physics network. Assessment was defined as testing students' ability to solve written algorithmic problems. Among physics teachers, that seemed to be an accepted definition too. Therefore, the physicists' position in maintaining the school physics actor-network by invoking the practice of assessment as a black box was also supported by physics teachers although for different reasons. For physics teachers, testing students on problem solving provided a direct and, indeed, convenient means of allotting marks to students; something that is commonly expected from teachers and is an integral part of their teaching practice. Hence, the syllabus or content of the physics curriculum must also *lend itself* to facilitate such practice.

> **Ahmed:**
> I feel from what you have just said as if there is something wrong with or missing from the unit [WFT] and that is why you don't recommend that it should be part of the core physics curriculum. **[A, 5, 20-21].**
>
> **T7:**
> Yes. The students normally use formulas and *equations to solve problems in tests. That is how they get marks. With such units, what can we do?* **[A, 5, 22-23].**
>
> **T6:**
> Right. How can we evaluate students in this unit? **[A, 5, 24].**

Thus assessment becomes an obligatory passage point for physicists and physics teachers, but as a route to different goals.

As educators from the ministry argued, changing the content of the physics curriculum would also entail changing the purpose of assessment and its techniques. And, to be sure, other means and different types of questions could be devised to assess students' achievements. However, the physics teachers did not find these means convenient. Instead, they argued that implementing PTS units that do not incorporate formulas and equations to some appreciable degree would have undesirable consequences when it comes to assessing students' achievements. For instance,

> **T6:** It will be difficult to evaluate students.
>
> **T7:**
> [Implementing PTS units] will have negative impact on students' grades and will effect their achievements. Things like decision making, giving an opinion or designing solutions are not necessarily attainable by all students. *Besides, how can we evaluate students on these things?* **[A, 6, 23-24].**

Not surprisingly then, while incorporating certain PTS topics in the physics curriculum was deemed desirable, these topics were considered secondary in relation to assessment. As one of the teachers put it:

> **T7:**
> Then comes the exam. How am I going to evaluate students, say, in the final exam. Definitely, I will focus on the parts that are basically physics. As for the rest of the content [i. e., the PTS topics], perhaps I will include a simple question. Something like: discuss the dangers of radiation. That's all. **[A, 11, 14-16].**

When dealing with assessment and examinations in the context of Bahrain, it is important to keep in mind that there are no external examinations, such as national, provincial, or university-entrance exams, since the adoption of the credit hour system and the implementation of the present physics curriculum in secondary schools. Nevertheless, written exams devised by teachers are mandated by the ministry and usually account for about 70% of a student's mark. The current evaluation system, however, gives teachers full autonomy and responsibility for evaluating and assessing their students. In the early stages of implementing this system, each teacher evaluated his or her students in the course, but some concerns arose regarding the standards and fairness of such evaluation. Having seen the variety of exams prepared by teachers to test students at the end of each physics course, I believe there was little difference in the quality and nature of these exams. Some were more demanding than others, but they all covered factual information and required students to solve problems commonly found in the textbook. One solution,

proposed by the ministry to the problem of standards/fairness, was that a selected group of teachers who taught the same course in a given term should coordinate and prepare a unified final exam to be administered to all students in their schools on the same day. In such circumstances, teachers worked together with little or no interference from the ministry's physics curriculum specialists.

With this brief background we can now revisit the relationship between the physics teachers, on the one hand, and assessment and the curriculum content on the other. This, of course, is not entirely a new issue. Educators who investigated school subjects from sociological and socio-historical perspectives have paid considerable attention to the relationships between (written) examinations and the academic status of a subject. For instance, Goodson (1987, p. 25) observed that "since the nineteenth century 'academic' subjects and written examinations have been closely interconnected." This connection, in fact, has been so strong to the extent that to judge the "academic" status of a subject "a central criterion has been whether [its] content could be tested by written examinations for an 'able' clientele" (Goodson, 1987, p. 25). Referring to physics education in England and Wales, Woolnough (1988, p. 224) noted that: "most of the motivation (for pupils, parents, and teachers) came through examination targets, to which society still gave high currency to physics." Nevertheless, such assertions do not address the nature of knowledge assessed and included in the examinations. The issue at hand is not whether the knowledge found in

PTS (or STS in general) could be tested or not by written examination, but what kind of knowledge would be tested in the first place. The excerpts from the physics teachers cited above clearly show that exams do shape the content of a curriculum. For instance, teachers were not comfortable with the content of the PTS units because it does not lend itself to the kinds of questions found in conventional physics exams that are mostly mathematical in character. But why do teachers insist on this kind of exam in the first place? And why do they take this for granted?

The answers to these questions vary, but some insight is found in the responses of the teachers whom I interviewed. Sometimes the reason was related to the status or value attributed to certain knowledge and the emphasis of that knowledge. Bybee (1998, p. 159) asserts that "assessment of students always conveys a clear message about the most valued scientific and companion meanings in a given science curriculum." Indeed, some physics teachers attributed a lower status to certain PTS topics and accordingly reduced their significance in assessment. I discussed the similar stance taken by physicists in the last chapter. But this was not always the case for teachers, as the excerpts cited above indicate. Sometimes the reason for maintaining the conventional exams had to do with convenience; teachers found the problem-based questions an easy and convenient means for allocating marks to students. They also believed that testing students in physics problems was more fair because "things like decision making and giving an opinion are not attainable by all students" (T7, A, 6, 24). In short,

physics teachers took assessment strategies found in the conventional physics for granted, and in doing so they contributed to the maintenance of the existing network, but they did so for reasons of their own.

Finally, "assessment" itself should be seen as an actor that shapes other actors and is being shaped by them at the same time. As such, assessment or exams become part of the network and not some external agent to be invoked to explain the maintenance of the network. To do so, would be to lose sight of how exams were constructed and black boxed.

The argument of the physics teachers, then, was to maintain the fundamental features of the traditional physics curriculum. In particular, to maintain the emphasis on mathematics and the specialized or "pure" sense of the subject. These features that teachers and others took as "natural" characteristics of school physics curriculum—and often identified with academic curricula (Goodson, 1987; Young, 1971b, 1976)—can now be clearly seen as heterogeneously constructed through associations with other human and non-human actors. What makes "abstraction" and mathematical emphasis stand up as distinctive features of a physics curriculum was the range of heterogeneous actors, including teachers, physicists, disciplinary knowledge, exams, marks and, as we shall see below, students and goals of physics education.

5.2 Goals of Physics Education: Whose Goals?

In the previous chapter I described the existing school physics network in terms of its constituent elements and relationships, including the goals of physics education. In particular, physicists argued that the primary goal of physics education is to prepare students for further studies in the fields of physics. They also argued that the existing (and certainly not a PTS) version of school physics was the one suitable to fulfill this goal. However, there was an obvious weakness in their claim about the priority of preparation for post secondary education. Of the total population of secondary students who opt for the science stream, only a small proportion continues their university studies in physics. In addition, not all these physics students become practicing physicists; some specialize in physics education and become teachers while others work in industry. Recognizing this constraint, physicists then argued that the existing school physics was adequate and, in fact, necessary to prepare students for a wide range of studies, including the sciences, engineering, and medicine.

This section examines the views of secondary physics teachers with regards to the goals of physics education. I explore, first, the extent to which physics teachers accepted, rejected or modified the "preparatory goal" argued for by physicists and, second, how they situated the PTS proposal within the context of the goals of physics education. Understanding the teachers' views on this matter becomes beneficial in considering the possibility for bringing about curricular change in school physics by

translating their interests so that the PTS becomes an OPP for them. More importantly, it provides a context for exploring the links between physics teachers and another element, the goals of the curriculum, and an avenue for exploring how power is constructed and maintained among actors in the school physics actor-network in Bahrain.

When discussing issues related to the goals of secondary physics education, teachers' responses could be classified into two categories, although both are similar in practice. Like university physicists, some physics teachers argued for the "preparation goal" as the primary function of school physics and, consequently, they saw their main role as helping students achieve that goal. By contrast, other teachers either didn't make any explicit link between school physics and university education or considered that to be a minor goal. Among this latter group, teachers argued for different "curriculum emphases" (Roberts, 1988), including "the solid foundation" and "an everyday coping" emphases identified by Roberts (1988) in science curriculum. For example, one of the teachers argued that "the first and most important goal is to provide students with the fundamentals of physics" (T1, B, 6, 5). While this teacher considered himself to hold a different stance than physicists, what he emphasized in a curriculum, rhetorically but especially in practice, was hardly different from what they would hope for. As an illustration, consider how he reacted to university physicists' views by invoking what he considered to be a different set of goals.

Ahmed:
Let us talk about the views of university physicists. They rejected these units almost entirely. **[C, 6, 8-9].**

T1:
[with laughter] Well, probably they want formulas, equations and problem solving. **[C, 6, 10].**

Ahmed:
Yes. And they did not consider the content of the [PLON] units as actual physics. The physics curriculum, as they see it, should emphasize problem solving and should be mathematical in nature. **[C, 6, 11-12].**

T1:
That is where we differ. As a secondary physics teacher, I find that their opinion should be rejected because we have different goals. They [university physicists] have their goals for teaching physics and we have ours for the secondary level of education. *Our goals are to help students build a solid foundation in physics, attract students and make them interested in the physics subject, promote thinking skills, spread science and physics among as many people as possible*....Later on, at the university level if they [physicists] want students to study certain topics in depth, emphasize mathematical manipulation and deal with physics in a mathematical manner, that would be fine. But that is later on. **[C, 6, 13-21].**

For this teacher, the curriculum suitable to fulfill the above goals "will emphasize concepts. It will be conceptually oriented but, of course, without ignoring formulas and problem solving skills" (T1, C, 7, 4). The views of this teacher might seem contradictory at first. His position reflects a tension and provides an example of Latour's (1986, 1987) translation. He admitted that school physics has become significantly abstract and has been portrayed as a difficult subject. He was also aware of, and particularly sensitive to, the wide range of students' abilities and interests within the science stream, and

developed certain strategies to cope with the situation. For example, focusing on concepts and conceptual understanding, adopting cooperative learning, and willingness to incorporate some PTS topics were part of his strategies to make physics accessible and interesting to most students without substantially changing the curriculum.

> **T1:**
> I go against those who terrify students by actually making physics a difficult subject or by claiming that the subject is complex and can't be understood by all. On the contrary, I try to make the subject interesting to students. I don't let them feel that it is a complex subject. I try to make it accessible to all students. *I don't want the 'weight' of my subject to be associated or equated with difficulty or complexity.* **[C, 13, 1-5].**

Compared to his colleagues, this teacher was more flexible in negotiating the physics curriculum. He showed willingness to incorporate more PTS topics in his teaching even if the result was to reduce some of the traditional content coverage and its reliance on mathematics. All this became more evident, however, in the later stage where we discussed the ministry's decision to go about piloting a PTS curriculum.

Another, perhaps more dramatic example of translation can be seen in the responses of another teacher. He was also in favor of a more mathematically oriented physics curriculum, and argued that such an orientation would be more interesting to students and teachers and would help simplify the content of physics. Furthermore, when asked about what he considered to be the goals of physics teaching, he said:

T5:
Generally, it is to help students acquire some understanding of the natural phenomena surrounding them. And be able to explain these phenomena and the various applications of physics seen in everyday life. **[A, 12, 23-24].**

Ahmed:
Do you have any other goals in mind as you teach? **[A, 13, 2].**

T5: No. Basically that's it. **[A, 13, 3].**

Ahmed:
How about preparing students for further studies in the sciences and engineering, in the university? Don't you see that as a goal in physics teaching? **[A, 13, 4-5].**

T5: Not really. [pause] Perhaps, it might be a secondary thing. **[A, 13, 6].**

As mentioned earlier, other teachers defined their role in terms of preparing students for further studies in areas related to science and engineering. One teacher specifically argued that conflict among (participating) groups over which version of a physics curriculum (i. e., a PTS or a traditional) is acceptable, was due to their disagreement on what ought to be the primary goal of physics education. In his words:

T8:
Clearly, the differences in opinions [amongst the various participating groups] are the result of differences on how they see the future of students. Do I prepare students so that they will continue their studies at university and get higher education? Or is secondary education the last stage of formal education, and the students will look for jobs once they graduate? That is the reason. That is why our opinion falls somewhere in between the two extremes and to fulfill both goals in the physics curriculum. *The physics curriculum as we suggest will prepare the university-bound students and*

> *also help those who will not continue in higher education, who will join the workplace, and in life.* **[C, 7, 9-14].**

When asked if he saw any contradiction between fulfilling these two goals—preparing students for university and for the workplace or life in general—he asserted:

> **T8:**
> No. I don't see any contradiction. I think we can fulfill both, but to different degrees. As physicists, though, I see us focusing more on the university preparation goal. We shall devote, say, 75% of the curriculum to physics and perhaps 25% to society and the PTS. Something like that. Yes, because this is academic schooling. It is not vocational or commercial education where students would *graduate to become laborer, technicians, and clerks.* **[C, 7, 17-20].**

In his reflective essay, Peter Fensham (1985) pointed out that society places two distinct demands on science education; the demand for specialist manpower and the demand for a more scientifically literate citizenry. The first demand requires the science curricula to be geared towards preparing secondary students for further studies and research in science and technology. The second demand, on the other hand, requires open-ended curricula that deal with a wide range of real life situations in order to prepare students for life in general. Fensham (185, p. 417) argued, however, that these two demands are "conflicting and not complementary as was almost universally assumed." The excerpt above associates PTS with the second goal and shows that there is some truth in Fensham's claim. Moreover, it captures a major paradox in secondary physics education; while both goals are simultaneously allowed and advocated in principle, the curriculum and

teaching practices respond primarily to the preparatory goal. What complicates the issue, and perhaps creates the conflict, are the different sets of associations and elements linked to each goal. For instance, "academic" physics, certain teaching practices, doing well in university, Masters degrees, Ph.Ds, scientists, engineers, high status jobs, etc., are associated with the "preparatory goal." By contrast, utilitarian or vocational physics, not doing well in university and low status jobs, such as clerks, technicians, and laborers all become part of the world encompassing the second goal. The following excerpts, taken from two interviews with another teacher, capture most of these elements and further show the kinds of evidence that this teacher used to enhance his claims.

> **T4:**
> Most of us would like for their children to go to universities, get higher education, and find good jobs. Our ambition for our children is that they will earn Master's and Doctorate degrees, not just to earn a high school certificate and then work in some industry or shops. **[D, 7, 18-21].**

> **T4:**
> Let me tell you something too. I've met with few students who graduated from technical school. The courses they have done in school, of course, focused on technology. Right? These students are now having a hard time at the university. They are not doing well at all, because they lack the fundamental skills and knowledge in physics and math. Even good students among them would need a lot of time and work to catch up with what they have missed; far more than what any regular student from the sciences would need. In fact, do you know that one of the physics courses, that is, Force and Motion [physics 215, in secondary curriculum], has helped so many first year university students. I have met with some of these students too and they were so grateful that they have taken this course in school because they found it helpful. **[C, 8, 14-23].**

An actor-network analysis can explain the divergence and hierarchy that exists between various versions of school subjects (e.g., disciplinary and general, academic and utilitarian, conventional physics and PTS). These differences are the result of different goals, the number and types of allies enlisted and associated with each version, and the size and strength of the network they form. From the perspective of ANT, there is nothing intrinsic or ontological about a conventional physics that makes it better or more appropriate than a PTS version. Rather, conventional physics is relationally stronger and more encompassing in terms of the allies it is associated with. Scientists, high qualifications, prestige and well paid jobs are 'things' that people take for granted as worthwhile achievements. And it is the link with these allies and the power of their networks that make academic school physics (and science in general) stronger than other versions.

The discussion about whether a PTS version constitutes an appropriate secondary physics curriculum eventually takes us to different networks. It was not a coincidence that those who argued for maintaining the school physics network defined the main problem around the question of adequate preparation for university. In doing so, they were able to draw upon a variety of human and non-human actors, many of which had been black boxed and difficult to challenge. In Callon's terms, this becomes a successful problematization. Problematization involves a formulation of a particular problem or question that allows the identification of the relevant actors and

the definition of their identities and roles. Focusing on the issue of preparing students for post secondary education, the problematization defined not only the goal of physics education but specified the roles and goals of other actors, including students, teachers, and the physics curriculum in general.

In sum, physics teachers argued to maintain the features of the conventional physics actor-network, including maintaining the content of the curriculum, goals of physics education, the roles and identities of their students and themselves. Their description of the network matched the one outlined by physicists, although the rationale and their goals were not always the same. This is interesting because it illustrates the effectiveness of the translation model and how it is enacted; in this case through the actions of teachers who seem to accept and incorporate in their practice the simplifications and definitions suggested by physicists although not necessarily for the same reasons or the same goals.

5.3 How Can We Decide? Who Counts to Whom?

The first two phases of this study revealed a spectrum of views concerning the significance of and support for adopting a PTS curriculum. Some of these views were contradictory, and most actors maintained their initial views and positions as they negotiated them in the second phase. Understanding the process of decision making with regards to the PTS proposal and the nature of that decision become significant in order to understand the construction and attribution of power, which is the central theme that this thesis explores

through physics curriculum making in a centralized society. Understanding the decision, in this case made by the ministry, sheds light on power relations and the politics of physics curriculum. However, we still need to explore the views of all actors so that we can put a full picture together. It will be possible then to conclude who, in practice, decides the 'final' shape of the physics curriculum and explain how that came about.

This section discusses the views and reactions of the physics teachers and physicists with regard to how a decision could be reached, given the diversity of views presented to them in the second phase. This discussion helps us understand actors' sense of status and politics, or simply "who counts to whom?"

In Chapter 4, I showed that university physicists claimed full authority over the physics curriculum, but still granted some weight to the opinions of university students and secondary physics teachers. There was a general consensus among physics teachers, physicists and university students that the views of secondary students "should not be taken seriously." Secondary students, most argued, were either not mature enough to decide what is best for them or would "naturally" prefer a PTS approach because it is easier and less troublesome. In response to a question about how shall we deal with the views of secondary students, who generally seemed in favor of the PTS, teachers said:

T7:
Their views don't count. Frankly, we should not take their opinions in these matters. Students prefer the easier approach. **[C, 9, 24].**

T8:
Yes, I agree with that too. We need not take students' views seriously in that. And as I said before, the most important people are those in the university [the physicists]....We may listen to [students] and then we can either consider or ignore their views. **[C, 10, 1-3, 7].**

T9: Yes. Their views should not be taken seriously. **[C, 10, 6].**

T4:
Perhaps students don't actually realize [pause]. You see the applications and technology—as I have had said before—interest and attract students, but students do not realize the significance of learning the fundamentals and of going deeply into the mathematical manipulations and problem solving. Compared to technology and social applications, students definitely would find those harder and troublesome. **[C, 10, 3-7].**

This reaction was also common among physicists who, in addition, would insert in their comments other claims attributing a lower status to PTS units compared to conventional physics.

Uph#3:
No problem. Many patients go to see doctors. When a doctor tells a patient that you need a surgery, the patient becomes frightened, upset and consults another doctor. The other doctor tells him "you don't need a surgery, just take this Panadol tablet." So, the patient leaves happily because he doesn't want to have the surgery, although he needs a surgery. So, yes the students may prefer these [PTS] topics and find them easy to learn. **[C, 10, 11-14].**

Uph#4:
The students want something that is attractive, that is nice and easy. They don't know exactly what is good for them....

> They usually prefer the easy way. Perhaps they noted that these units don't include a lot of equations and hence liked them. Their opinion is important but is not convincing and we shouldn't take the easy way to prepare them at this stage. **[C, 7, 19-23].**

Fullan (1991, p.182) commented that "we hardly know anything about what students think about educational change because no one ever asked them." While students are the acknowledged stakeholders in school curriculum (Connelly et al., 1980), their views are rarely sought and they are almost never involved in curriculum decision making and educational change. Of course, that is not to say that students do not occupy a place in the language and practice of educational change. Rather, as Fullan (1991, p. 170) observed, people think of students as "potential beneficiaries" and more in terms of "achievement results and skills, attitudes and jobs" rather than "participants in a process of change and organizational life." Fullan contends, however, that those involved in educational innovations "would be well advised to consider explicitly how innovations will be *introduced* to students and how student reactions will be obtained at that point and periodically *through implementation*"(p.189). By involving students at an early stage of introducing the PTS innovation, I took Fullan's advice seriously. In fact, it was the position of this study that students are more than just "beneficiaries" of the innovation, although many actors tended to refer to them in that way. They are significant actors whose views and actions shape the physics curriculum and could, indeed, influence the success or failure of the PTS proposal.

Despite the belittling claims and comments made by many participants about them, the actor-network depends in part on what and who students consider serving their interests and needs. As will be shown in the next chapter, the ministry and other advocates of PTS *have to* depend considerably on students' views if they are to succeed in establishing PTS as a legitimate and accepted version of school physics in Bahrain. This, however, is not a simple task and requires succinct "problematization" and successful "interessement" strategies because many other actors also attempted to enroll students by devising barriers between them and the PTS curriculum. Indeed, a variety of mechanisms were suggested by actors (including physicists and ministry educators) to translate the interests of students, as we shall see in the following chapter. However, as Callon (1986, p. 211) maintains, the device of interessement does not necessarily lead to actual enrollment of actors unless these actors accept the set of interrelated identities and roles attributed to them.

Secondary students were not the only ones whose views were considered insignificant by those who attempted to maintain the status quo in physics education. Industry, too, was pushed aside when it came to deciding issues of physics curriculum. Ironically, though, this was done by invoking "interest" and by restricting the involvement of industry to vocational education. In their discussion of the strategies for deconstructing claims and raising suspicions about their validity, Fuchs and Ward (1994, p. 491) argued that "interest and ideological commitments create links between motives and

statements and so pave the way for further deconstruction." In the following excerpt, attributing an interest to industry is used to rule out the objectivity of the industry's views that supported the PTS units.

> **T4:**
> As for the industry people, their views mostly count when dealing with technical education. But we should not give much weight to their views when deciding matters of curriculum in the academic science stream. It is quite natural for them to support a PTS approach, because it provides the kind of background they want for students who would work with them after graduation. This, of course, is to their interest. **[C, 12, 5-10].**

It is indeed revealing to note how "interest" is invoked to explain why certain people, in this case industry representatives, would deviate from accepting what is naturally assumed to be *the* physics curriculum, and instead choose another version. Yet, the same rationale or argument was not considered relevant to explain why others, such as physicists, were in favor of the academic physics. This is a typical reaction expected from insiders of a network (Latour, 1987).

> **Uph#1:**
> Of course, they [the industry people] are looking after their own interests or their interests as industry. **[C, 9, 24-25].**
>
> **Ahmed:**
> But don't we all have some kind of interest or a stake in this matter as well? Not necessarily personal, but perhaps professional or more general. **[C, 10, 1-2].**
>
> **Uph#1:**
> No. I am thinking about students. I am not thinking in terms of my own interests, or the interests of (pause). Also, I do not think in terms of a lower standard. I am not concerned with those who will not specialize in physics, or those who will not

> go to university. I am, however, concerned about those who will go for further education, to make sure that they will be successful. This is important. Besides, if a student achieves this level, this standard, then he will not have a problem in the future, even in industry. The technical training will not be an obstacle for such a student. It will not be an issue. **[C, 10, 3-12].**

Interest and subjectivity (as opposed to objectivity) often go together, and both are used as accusations by actors within a network to explain the behavior of outsiders and to weaken their claims. Attributing an interest to actors, to show that they have some stake in the negotiation and its outcome, questions the "objectivity" of their claims. For instance, physicists and physics teachers argued that the views of industry and secondary students' were not objective because these actors had an interest in PTS, and, therefore it was expected from them to support it. A similar explanation was not accepted when it came to explain their own views; the views of insiders were perceived as "objective" or pure from "interest." Even in exceptional cases, when an insider admitted that there was no such thing as objective, this term was qualified by adding terms like 'real' and 'totally,' thereby softening the accusation considerably.

> **Uph#4:**
> I will say yes. The opinions of [secondary] physics teachers are important. However, as for the others [industry and students] they each represent a particular view, and *each is concerned with his own interests or benefits. Their opinions go according to their interests. We, on the other hand, want to be objective.* I know that there is no such thing in life as real objective. In fact, some would argue that even physicists are

> not totally objective, but let us leave such philosophical discussion aside and get back to our topic. **[D, 3, 20-25].**

The incidental role assigned to industry in the existing physics network is not surprising because centrality was granted to actors according to their perceived link with the disciplinary knowledge of physics. Traditionally, industry had been considered a significant stakeholder in technical (vocational) education, but not in general (academic) secondary education. In other words, industry was strongly linked to the former but weakly linked to the latter. In Bahrain this was evident by the presence of representatives from industrial companies and establishments on vocational/technical curriculum committees and their absence from all committees pertaining to academic education. Yet the industry seemed to have accepted its peripheral position and was more or less satisfied with its intense, but fairly recent, involvement in technical education. In fact, the industry people whom I approached were themselves initially surprised to be consulted about a physics curriculum to be taught in the academic science stream, and were somewhat reluctant to be involved; it took a month of negotiation at various levels with one major industry before an interview was arranged with one of its engineering managers. A major concern of this industry, as I found out later, was to arrange for someone "who would not only be in a position to give an informed opinion that represented the company, but also who would have an adequate background in physics or physics-related subjects" (Reflective notes #10). For this reason, my suggestion to meet with someone from the personnel or

training departments was refused because they thought the persons in these departments did not have a reasonable background in physics. This suggests that from the start that centrality was accorded to the disciplinary knowledge of physics for deciding issues related to school physics curriculum. In another industry, I was allowed to meet with the Director of Training, but he also asked an electrical engineer to attend the interviews because he had more background in physics than the former.

The initial reaction of industry was conservative; they viewed secondary physics more or less as an academic endeavor whose main purpose is to prepare students for university. Furthermore, industry accepted the claim made by one of the physicists cited above that a student who learns physics in school according to the traditional standards "will not have a problem in the future, even in industry. [That is,] the technical training will not be an obstacle for such a student." The views of industry, however, changed considerably throughout the negotiation process and especially in the second stage once they saw an articulation of an alternative position with some backing to it. In essence, they saw the possibility of aligning themselves with the ministry to achieve a change that they now saw as possible and within their interest. The negotiation process was successful in translating the interest of industry into the PTS curriculum that they now saw as a route to achieve certain goals, for example, to get better qualified students to work in industry and to reduce the amount of initial training they require. The

following exchange between two industry people and myself illustrates this point.

> **INR#2A:**
> Students who join us from secondary education have to go through intensive training program here in [our company] before they take over jobs. Certainly, if you teach students a curriculum that is geared towards technology, that will then make their training easier. The same thing goes for university. If you follow a conventional physics curriculum and prepare students the way physicists want, then you will make their job easier. So, perhaps we, in the industry, are being selfish. Similarly, the university academics are being selfish too. They...want to make things easier for themselves. So, who is the victim in this case? It is the student. We should think more about students, and not just what the university or industry want? .... We should prepare them such that they can go in either direction, whether to the university or elsewhere in the workplace. **[C, 2, 19-28].**
>
> **Ahmed:**
> And how can we accomplish that? What kind of a curriculum will fulfill that?
>
> **INR#2B:**
> If you have a balanced curriculum.
>
> **INR#2A:**
> Yes. A balanced curriculum. Something like these two units, Ionizing radiation and Light Sources may do with little or no modification. **[C, 3, 7-9].**

Returning to the main issue of who counts to whom, and as the responses of physicists and physics teachers indicated, the involvement of industry in academic science education was not welcomed. This was due to the fact that industry's position did not match those actors who were in favor of maintaining the physics actor-network. Nevertheless, industry could play a

significant role in restructuring the network and establishing a PTS; they could become a credible ally for the ministry in its attempt to promote a PTS curriculum and to counter the powerful, extended network that physicists were able to mobilize for their position. For this reason, the ministry celebrated support from industry.

With students and industry displaced, who should decide issues of curriculum in the network? For some teachers, the answer was obvious: physicists.

> **T8:**
> *We start from the top of the pyramid. They [university physicists] will specify for us the scientific content that they require students to cover.* Then we design our curriculum accordingly, and we take into consideration to relate this content to society and technology. **[C, 9, 2-5].**
>
> **Ahmed:**
> Are you suggesting that university physicists should primarily decide on the nature and organization of school physics curriculum? **[C, 9, 6-7].**
>
> **T8:**
> Yes. They are at the top of the hierarchy. They have to tell us the conditions and specify for us the features of the curriculum they deem necessary. But, we will also make some consideration for the societal needs. **[C, 9, 8-9].**

This respondent even rejected a suggestion to form a committee consisting of all concerned parties to discuss the PTS proposal. This suggestion, however, seemed acceptable to all other teachers, although they imposed an important condition on the committee by granting the final say to the "physics content" itself.

> **T9:**
> I agree with your suggestion to form a committee of all these people to discuss this curriculum proposal. But the condition or the framework should be that physics or the scientific subject matter should be the baseline, the core, and then we negotiate and discuss how to enrich and add to it the applications, and social issues, and the other things. **[C, 9, 17-19].**
>
> **T6:**
> Yes. I, too, agree with that.
>
> **T4:**
> I think, it is a good idea to form a committee consisting of specialized physicists, industry representatives, and educators from university and ministry. Together, these parties can work towards putting what students called 'a balanced curriculum.' Of course, 'balance' does not mean that everything [that is, physics, technology and society] will have equal share or be given equal weight. *It means teaching the minimum requirements of physics knowledge which students need to have in order to succeed in their future endeavor.* I can't see how they would disagree on that. **[C, 10, 15-20].**

Since "the minimum requirements of physics knowledge" are more or less what the present physics curriculum covers, then who, but physicists, should be granted the final authority over the curriculum? In other words, who, other than practicing physicists, can claim to speak on behalf of physics? According to one physicist, this was true for an obvious reason:

> **Uph#1:**
> Because we are talking about physics. Do you consult an educator or someone from the industry to tell you what students should study in physics? Or, is it I, the physicist, who tells you what a student needs in order to become a physicist? **[C, 14, 12-14].**

Being able to speak on behalf of physics is, of course, not the same as speaking for, or representing, secondary physics education. But the

difference becomes blurred if one accepts the links, delineated in the problematization phase, between school physics, students, future careers, teachers and educators, on the one hand and disciplinary physics on the other. Problematization, it is to be recalled, deals with the framing of the problem, defining relevant actors and their relationships, and attributions of actors' roles and identities. From the perspective of those attempting to control others, successful problematization not only displays the series of relevant actors (for example, physics teachers but not industry), but also their accepted roles and identities (e.g., students want to do well in university and get better jobs; the ministry's role is to encourage students to get post secondary education, and ensure that they are prepared to achieve that). Speaking of the physics curriculum, successful problematization of this nature would lead to some division of labour, where the responsibility for selecting and organizing the content of the curriculum is granted to physicists, and to science educators the responsibility of helping teachers teach that content. Such a division was obvious in a response by a physics teacher:

> **T9:**
> We take the science from the physicists and also learn from educators things about methodology and teaching strategies. I realize that educators are more concerned with educating students to be self-dependent, think for themselves and learn actual problem solving skills. These are good things, they are right about that. But, as teachers we deal with students everyday and our concern is to teach them the scientific content. Not some general problem solving strategies or skills. **[C, 4, 16-19].**

Physicists are indispensable, and their version of school physics an obligatory passage point (OPP), in the goals of most actors.

5.4 Existing (Academic) Physics as an OPP for University Students

Similarly, one finds that traditional physics had been established as an OPP for university science and engineering students. Although university students were not totally satisfied with the physics curriculum they learned in school, they still rejected the PTS units. They argued that secondary physics provided them with an adequate background to cope with their university physics courses. While most university students admitted that the PTS units would remedy some of the problems they identified with the existing school physics, they still did not consider that to be sufficient to support a change towards a PTS curriculum.

> **USS#4:**
> Frankly, an obvious shortcoming in all the subjects or curricula taught in secondary school is that they are not significant to the student's life. We felt so while in school. We did not find the physics, chemistry or math that we were learning to be of any use or significance when it comes to our daily lives and practice. **[A, 7, 1-3].**
>
> **USS#3:**
> Yes. Perhaps except for biology, which I felt was important. **[A, 7, 4].**
>
> **USS#4:**
> True, we thought biology was close to our lives, but in general other subjects were remote from our life experiences. **[A , 7, 5-7].**

Ahmed:
But don't these units overcome that problem? **[A , 7, 8].**

USS#4:
Yes, and perhaps this is a positive aspect of these units.... *Perhaps then we can slightly modify the physics curriculum by adding some applications and try to relate the topics to real life, but still not to the extent done in these units.* **[A, 7, 9, 11-13].**

Not surprisingly, for university students the main concern is whether a PTS curriculum would have adequately prepare them for the courses they are studying at the university. This point can be understood in several ways. Students compared the content of the PTS units with the introductory physics courses they were currently studying, and raised concerns about covering the fundamentals of physics and the possibility that practical and social aspects might dominate the curriculum.

USS#4:
[T]he time will not permit for learning everything, and because of this time constraint and for the practical aspects and applications not to prevail over the scientific content, it is necessary that the curriculum focuses on the scientific or physics content. And you can mention the applied things a bit in order for us to appreciate and feel the importance of what we are studying. **[A, 15, 3-8].**

USS#3:
With these [PLON] units we have no connection or continuity between the two levels. Had we learned these or similar units it would have been a real problem for us now because they don't look at all like what we currently learn in physics. The content is different. By contrast, we find the physics courses we took before [in secondary school] to be similar to what we are taking now. This is also the case with chemistry and math. **[A, 10, 22-26].**

While some students focused on the content of the PTS, others were critical of its non-mathematical nature and the fact that the units did not emphasize problem solving.

> **UES#3:**
> After secondary school, a student will go to university, and, as we see it now, all what we focus on and need is how to solve problems. What helps us most is to know how to solve problems. **[A, 10, 21-23].**
>
> **Ahmed:**
> What about the other aspects that we talked about? The discussion, applications, developing ideas, new topics, etc. **[A, 10, 24].**
>
> **UES#3:**
> Won't help me in the university. Perhaps if I had learned according to the PTS, I would know a lot of interesting information, have a better awareness about physics and technology. But all that will not prepare me for my university physics courses. That is why I want to connect and relate the school curriculum with the university curriculum. **[A, 10, 25-27; 11, 1].**

PTS advocates would argue that this approach would equally, if not better, prepare students for university because it emphasizes active learning and actual problem solving (see, for example, Aikenhead, 1994b and also the next chapter). A similar argument was made by one of the university-engineering students. Unlike his classmates whom I interviewed, he graduated from a technical secondary school and was also doing well in his first year courses. This student saw merit in the PTS units and supported a move towards such curriculum.

UES#4:
I believe that perhaps less than 30% of the students in the Arab Gulf states actually attend universities. Yet the secondary curricula are mainly designed to teach students for the subsequent level of education, whether in university, college or elsewhere, and hence they lack other important features. They are not comprehensive. On the other hand, I believe that this [PTS] approach is more comprehensive, and still does not ignore preparing students for university. **[A, 17, 5-9].**

UES#3:
But imagine if you had learned these or similar units in school and now you are faced with the kind of physics we are doing. What would you do? **[A, 17, 10-12].**

UES#4:
Well, I was in a technical school with a science education [background] that is quite different than what you had in the science stream. Yet I am having no difficulties with the physics course. **[A, 17, 13-14].**

I found the views of this student encouraging and intriguing. His arguments were sophisticated and consistent throughout the three interviews, and his position was further reaffirmed when, later on, I presented the group with some of the physicists' views.

UES#4:
In the Western countries, they no longer equate literacy with writing and reading as we do in the Arab or Third World countries. Literacy has taken a broader scope. If you think in those terms you will probably find that this new curriculum is far better because it focuses on promoting literacy, awareness and understanding. **[A, 20. 1-4].**

UES#4:
University professors are used to do and teach certain things in a certain way, and they want students to follow that same thing. Yet, they never question the significance of all that. What do we actually gain by emphasizing problem solving? Students have been learning this style, solving problems for

> years, but what have we accomplished? *I think we should look at physics at two different levels. First, a general level, to be taught in secondary schools and this can be through a PTS or another approach. The second, is more specialized, and this can be done at the university level in the way they [physicists] want.* **[C, 4, 11-17].**

He provided an example to counter the arguments of his classmates who insisted on matching the secondary curriculum with university courses. Nevertheless, no other student found his argument to be sufficiently convincing.

> **Ahmed:**
> Here we have a good example, your classmate [UES#4] learned far less physics in school than you did, and he is doing fine in engineering. **[C, 1, 1-2].**

> **UES#2;**
> He will face difficulties and obstacles, unlike the science student who in school learned the same topics we are covering now. For example, in physics we are now learning about 'collision' and, at least, I have some idea about that from before. I know about elastic and inelastic collision, and now I begin to relate things, put them together and think about these topics more deeply. But imagine someone who has never heard about these things, never saw the equations, he has to start from scratch. *And on the top of that, that student has to cope with the [English] language difficulties, with new courses, and other problems that any first year student goes through.* **[C, 5, 3-11].**

The response from this student, which was also supported by his classmates, shows some of the reasons university students have for supporting the maintenance of an academic version of school physics. It also reveals that their interest or goal goes beyond simply receiving an "adequate preparation" in secondary school. For many students the first year in

university is critical; they have to cope with language difficulties (English is the medium of instruction in science and engineering at this level), new subjects and even different teaching and learning styles. Therefore, the fact that most of what is covered in the secondary physics curriculum is repeated in first year physics is considered an added bonus. After all, that will help them "catch up well, and makes it manageable to devote more time to other new subjects."

I said that it was encouraging to find one university student showing strong support for a PTS curriculum, and other participants who were in favor of the proposal felt the same way. But this was encouraging only in the sense that it suggests that advocates of PTS could find other students who would support the proposal. This suggests a source for locating allies who can be brought together to support the claims of PTS advocates in the larger public. At the moment, however, this particular student represents no one but himself. His arguments, no matter how plausible and based on experience, were either ignored or brushed aside by his classmates who saw their interest being more defined in terms of doing well and managing their study time at the university. As for other actors, one of the physics teachers supported his claim regarding the importance of maintaining the academic nature of curriculum by invoking technical school students. He cited examples where students from technical education were experiencing difficulties in university compared to their fellow science students. This difference in performance between science and technical students could, of course, be attributed to a variety of reasons;

nevertheless, in this context, opponents of PTS choose to focus on one explanation for that difference—the quality of the secondary science education. Similarly, but definitely stronger, claims were made by university physicists; the strength of their claims were due to the number of claimants, and the multitude of student examples over a prolonged period of time.

> **Uph#4:**
> Generally, when we compare [secondary] science students who while in school have practiced problem solving and using math in physics, no doubt you see a noticeable difference in their level of understanding, compared to students who come from technical schools. This is something we all notice in our teaching, our lectures. We witness it everyday in the classrooms. Students from the science stream are far better. **[D, 4, 16-21].**

How did university students then approach the issue of conflict over the PTS curriculum when I confronted them with a diversity of views? One of the engineering students summed up their position:

> **UES#2:**
> You have accomplished an important task by eliciting and gathering the views of the concerned parties. You can now put all that before you and make use of as much as you possibly can to compromise and make a curriculum. **[C, 1, 16-19].**
>
> **Ahmed:**
> How do you think I can do that? **[C, 9, 9].**
>
> **UES#2:**
> For example, the suggestion from the physicists and physics teachers to add a few pages about PTS or some PTS essays after each chapter seems like a good compromise in that it tells you that PTS is not totally rejected. Of course, you should not expect that half of the physics textbook content be of a PTS type in order to satisfy science educators. No [with laughter]. **[C, 9, 10-12].**

In summary, while university students were not entirely happy with the physics curriculum they learned in school, they still argued to maintain this curriculum and rejected the proposed PTS approach. Students in criticizing the existing curriculum raised issues of "relevancy" and "usefulness," and this suggests that they should have been attracted to another version of physics (such as a PTS) which emphasizes practical problem solving and learning physics in the context of technology and real life. On the contrary, students did not support aspects of PTS that address these issues; their responses indicated a desire only to slightly "improve" the conventional physics curriculum for motivational purposes. In general, students saw this curriculum, irrespective of the problems raised, as indispensable and an obligatory passage point (OPP) to success in university and the route to future careers.

5.5 Where is the Ministry? The Story of T2

I find the overall picture of the politics of the physics curriculum sketched by physicists and, especially, physics teachers striking because of the omission of the ministry (and particularly the physics curriculum specialists) at the top of the decision making hierarchy. As discussed in Chapter 3, the official control of key elements of the curriculum, such as the goals, subject content and textbooks, implies that the ministry possesses the utmost power over the curriculum. Nevertheless, at no time throughout the discussions with physicists and physics teachers was the ministry referred to as an agent that

had *the final say* over the curriculum. This means that although they were aware of its legislative and political power, they recognized that the ministry could not determine the future of physics education without their cooperation and approval.

Indeed, the ministry has demonstrated this power over the years; physics curriculum have always been developed and written mainly by ministry specialists who consulted with physics teachers and university physicists once a particular curriculum was almost fully drafted, and there never have been any fundamental disputes. So in principle and in practice the ministry *appeared* to have exercised full control over the physics curriculum. To appreciate that, I quote from one physics teacher who became interested in seeing a PTS version implemented in schools. Of all the teachers interviewed, she was the only one who fully supported the move, but recognized that it would result in a reshaping of the whole network.

> **T2:**
> I might sound a bit pessimistic though. You see, if the ministry is convinced, if they approve this approach, it will be implemented. As far as I remember, in the ministry they have never considered the opinions of teachers, students or parents. As long as they are happy with this curriculum, they will implement it. They have never concerned themselves much with our opinions or that of others. **[C, 2, 10-15].**
>
> My advice to you, if you are really serious about getting this implemented, is to work on the ministry people, those on the top, to secure their support. **[C, 2, 16-17].**

There is truth in this teacher's assertion, but only as long as we look at physics curriculum making from within the existing actor-network, with its

interrelated set of actors, roles, identities and relations. From the network, her perception of the ministry's power is understandable. However, because the primary aim of all previous projects in secondary physics was to update the curriculum, textbooks and laboratory manuals, there was little reason for conflict to arise. Disagreement, whenever it arose, focused on the accuracy or depth of analysis of the topics, and among the three groups—the ministry subject specialists, the science teachers, and university scientists—such disputes were successfully resolved. In essence, there was an implicit (and sometimes explicit) assumption shared by these groups regarding what counts as secondary school physics, what purposes it should fulfill, and who should learn what kind of physics.

One of the ministry officials described previous reforms in science curricula as a process leading to "reorganization of the existing content and different presentation [without] changing the philosophy, the inclination, and the other components of the curriculum" (MEP#3, B, 17-18). In this respect, previous reforms can be regarded as "first order change" (Cuban, 1988, p. 228) since they assumed that the existing goals and structures were adequate and only attempted to improve the effectiveness of existing practices. Such changes do not alter the identities and roles of the actors and do not disturb their relationships; first order changes do not restructure existing actor-networks and, for this reason, they are not problematic.

The situation differs if one rejects the existing school physics for PTS. To do so is to step outside the existing network, to challenge its assumptions and

the interrelated roles and identities attributed to (human and non-human) actors. This type of change requires abandoning, or restructuring, the existing network and, as I shall explore further in the next chapter, is difficult to achieve because of the various obligatory passage points and black boxes. We have encountered some of these black boxes but others, such as "status" (Goodson, 1987; Werner, 1991b; Young, 1971) and "prestige," associated with the subject, the teachers or students, also need to be dealt with. As I discuss in the following chapter, although the ministry accepted PTS, their plan for enrolling and mobilizing support to establish PTS, reflects an awareness of the complexity of the situation involved; to say the least, the ministry's new stance puts it in conflict with traditional allies. By exploring the views of the ministry people and the nature of their decision in relation to other actors, we can see the difference between legislative and "real" power or, in Latour's (1987) terms, the difference between power in principle and power in practice.

For an established insider, like myself and the teacher above, stepping outside the network that one belongs to creates risk since this calls for reshaping one's identity, experience and goals. I experienced this challenge during the early stages of data collection, and so was sympathetic with this teacher as she identified the tensions and described them as "contradictions" when reviewing the interview transcript; she was relieved to know about the views of other actors who supported PTS. In reflecting on her role as a physics teacher, she said:

T2:
Perhaps we are used to this. As teachers we have been teaching physics in this way for years. For me, I have been doing it for more than 16 years. It will not be easy to change. Any teacher or I might not accept this new version [of physics]. All my experience, which I have accumulated over the past years of teaching and learning, will now have to be reassessed and winnowed. *That is what all this means. It is going to be tiring. But that does not mean that what we are doing now is the right thing.* **[B, 1, 16-21].**

Ahmed:
Are you saying that, at this point, your opinion is actually for the PTS option as a curriculum emphasis for school physics, rather than to add a few PTS topics to the existing curriculum? **[B, 1, 23-26].**

T2:
Yes. And as we are talking now, I believe my view is beginning to crystallize even more. Initially, I was not quite certain, I felt that to adopt PTS would lead to reshaping the physics curriculum, somewhat drastically, but I was not sure how. I think now things are clearer to me. The goals of teaching physics need to be reassessed, and the content and its organizations all has to be reshaped. **[B, 1, 27-32].**

This teacher was enthusiastic about a PTS approach and demonstrated sincere commitment to its goals. She focused on the students, "to develop their minds, help them become critical and think about controversial issues." [T2, A, 18, 9-10], and so found the units Ionizing Radiation and Light Sources particularly attractive. More importantly, she challenged the claims made against the PTS approach by other actors and showed willingness to engage in discussion with her colleagues and others to support a move towards this curriculum emphasis. For instance, when confronted with the claims that

problem solving and mathematical manipulations normally found in physics are helpful in developing critical and analytical thinking mentioned, she said:

> **T2:**
> That is nonsense. I know that well. I socialize with physics teachers. They are all physics graduates, and I tell you that, when we discuss certain issues or topics, I rarely notice the critical and analytical thinking that these physicists talk about. No doubts, they all have done numerous physics problems, they are good at that. That is for sure. But, I don't see analytical or critical thinking among these individuals. I don't want to say all, but most of them. **[C, 1, 11-17].**

Obviously she is an ideal candidate for piloting a PTS project.

Summary

In this chapter I explored the responses of secondary physics teachers and first year university students to a proposal to introduce a PTS version of physics in secondary schools. The context of discussion and negotiation proved valuable in testing the links between these actors and the existing physics curriculum. The analysis revealed that most teachers and university students were strongly linked to the existing school physics; many of these actors saw some merit in the PTS materials, but they did not link themselves to these materials as they did with the existing curriculum. In particular, physics teachers strongly associated themselves with elements of the existing school physics: e.g., physics, assessment, the content, and students' role. They accepted (and defended) the simplified definitions of these elements as sanctioned by physicists and mobilized them in their practice, thereby

contributing to the maintenance of these elements as black boxes. However, they did so for reasons that did not always coincide with those given by physicists. From the point of view of ANT, this was an example of translation, whereby the physics curriculum was established as an OPP for physics teachers.

Similarly, university students were in favor of maintaining the existing school physics, which they argued had adequately prepared them for university and made it possible for them to devote more time to new subjects. For university students, the physics curriculum was also an OPP to success in university and to future careers.

CHAPTER 6

RESTRUCTURING THE SECONDARY SCHOOL PHYSICS ACTOR-NETWORK

The previous chapters dealt with actors interested in maintaining the school physics actor-network. By exploring the views and reactions of certain actors concerning the proposed PTS units, we learned about the basic features of the actor-network and its constituting elements. In addition, we found that the fundamental features of the network were strongly supported by university physicists and students and most secondary physics teachers. These features included an emphasis on mathematical aspects of the curriculum content, a focus on problem solving in teaching and assessment, links with disciplinary physics, and a priority on preparation for post secondary education, among others. Finally, we saw that the existing physics curriculum had been established as an obligatory passage point (OPP) for university students and secondary physics teachers who accept these.

In this chapter I focus on the views of actors who became interested in PTS and argued for redirecting school physics towards a PTS curriculum emphasis. The key actors in this group are Ministry of Education personnel, but their position is supported by industry representatives and (so far) a few physics teachers and secondary students. Ministry personnel were attracted to the PTS proposal and found it consistent with their philosophy and goals for science education. Nevertheless, they recognized the fundamental changes that would accompany such a curriculum in relation to the various actors

involved. Their responses can be understood in terms of their efforts to reconstruct the network sustaining conventional physics curriculum. Employing actor-network theory, the analysis of the ministry's views and their efforts will develop along two dimensions: the links between the various elements (including the advocates of the PTS themselves) and the ministry's decision on promoting a PTS curriculum. I also explore how the innovation is modified in the process of reconstructing the actor-network.

The challenges brought by the PTS proposal and the ministry's enthusiasm for it created an opportunity to study decision-making in action. The ministry is not treated as a black box (or a simplified network, in Callon's terms), but as a complex, heterogeneous actor-network in its own right. Similarly, the decision making process itself is not seen as a black box that produces ready made decisions.

6.1 Linking the Ministry to the PTS Proposal

Discussion about STS in science education emerged in Bahrain rather recently, during the late 80s and early 90s, and so far has been confined among ministry and university science educators. Such discussion normally revolves around issues related to scientific literacy, interaction of science and technology, and positive and negative aspects of science and technology. For example, two brief notes about STS as a new theme for reforming science education by the head of the secondary science education department (in the ministry) appeared in two consecutive issues of *The Science Newsletter*

(March, 1994 & February, 1995) published by this department. Moreover, in a letter to the editors of *The Science Newsletter* (March, 1994), Dr. Ali Fakhro, then the Minister of Education, pointed out the importance of merging science and technology in science curricula and suggested that science curricula should explore both positive and negative aspects of science and technology. The February, 1995 issue of *The Science Newsletter* also included a summary of a study conducted by Matter (1994), a member of the science education department in the ministry, which focused on introducing STS issues in intermediate (grades 7-9) science education. Finally, STS in science education appeared as a central theme in a recent report produced by two science education members of the ministry (Al Khalifa and Mattar, 1996). The report was prepared at the request of UNESCO and focused on the enhancement of scientific and technological literacy for girls and women and the promotion of science education for all in Bahrain. Unlike most STS discussion in Bahrain, which focuses on primary and intermediate science education, this document invoked STS within the context of secondary science education, suggesting that more attention should be given to goals related to scientific literacy.

As far as the ministry is concerned, this research (and the PTS proposal) did not emerge suddenly, although its focus on rethinking the secondary physics curriculum was new. Therefore, a significant aspect of the current study is that it opened some possibilities for looking seriously into considering STS in senior secondary science education in Bahrain.

As did university physicists, the Ministry of Education personnel also raised in their discussion of the proposed PTS units issues related to students' and teachers' roles, assessment techniques, goals of physics education and the content of physics curriculum. However, unlike university physicists, the responses of the ministry people showed support for a move towards a PTS curriculum which they argued is consistent with the ministry's philosophy for secondary science education and with "contemporary views" of education.

For instance, a member of the ministry's science education department summarized what he considered to be the positive aspects of a PTS curriculum as follows:

> **MEP#1:**
> The point behind this [PTS] curriculum approach is not to fill the student's mind with concepts and information. Rather it will help students better understand science. Also, this approach emphasizes inquiry learning. While in our [current] curriculum we require teachers to use inquiry-based strategies, the curriculum you propose actually puts students in situations that force them to explore and inquire. This curriculum also focuses on social issues and problems of concern to society. With such curriculum we can explore all sorts of issues and problems: communications, energy, transportation, water, social aspects, and look for possible solutions. **[A, 20, 1-28s].**

The positive aspects emphasized in the excerpt above are not new. Educators generally find the inquiry approach and the inclusion of social and technological issues as a major contribution of STS education. Not surprisingly, then, other members of the ministry made similar remarks.

However, what is important to see is the extent to which these actors hold on to these features compared to other aspects of a physics curriculum, and also what kinds of arguments they are able to make in support of them when challenged. One of the challenges brought by PTS, as we have seen in previous chapters, is that it downplays the wide content coverage found in traditional physics curriculum. For university physicists, most secondary physics teachers, and university students this content coverage was a significant feature that was strongly supported and not negotiable. On the contrary, ministry educators were less tempted to focus on this aspect and, when challenged, held on to the features emphasized by the PTS units.

> **MEP#1:**
> I am not particularly concerned with covering all domains or fields of physics.... The students who will later on specialize in that will cover all that in university. As for secondary education, the purpose is to promote scientific literacy, to educate students to become good, productive citizens.... All students in the science stream are taught science, but they are not taught to necessarily become scientists. That is a job for the university. **[A, 37, 5-13].**

> **MEP#2:**
> Of course, I wish I knew a precise answer to this question [that is, how much of the traditional scientific content do we need to maintain in a physics curriculum?]. But we are certain that what is currently being taught to students is actually a lot, far more than necessary. And that has occurred at the expense of teaching students the process of science and achieving the important goals [decision making, scientific literacy, and problem solving] we talked about before. **[B, 11, 6-9]**

Ministry personnel also noted the need to reexamine and redefine assessment strategies to be consistent with this alternative approach which they were supporting. They realized that a PTS curriculum would require a significant departure from the assessment practices commonly employed in school physics. Assessment was problematized by rejecting the simplified notion accepted within the existing school physics actor-network.

> **MEP#1:**
> If we look into the kind of tests and evaluation methods that we use in physics, we mainly find questions that have definite answers. All answers are predetermined. Whenever we prepare a final exam we also prepare and write the model answers to go with it. There is no disagreement on that. Right? *This kind of evaluation will not work with an STS or what you called a PTS curriculum.* With such curriculum, we must include issues, allow for multiple solutions, disputed views. *No answer might be totally correct or wrong, but we need to examine and judge the strength of students' arguments and solutions and how the scientific knowledge has been utilized.* **[A, 29, 3-13].**

The relationship between assessment and the content of physics curriculum was also highlighted. The following excerpt critiques the present practice and stresses the need to redefine the nature of assessment and its purposes. By "contextualizing" assessment, its purpose is not primarily to assess students' learning of scientific content and problem solving, but to see if students can apply the concepts and demonstrate decision making skills in real life situations. All this is in harmony with the emphasis or what Roberts and Ostman (1998) recently called "companion meanings" of the STS and PTS curricula in science education.

> **MEP#3:**
> Unfortunately, our present physics curriculum, and because of its disciplinary orientation, focuses on the scientific content and concepts. It helps students know and memorize physical laws and concepts. Also, the examination papers emphasize similar aspects. But if we adopt an integrative approach, as in these [PTS] units, then our assessment strategies must change too. Assessment will be of different type. .... The purpose will be to see if students can apply and use the concepts, know how to solve actual problems, suggest alternatives and select among them. We have to assess students' achievements through project work, in real life contexts, in society, industry, etc. I believe this is what contemporary education is calling for nowadays. **[3, 2-17s].**

To reject the traditionally accepted assessment techniques and the 'purified' notion of a physics curriculum also implies a reduction in the significance of engaging students in problem solving and mathematical manipulations. Engaging students in these activities, as we have seen, is at the heart of the conventional physics actor-network. Moreover, one of the main arguments presented in favor of maintaining such an emphasis in the curriculum was that it would help students become critical and develop analytical thinking. Accordingly, it was vital to see the extent to which advocates of the PTS (whether from the ministry or their potential allies) would hold to these features when challenged.

> **Ahmed:**
> How about the argument that the problem solving, as we know it in physics and math, promotes critical and analytical thinking and would help students become actual problem solvers?
>
> **MEP#1:**
> Absolutely not. On the contrary, I think...when you give a student a problem like the need for fresh water in Tanzania,

where there is a real problem and an actual analysis of that problem and different ways of solving it. Not to manipulate symbols and do arithmetic. We should not associate the physics subject with solving equations and doing problems. It is not correct to do so. I don't agree with that. **[C, 3, 1-5].**

MEP#3:
Concerning the emphasis on mathematical analysis and problem solving. That depends on the kind of [physics] problems and where do we get them from. In reality there are numerous problems which also involve technology and society. Besides, it is not true that only these kinds of problems promote critical and analytical thinking. On the contrary, I think it is the approach you are proposing that does that. These units, from what I have seen, are better geared towards problem solving and this is what encourages students to think, analyze situations and actually solve real problems. **[12, 4-10].**

The ministry educators were firm in their position with regards to this issue, and so were their potential allies. The following excerpts from an industry representative and a university physics educator are illustrative.

INR#2A:
[Conventional] problem solving will develop some sort of logical and numerical reasoning in students. But let us not forget that students do a lot of math. So, the math courses will take care of that. Here, in physics, we should be concerned with understanding the concepts and laws of physics. Once that is achieved, solving the problem becomes sheer mathematics to come up with the final result. *The units you gave us included the needed concepts and laws of physics, but ignored the mathematics and numerical manipulations. That's O.K, because I don't think that was necessary in the first place.* **[C, 1, 14-21].**

UPE:
With regards to [this issue], I can't recite any research to support it, but I have read a lot of research which shows that plugging numbers into formulas and problem solving do not indicate understanding of physical principles. So, that by itself, and actually qualitative questions provide a

> better measure of understanding and train students to acquire the physical principles. **[C].**

The content of a physics curriculum and assessment strategies were not the only actants problematized and redefined by ministry educators. Another significant actor was the student, and ministry educators paid considerable attention to redefining the student's role and identity in relation to a PTS curriculum. Whereas in the existing physics actor-network a student's identity and role are defined in terms of learning the disciplinary knowledge of physics in a manner described by physicists, a PTS curriculum would require a redefinition of such identity and role. In a PTS curriculum, the link between students and academic university physics is weakened and the links with society are strengthened. In other words, students are defined in terms of their relation with society and the workplace and not the academic training in physics. A PTS approach provides different trajectories for students than merely the one leading to academic work in the university. Of course, one may start with such a view of students and arrive at a curriculum that would be different from the traditionally accepted one, a curriculum more appropriate to fit PTS.

> **MEP#2:**
> To decide on the nature of the curriculum, we must first go back and ask ourselves: What is it that we expect a student to get from the curriculum? *We would like a student to acquire several skills, to be a responsible citizen, to have positive attitudes towards work, to be a problem solver. That's what we want and hope for our students.* So, how can we achieve that? What approach or what sort of physics curriculum would help students fulfill and achieve that? Clearly, that

> curriculum will include some physics concepts and principles, and that will be presented and organized such that they will link physics with technology and society. We need to focus on that [link] and emphasize the mutual interrelationships among these three elements. Not just to show that physics leads to applications. All these, in my opinion, are important aspects of a physics curriculum. **[A, 19, 9-20].**
>
> **MEP#2:**
> In schools we are talking about general education. At this educational level, *the main concern is that we see student's personality be fully developed, as a human individual who feels and acts with the environments and surroundings, feels for and interacts responsibly towards social and environmental problems*. All these should be embedded or added to the natural phenomena that the student studies and explains. **[C, 3, 1-8].**

This support for the PTS units and enthusiasm expressed by my colleagues and superiors in the ministry were encouraging and gave me a sense of relief. For the project to succeed, the ministry had to approve it, although its support is not sufficient as I initially thought. To get a commitment to develop the project further, I negotiated with my colleagues and superiors, and secured their support to engage in the third stage of negotiation with other concerned parties. To that extent, I believe I was quite successful.

> **MEP#3:**
> The educational and political leadership in the ministry and the country have put their trust in the Directorate of Curriculum Development, to propose change and improve education, to try out our ideas. So, in the science department you discuss the matter, come up with a proposal and submit it to the Director, and we can, once everything is ready, start piloting. *So, nothing should stop you*

> *from piloting, from experimenting. We only need a preliminary approval... and I do encourage you to go on with this.* **[C, 19, 1-8, 16].**
>
> **MEP#2:**
> We want to adopt the [curriculum] emphasis as it is, only with some modification to suit our society. Although we are starting with implementing certain units, our goal is to reach a stage where we implement a full physics curriculum based on PTS. **[D, 6, 22-23].**

To achieve that, however, I could not assume the role of a disinterested researcher who explores a certain phenomenon. Indeed, my roles as a researcher, physics curriculum specialist in the ministry, and networker were so interwoven that it was difficult to separate the three, especially when negotiating with ministry officials. The ministry took my proposal seriously, in part, because I was seen to be a member of the ministry whose duties included suggesting ways to improve physics education in the country. On several occasions during the data collection phase of this study, some ministry people asked me questions and raised issues concerning the move towards adopting more STS or PTS at the secondary level. Those instances provided opportunities for networking within the ministry and also meant that the ministry educators took my proposal seriously.

> The [ministry personnel] has been constantly supportive of my project from the start. [This actor] has been intrigued by the STS movements in general.... Nevertheless, I feel that [This actor] still had some doubts regarding the fate of such an innovation when it comes to implementing STS or PTS at the secondary school level to replace the disciplinary sciences. [This actor] needed further backing that a PTS curriculum can successfully be implemented and will indeed help students "achieve the high and noble goals we are

> setting for them." [This actor's] hesitations became clear as we moved to the next phase of the study and as I negotiated with her our decision and what can and can't be said to other participants. [This actor] felt that we were about to make "a big change in how the physics curriculum is conceptualized" and of which the consequences are not totally known to us, at least in practice. [This actor] still considers "preparing students for their future studies in university" to be an important, though not the primary, goal of secondary science education. Although [this actor] did not believe that a PTS emphasis, or units like the ones we saw, will jeopardize the achievement of that goal, such belief was, to some extent, not firm enough without further support and assurance on my part. I think this is the reason that on several occasions, and not necessarily during the interviews, [this actor] would make comments like "probably with many PTS units we will be able to cover enough of the traditional physics content to keep people happy and provide students with the adequate background." One day [this actor] asked: "Ahmed, let us say that we went along and designed the whole physics curriculum as a PTS, how much of the traditional content, just the physics, do you think will be maintained?" Perhaps 50% or a bit more, I thought. I was not totally sure at this point, but I was certainly thinking about what some secondary students and especially industry people said with regards to the significance of basic physics for them. "50% will be enough I think", [this actor] replied. **[Reflective notes #17]**

Without the assurance I was providing (as a physics curriculum specialist at the ministry), the ministry might have been more hesitant to indulge in such a project at the rate I was pushing forward. In making my argument, I frequently mobilized the literature in the field of science education and referred to the research findings to support my views and affirm the ministry's position. In other words, these findings were actors in my network. Furthermore, with the help of the data gathered in Phases One and Two of the study, I was also able to mobilize several actors, particularly from industry

and secondary students, who made claims that I saw as supportive of a move towards a PTS curriculum. These actors and their claims were, in turn, mobilized by other ministry members and enlisted as potential allies for promoting the innovation.

> **MEP#2:**
> This is a very crucial point. It also refutes the academic's argument for the need to emphasize mathematical manipulations and problem solving. Applying physics does not necessarily mean doing these kind of problems. The engineer whom you spoke with, his response provides a good example against that alleged necessity.... *And this also supports and strengthens our position.* We can actually say that whether in everyday life or workplace a student will benefit more from a PTS version of physics than the version backed by academics. *I see this as an excellent point in favor of our project. Now we have some students and some people from the industry too. That's nice.* **[C, 8, 22-25; 9, 2-6].**

Another point that deserves attention is related to the transformation or change in the nature of the (PTS) innovation itself. At this stage it should be noted that the innovation had undergone some change in the light of my negotiation with the ministry and other actors. The proposed (PTS) curriculum I started with, and as exemplified by the three units selected from the Netherlands' PLON project, fitted into Category 6 (infusion of physics into PTS content) in the "Categories of PTS Physics" scheme modified from Aikenhead's (1994, p. 55). This is because, collectively, the three units included about 30% of their content as "pure physics" and the rest as PTS content, and students' assessment reflected these proportions. My response to one of the ministry officials (see reflective note above) indicates that we

placed the (PTS) innovation in Category 5 (physics along with PTS content) or somewhere between Categories 5 and 4 (physics through PTS content). In Category 5, the curriculum included about 50% of its content as "pure or disciplinary" physics and students are assessed equally in both this and the PTS content. Although the innovation is still far from the conventional physics and from what physicists and most physics teachers would accept (e.g., Categories 1, 2 and 3), it is no longer the same innovation that I started with. This modification resulted from my negotiation with the ministry and other actors, such as industry, secondary students and teachers. Industry was supportive of the PTS proposal and, as I mentioned in the previous chapter, saw their interest and goals being served by this version of physics. Still, they paid significant attention to the concepts and principles of physics and regarded them as essential for the workplace, as illustrated in the following comments from an engineer.

> **INR#1:**
> To me, physics is, as a parent and as someone who has been working in industry for 30 years, I feel that a physics curriculum should include theories and principles of physics, comprehensive laboratory sessions, applications in industry. These are essentials. A group thesis or project on applying physics principles and theories in society will be good too. **[A, 2, 3-8].**
> Basic concepts of physics are what we need and mostly use when working in industry. I always go back to these fundamentals, say, from my O-level physics when I forget something. All of a sudden, for example, I want something that has to do with air conditioning and I want to know about wet bulb, dry bulb and humidity. These are my principles. So, principles and concepts for me are still very important because I can see when I come to industry, if I

> don't have them, if I don't have the solid base then I can't talk about it. **[A, 2, 34-40].**

Modification of the innovation at this stage was necessary both to enroll the ministry and to maintain the alliance with industry (and perhaps others). This illustrates the difficulty of convincing and maintaining the alliances with all these actors if the innovation is to be kept intact. Thus, modifying the innovation was a price worth paying to get a commitment from the ministry to take it further towards implementation.

Latour's (1987, p. 130) argument that a chain is only as strong as its weakest point applies to the ministry and the existing school physics actor-network. Up until this point, the ministry (including myself) had been an actor (enrolled) in the existing network and had played a significant role in shaping physics the way it now is in Bahrain. Yet the link between the ministry and the conventional physics curriculum and its primary goal is the weakest compared to how others in this network are linked to them, and this accounts for the relatively immediate support the PTS proposal had received from the ministry educators. This is the result of negotiation which started a few years ago and was intensified by my proposal to introduce PTS in secondary schools. This process continued and, in the third phase of this study, I negotiated further with my colleagues and superiors the ministry's decision regarding the PTS proposal. In doing so I was involved in shaping that decision.

> **Ahmed:**
> How about if we take this as a two-stage piloting? After piloting with two course [units], we then move, in the next stage to piloting a complete or mostly PTS curriculum in two schools. Of course, then it will make more sense to follow students after their graduation from school to join university. **[D, 5, 17-21].**
>
> **MEP#2:**
> Yes. That is a good idea. Not only that will facilitate the process of following students, but it has been done before in other subjects as well. So, we implement a PTS curriculum in a school or two first. That sounds good. **[D, 5, 22-24].**

Eventually the result was a decision that the ministry approved and this allowed me to negotiate with other actors. At this stage, I was not simply representing myself, but the ministry of education.

> **MEP#2:**
> You may tell them [university physicists] that the ministry approves this curriculum and is going to pilot it and, if the piloting succeeds in the light of the criteria we specified earlier, then a PTS curriculum will be developed and fully implemented. **[D, 7, 15-16].**

To summarize, starting from the notion that secondary school physics is an actor-network we saw that a substantial change in the physics curriculum would necessarily entail a restructuring of this actor-network. The process entails identifying actors and defining their allowable identities and relationships within a PTS curriculum. These activities refer to problematization, one of the four overlapping phases described by Callon (1986) in the process of networking. Moreover, both human and non-human actors need to be involved in the networking and analysis; for example, the

content of the curriculum, formulas, the role of problems and assessment, and the definition of physics, were considered to be significant elements by the actors and constantly invoked in one way or another. In their effort to establish a PTS curriculum, ministry educators have to deal with these non-human actors along with students, parents and teachers; as such, the redefinition of assessment and the goals of physics teaching was as important as the redefinition of students and their roles. Finally, it should be noted that the PTS innovation has undergone some change in the process of negotiating the proposal with the ministry and other concerned actors; instead of being a Category 6 curriculum, the innovation is now placed at about Category 5 where the pure physics content is given more weight than before.

Having explored the ministry's position regarding a PTS curriculum, I now focus on its decision and strategy to proceed with piloting some PTS material in secondary schools.

6.2 Curriculum Making and Networking

Ministry officials were aware of the difficulties of introducing such change. Given the differences with the traditional curriculum, they anticipated significant resistance from many actors. Their anticipation was confirmed by the views and positions of university physicists, physics teachers and students which were elicited during the various interviews.

> **MEP#3:**
> The only thing I am worried about is the resistance. Bahrain is a flexible country, and the people are nice and accept change. That is to say, their resistance to change is usually limited, or in most cases according to my experience. *But the kind of change that you are proposing in physics is drastic. There is a change in the nature and organization of the scientific subject and content.* **[10, 1-6].**
>
> **MEP#2:**
> In principle, I have no objection whatsoever to this [PTS or STS] project. What I fear is the people's reactions to it, and I worry about the improper implementation.... We can and have the right to improve and change curricula as we wish, but we have to be very careful. **[A, 9, 19-23].**
>
> Based on our previous experiences with curriculum development and innovations, I think we should have no trouble getting the approval for a PTS curriculum. We can take it through the normal channels in the ministry and pass it with no problems. *But a PTS version will obviously be confronted with strong opposition from the field and from parents.* For instance, from what you have told me, the teachers are not happy with this project. **[C, 1, 13-16].**

Consequently, the ministry was cautious with how to go about promoting and, eventually, implementing this innovation. Achieving this task would require certain activities such as redefining actors' roles and identities, enrolling and convincing other actors, involving new actors (allies) in the curriculum making, marketing the innovation, creating or redefining "interest groups," and modifying both the curriculum decision making process and the innovation itself. These activities depict curriculum making or change as a process that involves the construction of a network in a manner consistent with Actor-Network Theory and the Translation Model (Callon, 1986; Latour, 1987; Callon & Law, 1997). For instance, the list of activities illustrates that

neither the innovation nor its social context is taken for granted. Both are fluid and could be reshaped. However, since the ministry wished to maintain as much of the original qualities of the innovation as possible, its efforts were more focused on the social context—for instance, defining, convincing and enrolling groups, involving new actors as allies, and modifying the decision making process. Nevertheless, that did not exclude the possibility of modifying the PTS innovation itself, and it is in this sense that both the innovation and the context or the social world co-evolve constructing each other and forming an actor-network. To elaborate and further illustrate the activities outlined above, I discuss the ministry's decision and plan around three overlapping points: the pilot, enrolling students and parents, and the decision-making process.

6.2.1 Piloting: A Platform for Negotiation and Translating Interests

Stories of constructing black boxes, whether they are facts, machines or school subjects, are stories of translations and establishing networks. According to Latour (1987, 1991), two things are necessary to establish a black box. First, enroll others such that they participate in the construction of the black box and spread it in time and space. Second, control their behavior so that what they spread in time and space remains more or less the same. As for the PTS in Bahrain, the process of networking has only begun and certainly much more than the support from the ministry will be needed. Other actors must be enrolled in the construction of the network. In addition, the

alliances of those who choose to link themselves with the innovation need to be tested and strengthened. And to do so, we need to engage actors in a concrete experience with the PTS that will test traditional links. A pilot provides the opportunity.

> **MEP#2:**
> With regards to this project or this curriculum orientation in particular, I personally don't approve of it originating from the top. I don't like the idea of the ministry adopting it first. What I would like for us is to pilot first. We want to see how the project progresses, so we pilot it in some schools by assigning it as an advanced elective course. We prepare teachers and work with them, collaborate with them and follow the project and its development. *This is an important point- and I had mentioned it before- we want the teachers to be convinced and so it is crucial to have them on our side.* We also need a media campaign. *Even parents, we need their support and we've to involve them in every step.* After a while, perhaps a few years later, we move to full implementation. Then, too, the project will need full support. In fact, I think *the big battle is ahead of us then.* So, we have to be careful and cautious. *That beginning, piloting through elective courses, will give us indications for what to expect later on.* **[B, 5, 23-24; 6, 1-10].**

> **MEP#3:**
> And we pilot for a year or two. During this period we market the project inside and outside Bahrain to win some university [physics] professors on our side. We get them involved with us. Of course, before we begin we need some of them with us and while piloting we try to win more. *And, also, the [physics] teachers. In fact, they are most important,* because we might disagree with a university professor and work on our own forgetting about him and his university, but the main problem is the teacher- what will he or she be doing in the classroom?**[7, 8-15].**

It is not difficult to see that piloting is, in fact, an essential stage in the construction of the network, one through which the interests of certain people

can be translated into the project. In essence, piloting would be an opportunity for the ministry to engage in problematization, devising successful interessment strategies and, eventually, enrolling certain actors in constructing a PTS actor-network. Interessement, it is to be recalled, refers to the activities and strategies that an actor (a network builder) uses to impose and stabilize the identity of other actors defined through problematization. The point behind interessement is to create barriers (physical or otherwise) between the actor whose identity is to be stabilized and other actors who might want to define it otherwise. Therefore, a particular concern for the ministry is to counter the interessment strategies of others, such as students and university physicists, who might attempt to create barriers between, say, students and the curriculum innovation.

> **MEP#2:**
> [T]hose students who will not be involved in the pilot and would continue with the traditional physics curriculum, those students may degrade the new curriculum and tease participating students, make them feel that they are doing a watered-down or soft curriculum. I don't want such factors to affect or jeopardize the success of the project. We need to pay attention to them and prepare the environment. **[D, 2, 14-20].**

> **MEP #3:**
> They [universities] might say that our students did not actually study physics. Or they might not allow students in certain departments, or to specialize in certain areas. They could ask them to do orientation courses, etc.
> All that required, first, a national committee to *think about all the consequences of this curriculum change and suggest ways to deal with them. As we plan and prepare the material, we think about how to deal with universities, not just in Bahrain but other Arab universities too.* Second, such a project requires marketing in order for us to win some countries on our side.

> At least within the Arab Gulf States, we must try to convince these countries. **[6, 18-28; 7, 1-5].**

In general, and especially with regards to students, interessement efforts from physicists are far more difficult to counter than those from fellow students or others. For instance, requiring students to take orientation courses or tightening the criteria for accepting students are among the most concrete and effective interessement strategies that university physicists can devise to create barriers between secondary students and the PTS innovation. Such strategies were, indeed, suggested by university physicists when they became concerned that secondary students might be attracted to the PTS materials and thus there was a need to overcome that.

> **Uph#4:**
> Currently, the criteria or conditions for accepting students in our university are loose. If it were for me, I will put stronger conditions, make it more difficult to get into the university. This, I say, regardless of your decision to change the [physics] curriculum. So, you can see how much that would be necessary if the physics curriculum is actually changed towards that [PTS]proposal. **[D, 9, 3-7].**

> **Uph#1:**
> [With laughter] The students are, of course, smart. They are not dumb. That is why there will be a need to arrange with the ministry such that those students who don't take these [conventional] or the advanced level physics courses will be required to take a preparatory or orientation course as a compensation. But, that has to be arranged between the ministry and university and both should agree on how to go about implementing it. **[C, 2, 15-18].**

> **Ahmed:**
> Are you saying that you are actually considering that option if the ministry adopted a PTS curriculum? **[C, 2, 19-20].**

> **Uph#1:**
> Yes. But, as I said, the university and the ministry both have to formulate and agree upon a suitable procedure and course of action which will include: Who should be admitted to the university, what courses must be taken at schools, and what grades are acceptable, and so forth. **[C, 2, 21-23].**

The emphasis on negotiation and involving the ministry in planning future actions if a PTS curriculum is to be implemented, are significant. Although university physicists became upset with the ministry's decision, they conceded that they were not in a position to take practical actions against it, at least not unilaterally. In effect, they acknowledged the hierarchy of the political context they were operating in and attributed power to the ministry.

> **Ahmed:**
> So, in essence, you are accepting the ministry's decision and will not attempt to change it? **[D, 8, 2].**

> **Uph#4:**
> It is against my character to take any direct action to change your decision. That will not happen. When the official people, people in that position, make certain decision we go with them and with their decision because we assume that such decision is based on careful analysis, study and calculations. That it is carefully thought about. I am not saying that I am wrong. No. I still insist on my position. I believe that what I said was right. If the ministry still insists on its position and decision to adopt this curriculum project, I will, however, continue to oppose it in my heart. **[D, 8, 3-10].**

It is not possible to say at this point whether or not the university will be able to take some practical actions against the innovation, but their opposition is not going to be passive. In addition to the possible actions suggested above, other legitimate maneuverings were suggested.

Ahmed:
So, my question to you is this: What are you going to do about this [decision]? **[D, 7, 18].**

Uph#4:
And what can I do? During the past time and over the three or four meetings we had together I have tried to give you my honest and clear opinions. And I hope that you found them useful. *Yet, because of my concerns for students, I will not sit back and isolate myself. If there is any chance, say, through some official channel or committees where I can give my opinion, then I shall do so.* Of course, my views and opinions are with regards to the physics, its content and organization. It is important that I convey these views to other officials or ministry people. **[D, 7, 19-24].**

Uph#4:
I am not in a position to decide about who should and who should not be admitted [to university]. If such a student [who learned a PTS curriculum] was admitted to university, he will attend my class as any other students who learned physics according to the way we know it. I will give my lecture and explain things in the same way to all students. I will follow the same usual style....I will not detour from my path to compensate any lack of fundamentals, no special considerations. I will try as much as I can, *but will not devote extra time or give additional lectures to these students. And I will not reduce the level of my exams to accommodate them, no.* **[D, 8, 15-26].**

As the first excerpt shows, the purpose of these activities is to dissuade ministry officials from their decision. The second excerpt conveys a clear message (or threat) to students that, if made public, could be a potential barrier between secondary students and the innovation. It is in this sense that these activities should be understood as interessement strategies, ones which the ministry needs to take seriously if its problematization is to be successful.

Both human and non-human allies are significant and need to be recruited for the innovation to succeed. Examples of non-human actors include research and data from the piloting. In effect, the pilot site will allow advocates of the PTS approach in Bahrain to gather data that are particularly relevant to the context of the project to support and strengthen their claims. The significance of this aspect is clearly argued in the following excerpts:

> **MEP#2:**
> Of course, we will continuously follow and evaluate the project in the trial implementation. The curriculum specialists and teachers will be involved in that so that we can get some data and results....Perhaps we might see a considerable improvement in student's achievement *such that we can stand up firmly and announce the results publicly to society*. **[D, 2, 2-11].**
> I also recall that you talked to me about action research. I liked that. I think this is important and can be done during the trial implementation [of the PTS curriculum] to gain a deeper understanding about what students learn and the teaching-learning process as a whole. **[D, 6, 17-19].**
>
> **MEP#3:**
> At least within the Arab Gulf States, we have to try and convince these countries. [It will be good] *If we can support our claims with a model that we produce in Bahrain and present it to them.* We can pilot in one or two schools and use that to show other people the kind of education or learning you hope for. **[C, 7, 1-5].**
>
> That is why when piloting it will be good to define a set of competencies, then we can compare students' achievements in both the PTS and the traditional approaches. We don't want to test students in scattered, isolated concepts, or bits and pieces. No. *I believe such a study will win you many people and provide more support for the emphasis you are proposing.* **[C, 16, 18-22].**

A significant aspect of conducting research, then, is to extend the list of allies to support the innovation. Favorable *results*, if obtained, will allow the ministry educators to "stand up firmly and announce" their claims publicly. With such actants on your side, your claims are stronger and more credible. There is also an added need for obtaining favorable results from research that is conducted locally. To be sure, advocates of a PTS innovation could (and in fact, as I did throughout the course of negotiation) mobilize research and results conducted elsewhere to support their claims for promoting the innovation in science education. However, the remoteness (socially, geographically, etc.) of these results makes their link to the Bahraini context rather weak or vulnerable. Indeed, physicists and physics teachers attacked the proposal by focusing on the place of origin of the units and the idea itself- that is, because they were Western or European. Part of their arguments also involved that "what works in the West might not work for us." Therefore, enhancing one's claims with findings that are produced locally will have stronger impact on the dissenters and will provide greater support for the innovation. As such, early stages of piloting some PTS materials will be ideal for gaining support and building momentum for the innovation. Interestingly, actors from outside the ministry such as an industry representative who was in favor of the innovation and pushed for its adoption by the ministry also suggested this.

> **Ahmed:**
> With all what you said [about the advantages of this approach], you still think that a PTS approach has to be

tried out in Bahrain before we can give any final judgment with certainty?

INR#2A:
Yes, because you are dealing with a different culture, a different society. There are cultural issues that need to be considered. Even the way our children are raised at home, you know, is different from how children are raised in Europe of the West. The educational system is somewhat different too. *Besides, the people are not ready for the change. You know, in this case you are talking about change. Not any change. Not just at the students' level, it is at all levels. Teachers and societal. Different method, different content. So, it is a drastic change.* **[C, 5,7-13].**

Again we see that there is more to piloting than merely testing the innovation itself. It allows the innovation to be accepted gradually, one step at a time, because of the considerable change it represents and the anticipated resistance. The following exchange between two industry people and myself regarding piloting further confirms this point.

INR#2A:
We can always have a pilot scheme. We can try it. Before widely adopting any new approach we must try it first...Yes, it is more sensible to pilot first.

Ahmed:
What do you have in mind when you say more wise, or it is more sensible to pilot first? What are your concerns?

INR#2A:
Because you have so many variables. You are concerned about students, about the teachers and how are they going to teach this.

Ahmed:
You mean the opposition of teachers that you talked about earlier?

INR#2A:
Yes, but not just that but also the quality of their teaching too. The pilot or approach might fail for some stupid reasons.

INR#2B:
Yes, because of some vested interest on part of teachers that could lead to that failure.

INR#2A:
Yes, and not because the approach is not good or what you are proposing does not work. **[C, 7, 8-17].**

Approaching the innovation through piloting has an advantage since it is expected that the project will be confronted with wide opposition. The pilot, as one of my colleagues suggested, would also "give us indications for what to expect later on" as we move to full implementation. The concern here is with the size and type of resistance and which cannot be entirely known in advance before the innovation is actually put in schools. Resistance is expected from multiple sources and, in particular, from actors for whom the conventional physics is an OPP. At this point, these actors do not see their goals as being fulfilled through the innovation.

Implementing the innovation in two schools (as a pilot) would limit the number of people who will be initially involved and, hence, need to be controlled. This is particularly important in dealing with secondary physics teachers who, by and large, opposed the PTS approach. To begin with, one needs to convince (perhaps tentatively) only a few teachers and gradually translate their interests and enroll others as the pilot progresses.

> **MEP#2:**
> It is better not to rush things. We should take it gradually, one step at a time. Therefore, it is better to start with very few teachers whom we can convince of this project and help them implement properly in the pilot. We shall provide them with all the support they need *to ensure proper implementation*. So, to start with, we need teachers who are convinced. **[C, 12, 13-18].**

The female teacher (T2) referred to in the discussion at the end of the last chapter may be an excellent candidate to mobilize. Besides her enthusiasm about the innovation, her reputation as an established teacher with long experience in teaching physics in secondary schools adds to her credibility and the credibility of the innovation.

The amount and nature of effort (translation work) needed to convince and enroll teachers in the innovation will vary depending on what we (the ministry and other advocates of PTS) believe to be the reasons for their opposition. If the reason is simply unfamiliarity with the materials and the approach, then professional development and consultation might be helpful. However, if the reasons are more subtle, such as "material interest," and maintaining "status and power relation" as suggested below, then the task is clearly more difficult.

> **MEP#2:**
> Frankly, what I fear the most is that if teachers are not convinced. If they don't believe in it [the innovation]. If it is a matter of unfamiliarity with this new version then that problem can be handled. It can be easily overcome. We can provide workshops, supervision, and seminars. Probably they will be comfortable then with this curriculum. **[C, 11, 1-5].**

> Most, if not all, physics teachers are not familiar or in touch with the science education literature and the development in our field. They see their subject [physics] as the most difficult and prestigious of all. The teachers feel that students always need them for explanations and help. Teachers also provide a lot of private tutoring in physics. You are well aware of that, of course. In the university, physics also has a special reputation. **[C, 11, 7-13].**

While it is reasonable to expect that teachers' reluctance to support the PTS innovation is partly due to unfamiliarity with the new approach, the data gathered in the second and third phases of this study indicate that it is not the main reason. Indeed, and as I have shown in the previous chapter, a PTS version challenges many aspects of the existing curriculum network which teachers take for granted and mobilize in their practice as black boxes. Previous chapters dealt with many of these black boxes, like goals and assessment, but status, material interest and, certainly power relations are equally important and they are similarly constructed in the actor-network. Therefore, one has to be careful about how these properties are invoked and attributed to actors. From the perspective of ANT, an agency (whether human or non-human, social or natural) is an uncertain achievement constructed by a heterogeneous network (Law, 1994). Therefore, like any other agency, power and status are not achieved once and for all— they exist only as long as the network that constructed them remains stable. In other words, power and status are effects or results of (relatively and temporarily) stable networks and not the cause of their stability. The implication of this argument is that status, power, role and identity, to name some, should be treated as "relational

effects" (Law, 1994), and certainly not as starting points to account for the establishment of school subjects as black boxes. The idea, then, is not to ignore the strategies and techniques by which these effects are created. This point is, indeed, significant and I shall try to illustrate it further below.

In the excerpts cited above, a ministry official pointed out that physics teachers "see their subject as the most difficult and prestigious of all" and that they "feel that students always need them for explanations and help." These comments indicate, and rightly so, that from the point of view of teachers, the move from conventional to a PTS physics is problematic because at stake are status and power; there is a risk of losing these gains or achievements. Teachers' status is directly related to the status of the subjects they teach. In this respect, physics teachers are considered to have a higher status than others who teach, say, home economics, Arabic language, geography or Islamic education, to take some examples from within the academic subjects. But how is it that physics has a higher status than these subjects do? After all, they are all academic subjects in the sense that they are required subjects and students are assessed through written exams. Actor-network is helpful here because we no longer need to see status merely as a social construct. For example, it is not possible to understand the status of school physics without referring to the difficulty level of the subject compared to others. To be sure, and as we have seen on several occasions, physicists and physics teachers appear to relate the status of their subject in part to how easily students grasp its content. The process employed by teachers in

selecting and emphasizing certain content in the physics curriculum, coupled with certain teaching practices, create a difficulty level of the subject and shape the relationship between students and teachers. This, however, is only part of the story for there are other elements linked to physics that contribute to it status, and consequently the status of the teachers. School physics is a pathway to high status jobs, like medicine and engineering, and as such it is strongly linked to these professions. It is, as I have shown, an OPP for students seeking success in university and for future careers. Furthermore, these professions are themselves powerful actor-networks that create such status. These networks are powerful in the sense that they encompass many heterogeneous elements as black boxes that people in different settings take for granted and mobilize. In short these networks are not simply social. To talk about the status of physics, then, is to speak about assessment, the content, how teachers teach, but also about higher university qualifications, physicists, medicine, engineering, better salaries, and a lot more. The links of these elements to school physics create and maintain its status, and the link of the physics teachers to the subject creates their status too. As long as these links (relationships) hold, and as long as school physics remains an obligatory passage point to students seeking university degrees and better careers opportunities, the status of the subject remains. It is in this sense that 'respected' status becomes an achievement, an effect of the network at large; a network that is defined by its heterogeneous elements and the relationships among them.

Similarly, one can talk about the power of physics teachers and how is it that the ministry is so concerned about their views and position. This is particularly significant if we remind ourselves of the social and political context where the ministry is under no obligation to negotiate its innovations with teachers or seek their approval. And the physics teachers know that very well, as I have shown in a commentary made by one of them. This was also evident in the teachers' reactions (elicited in the third phase) to the ministry decision. Although they argued forcefully against the ministry's decision, the teachers didn't consider themselves capable of altering or even publicly opposing it. In fact, they argued that they would have no choice but to implement the decision if that is what the ministry wishes. Still, their strategies for coping with that decision need to be taken seriously for they show that the power of physics teachers is something that is attributed to them by others, in this case students and parents. It is not something that they permanently own.

> **T4:**
> Such curriculum will be very weak. And if I am forced to implement it, then, as an employee who is also concerned about his job and making a living, if I am forced to implement such a curriculum, then I shall do so and look for and create other instances where I will teach students the fundamentals of physics and give them the scientific background which the PTS will not cover. **[D, 4, 1-5].**
>
> **T4:**
> I am not against the PTS, but it has to be modified, such that it will adequately prepare students for university. And if the decision is to actually implement a PTS curriculum, then we will implement. But all what I am saying is that

> when implementing the curriculum *we will teach it in a way that will help university-bound students. To teach it as it is will be good only for those who will go to work after high school.* **[D, 5, 21-25].**
>
> **T1:**
> I have always been concerned with preparing students for university, and probably you know that well. The teaching strategy I have developed and used helps students feel at home when they are in their first year at university. I have talked to you about that. That kind of activities will cover up for any shortcomings in any physics curriculum, whether it is a PTS or anything else. *I still follow this strategy, and perhaps I will use it more frequently when a PTS curriculum is implemented.* **[D, 6, 4-9].**

What makes these teachers insist on doing something that is not consistent with the ministry's recommendations is the fact that the conventional curriculum is an OPP for students and teachers. At the classroom level, students (and their parents) would see teachers as guardians of this OPP. However, teachers also see physicists as guardians because, as shown in the previous chapter, their interests have been translated into maintaining the conventional physics curriculum as an OPP. The issue, then, is not simply the ministry on the one hand, and its employees on the other, and where the former has power over the latter. For this reason, the ministry has to take teachers' reactions seriously. Ministry educators attribute to them the power over the curriculum at the classroom level. But, of course, none of this would have been possible without the presence and participation of students and their parents (see also the next section below). Due to the success of the network to establish the curriculum as an OPP for students, parents and

teachers, the whole network holds together and, in turn, allows us to see the differential relations in terms of power and status.

It is then possible to look at teachers' resistance and attempts to maintain the fundamental gains of the existing network (which would include the features of the curriculum, assessment strategies and, of course, material interest, status and power) as a test of the strength of the whole network. Furthermore, the strategies suggested by teachers to maintain the fundamental features of the present physics curriculum clearly involve students and parents.

6.2.2 Enrolling Students and Parents

The second observation about the ministry's decision and plan to implement the innovation is the great emphasis placed on convincing and enrolling students and parents, in addition to teachers. Interestingly, students and parents are new actors introduced in curriculum making since the ministry never involved them to the extent that is now suggested. In this situation the status of students and parents has been elevated such that their opinions and whether or not they are enrolled becomes an important criterion in determining the success of the pilot and in encouraging the ministry to proceed to full implementation.

> **MEP#2:**
> We get feedback from students and their parents. For such a project to be successful we need to inform parents about this new approach and highlight to them its significance. Once we pull some support from these students and their

parents we can publicize that and move to implement more courses. **[A, 9, 7-13].**

MEP#2:
We need students' opinion as well as the opinions of the parents. Based on their feedback and input we can find out if the project has been successful and whether or not people have accepted this curriculum approach. **[D, 3, 12-14].**

Ahmed:
Whether or not students and parents accept the curriculum innovation? Is this really an important criterion?

MEP#2:
Yes. Whether they accept it, and how much they benefit from it. **[D, 3, 15].**

The notion that the innovation will be considered successful if students and parents accept it deserves further clarification. Obviously, one does not need to pilot if the purpose is simply to "find out" what these actors think of the innovation. Conducting surveys and some interviews would probably do the job, and that is, in part, what the first two phases of this study accomplished. What is seen here is a possibility for negotiation and redefinition. The views of secondary students elicited in phases one and two of the study were encouraging as far as the ministry was concerned. Although four of the thirteen students interviewed were particularly critical of the PTS units (see below), the others were quite happy with them and made some strong arguments in defending them against the claims made by fellow students. As an example, consider the following exchange among the female secondary (grade 12) students. The discussion focuses on the notion of creating "a balance" in the physics curriculum. A balanced curriculum,

according to students, gives more or less equal weights to the pure physics and PTS content. Male students and one of the industry engineers also proposed this notion.

> **SG3:**
> But we stressed the notion of balance in the curriculum. So, the [physics] problems and other theoretical aspects and content will not be totally ignored. **[C, 3, 15-16].**
>
> **SG2:**
> Still, though, the criterion of balance implies that something will be covered on the expense of something else, some aspects might prevail. Others will be ignored. **[C, 3, 17-18].**
>
> **SG6:**
> But what is the purpose of learning physics in the first place? Is it to learn the physics and then graduate, then go to study at university and finally teach that to students. Is that it? What we learn should be related to life. It should be socially relevant and useful. **[C, 3, 19-22].**
>
> **SG3:**
> [addressing SG2] What would you say if someone argued with you or asked you about the purpose of studying physics? Would you say that this is a science and you learn it for its own sake? There has to be a broader goal beyond that. **[C, 3, 23-27].**

This shows that there is some possibility for enrolling students. Yet those who volunteered to be interviewed were among the high achievers in their schools but they don't represent the whole population. More importantly, the link between students and their parents is so strong that in many cases one would expect the latter to either influence the decision of the former or actually make that decision on their behalf. The ministry had a concern whether the innovation could fulfill the goals of the students as seen by their parents:

> **MEP#2:**
> You have to be aware that a major change in the curriculum might be associated with a great resistance or opposition. Parents are concerned that their children eventually join the university, to study medicine and engineering. So, they might resist this strongly if they feel that that goal is in jeopardy. **[D, 4, 16-29].**

The positions of students and parents cannot be taken as fixed or permanent, but as negotiable in the problematization phase during the pilot and the accompanying activities. One activity is the involvement of parents in the pilot and its progress, thereby creating closer relations among parents, ministry and the innovation. Of course, one cannot determine beforehand and with certainty how these actors will behave with each other.

Another important activity mentioned by a ministry official was a media campaign to educate the public about the innovation and the significance of its goals and underlying philosophy, and the different learning experiences it could provide for students. Similar suggestions were made by a university physics educator and a member of the industry.

> **MEP#2:**
> I believe we need to prepare the Bahraini society through a media campaign, which educates people towards the importance of achieving and acquiring the goals and skills that are advocated in this curriculum trend. **[D, 6, 11-13].**

> **UPE:**
> The ministry should go on with this project, but that needs to be accompanied by an intensive program to raise the awareness of the people. Most people, including those who opposed this project, have not been exposed to the literature in science education, for example, about scientific literacy. People need to read about it, about its philosophy.

> So we need to distribute literature, write and talk about it, to enlighten the people and the public about the philosophy behind this curriculum approach. **[C, 5].**

At the heart of these activities is an attempt to create "interests" in the PTS innovation. According to Latour (1987, p. 109) "interests are what lie in between actors and their goals, thus creating tensions that will make actors select only what, in their eyes, helps them reach their goals among many possibilities." Thus, the point here is to make many actors see a PTS curriculum as a route to their goals. In *Science in Action*, Latour (1987) suggests a variety of ways (which he calls translations) to achieve that, and some of them are especially significant when the goals of an actor are explicit and there exists an established path to it: displacing (reinterpreting) goals, inventing new goals, and inventing new groups endowed with new goals. These strategies can help us understand the significance of the activities emphasized by the ministry and their allies with regards to educating the public. For example, the ministry knows that for certain students and parents the preparation for university is a primary goal[1]. But that goal could be reinterpreted or "displaced" such that to make the achievement of that goal more attainable. And it is here that arguments about students not enjoying physics and the claim that university physicists frequently complain about the standards of students may be highlighted and employed to offer PTS as an

[1] Secondary students' views and the establishment of the existing curriculum as an OPP are dealt with below in this section.

alternative (a detour, so to speak) to help students better prepare for university.

> **MEP#2:**
> At the present students complain about the 'dryness' of the subject. They do not find it relevant. University professors also complain about the levels of high school and their weaknesses. They argue that students are not well prepared. All this, despite the amount of physics we teach to students and the extensive practice they get in solving problems and that kind of stuff. That is why the new approach might be better for them. Students will be better prepared, because they will be self-dependent and capable of learning. We have to make this clear to the people. **[D, 5, 11-17].**

As another example, consider the arguments made earlier by a physics educator and a ministry personnel about educating the public. The notion that people, at the moment, are "unaware" of the significance of the goals and qualities of PTS or STS in general means that their explicit goals do not include the goals emphasized by a PTS or STS curriculum. So, the idea is to "make up" goals such as "overall growth of students," the development of decision making skills, and attaining scientific literacy, and convince the public to accept them as their own and, then, to see the PTS curriculum as a way or an OPP to achieve these goals.

In accordance with Actor-Network Theory, one should not separate the innovation from its context, and both should be viewed as fluid. For example, in exploring the views and positions of university physicists and physics teachers, we noted some attempts to redefine the innovation and its purpose in order to enroll it in the present physics actor-network. On the other hand,

when analyzing the views of the ministry educators we observe that the focus is more on redefining the context and less on redefining the innovation itself; creating interest and educating the public is part of an attempt to redefine existing groups or create new groups. From the standpoint of ANT, "interest groups" do not simply exist "out there" to either resist or adopt an innovation. Their definition, goals and interests are created and shaped in the process of translation and becoming part of the actor-network (Latour, 1987, 1991). This is a direct implication of Latour's (1987) fourth rule of method, which contends that society is the outcome of the settlement of a controversy and, therefore, cannot be used to explain the settlement of a controversy. I illustrate this point with an example related to teachers and then return to secondary students.

Initially, many physics teachers were particularly attracted to the unit Light Sources which is similar (in terms of its content) to one of the physics courses currently taught in schools. The course is called 'Spectra' (Physics 214) and is part of the curriculum that has been implemented since 1990. The course also included certain topics that are not dealt with in the unit Light Sources. These topics, however, were either not part of the old curriculum or were not as thoroughly dealt with before. That is to say, the physics teachers who have been teaching physics for more than 10 years in Bahrain have never taught these topics before since they were not part of the curriculum. Yet these teachers argued that these topics are important either as part of the academic preparation of students or for their own sake as part of giving

students a good background in physics to be able to understand natural phenomena. Accordingly, they insisted on including these topics in the unit "Light Sources" if it was to replace the Physics 214 course.

> **Ahmed:**
> How about then if we use this unit [LS] to replace the course "spectra" [i. e., Physics 214]? What do you think of that?
>
> **T4:** That would be nice. Yes, we can do that.
>
> **Ahmed:** So, you actually prefer this unit to the 'spectra'.
>
> **T4:**
> Yes, but after we add to it the discussion about quantum theory of light, the photoelectric effects and its equations, and the last part which is about atomic spectra and Bohr model. Without that it is not possible. These are necessary for students who will continue in the university. Otherwise, no. **[A, 11, 12-18].**
>
> .....
>
> **Ahmed:**
> And what would you suggest to improve this unit [LS], to make it acceptable to you?
>
> **T5:**
> First, to include solved problems as examples. Second, to add and expand on some of the topics like the photoelectric effect, black body radiation, and X-rays spectra. Also, to improve the discussion on the Bohr atom, by including the formulas to calculate the energy levels and the rest. **[A, 8, 20-22; 9, 1-2].**

The current curriculum was an innovation at that time, and it was mainly the result of the ministry's physics curriculum specialists' efforts to update the curriculum and increase its effectiveness. To be sure, at that time, many physics teachers did not appreciate the increase in the content's depth and coverage that the 'new' curriculum introduced. They even resisted it and there

were some minor modifications, but things stabilized. Thus, although we were dealing with first-order change (and hence, easier to implement) it still produced certain effects on teachers. In part, it shaped their practices and created their beliefs. The teachers were the result of the extensive work that the ministry had undertaken to convince and enroll them to promote its curriculum. And there is more. The establishment of the new (existing) curriculum also modified the "material interests" of the teachers. In one of the excerpts cited earlier, a colleague from the ministry pointed out that physics teachers "do a lot of private tutoring." Tutoring is not a new phenomenon; however, in the previous years private lessons were mostly needed by grade 12 students because there was a national exam at the end of that year, and the graduation of a student from high school depended mainly on the grades on the final exams. But with the credit hour system, and the organization of the curriculum by (mini) courses, the commutative grade point average (CGPA) became significant. That also meant that every mark a student obtained in a given course counts towards the final grade. Accordingly, private lessons became common among students (including high achievers) and in every physics course. In fact, in recent years, private lessons became a "socially condemned" phenomenon to the extent that the ministry has tried to control it.

The point I want to make here is that these physics teachers are not the same social group that existed more than a decade ago and taught the old curriculum. They have been redefined and that included, in part, their

practice, beliefs and their material interests. Similarly, if the ministry succeeds in enrolling the physics teachers in the construction of the PTS curriculum, we would no longer have the same group of teachers, but a group with new or redefined goals, different perspectives for how to achieve these goals, and new roles and different interests. In brief, a new group. It is in this respect that ANT deals with the social world and interest groups as fluid and as network effects. To treat groups as network effects is to suggest that they are the results of the settlement of controversy and not the cause for its settlement.

Returning to students (and I am thinking here about students in the science stream), it is not helpful to think of them (at least not initially) as a homogeneous group with a common goal and interest, but as subgroups with different goals and aspirations. Presently, secondary students in the conventional school physics network are seen as a uniform group with one trajectory leading to university education in physics or science. Even when certain actors admitted that only a small minority of secondary students would specialize in science, there still seems to be an accepted wisdom that the conventional curriculum is ideal for all students. In other words, the goals and interests of the majority (which are different from those of the university or science-bound minority students) are assumed to be fulfilled "indirectly" with that curriculum. This was evident in claims made in favor of engaging students in learning the traditional content of physics irrespective of their future destinations.

> **Uph#1:**
> This emphasis [on the basics of physics and problem solving] *is equally important for all students irrespective of their future destinations.* Why? Because by learning the fundamental laws of physics and their mathematical formulations and by using these to solve problems in physics, that practice leads to enhance students' logical thinking. In the future, if a science or physics student decides to work in, say, business or commerce he will probably be more successful than a student who in secondary school specialized in that field. Why? Because their thinking will be more logical, more analytical. **[A, 2, 5-11].**

One option for the ministry and advocates of PTS is to problematize the population of students and its goals. That is, to reject the notion that secondary students in the science stream are necessarily university-bound and acknowledge that the latter is only a minority. Some ministry officials argued for new goals for physics education and more varied trajectories for students, but that problematization is not yet established and widely accepted among students and parents. And it is here that activities directed towards "educating" the public (basically parents) become important in order to constitute a new grouping of students and parents.

Creating interest in the PTS curriculum by targeting the non university-bound students and their parents is essential to promote the innovation, but it is far from enough. This is because a PTS curriculum is proposed as a replacement for the existing curriculum and, hence, it has to be established as an OPP for *all students* and not just the non university-bound. Although university-bound students are a minority, the number of actors linked to them

(e.g., parents, physicists, status, well-paid careers and so forth) and the nature of their associations make them as large as the rest of the students, if not larger. Therefore, the task of establishing the innovation as an OPP for *all students* is more difficult than convincing the majority non university-bound students, because it is here that our claims (as advocates or networkers for PTS) cross those of physicists and their allies, in Latour's (1987) terms, at a right angle. Latour (1987, p. 210), however, argued that "[T]here is a direct relation between the *number* of people one wishes to convince, the *angle* at which the claims clash with other claims and the *hardening* of the facts, that is the *number* of allies one has to fetch." The claims made by the ministry and other educators about the significance of the PTS (or STS in general) and the feasibility of this approach to prepare students for both university *and* life in general need to be "hardened"; one possible suggestion, mentioned earlier, is through conducting research and obtaining data to support the claims.

Most recently, Roth and McGinn (1998) employed actor-network analysis to show how "grades" act to stabilize educational networks. Within the context of school physics, they show how the interest of students, particularly high achievers and teachers are translated into the interest of universities to maintain the current practice of assigning grades to students. The current study suggests that the claims made by Roth and McGinn can also include other aspects that are peculiar to the physics curriculum, such as the emphasis on mathematics and problem solving. The following excerpts taken from interviews with secondary students provide vivid examples of how the

interest of students is translated into maintaining the major features of traditional school physics, and consequently reveal some of the difficulties that advocates of the PTS innovation will have to consider as they attempt to enroll students.

> **SG4:**
> If the entire physics curriculum is made like these PTS units, even if similar to the units LS or IR, we will not be learning the theoretical parts of physics. We will be shocked once we go to the university.
> In fact, it is the physics problems and the equations that make a physics course interesting and challenging
>
> **SB3:**
> The question is, would this [i. e., the PTS] be useful to us in the university? I think there should be continuity, a link between what we study in school and will be studying in the university... For this, units like WFT and IR are better left as electives.
>
> **SB6:**
> If you remove the math, the formulas and equations, you no longer have a physics course.

Although these views were not shared by all students, they represent the views of "potential scientists" (Costca, 1995) and, as I said before, potential engineers. According to Aikenhead (1996, p. 36), and as the excerpts above illustrate, potential scientists enjoy the challenge of doing the idealized problems normally found in physics and mathematics and "would see little value in solving the life-world, concrete and consensual problems typically found in STS curricula." Therefore, it is understandable that the ministry pays considerable attention to secondary students (and their parents) because they

are vital actors in the network. In spite of the belittling claims made by many participants about secondary students, the success or failure of the PTS actor-network will depend on what and who they (and their parents) consider as best serving their interests.

6.2.3 Modifying the Decision Making Process

Perhaps another, more dramatic example that illustrates the fluidity of the "social context" in the curriculum making process is the change in the decision making process itself. As several excerpts cited earlier illustrate, while the ministry officials still believe that they are capable of making a final decision to adopt a PTS curriculum by following the normal procedure, they do not seem to favor such a procedure in the light of the anticipated resistance from university physicists, students, parents and teachers. In essence, it is realized that a decision has no strength or value if others don't implement it or if it is altered drastically. Latour (1986, p. 276) reminds us that "no matter how much power one appears to accumulate, it is always necessary to obtain it from others who are doing the action." The ministry illustrates this shift in how power is conceived from the perspective of ANT.

> **MEP#2:**
> Think about it, if teachers are not convinced, their dissatisfaction will be conveyed to students and consequently to parents. With that we might be *facing students, parents and the teachers. They might even cooperate, form a front against the project. That is why I say that in this case, with this project, it is not feasible to take it through the traditional route. Not to start from the top of the hierarchy,* but

> rather to start from the base, with teachers, and build up our position. **[C, 1, 13-16].**

So the perceived power of the ministry was indeed obtained and can't simply be used in this new situation; it needs to be negotiated and reconstructed.

The restructuring of the decision making process, however, has implications for who is to be involved or excluded in the early stages of the decision making, preparing and piloting curriculum materials, and for what purposes. Certain actors, such as science educators, industry, students and parents, will be brought to the fore (as we have seen) while others might be marginalized.

> **MEP#3:**
> We will need qualified people to design the curriculum and prepare materials. Not only the curriculum specialists. *We will need people from the industry and from other institutions to participate with us* in designing the curriculum and preparing materials. Not like we usually do where the curriculum specialists work in isolation with the academics and review existing curricula and come up with a curriculum. No. Very often this process only leads to reorganizing the content and different presentation. This way, you are not changing the philosophy, the inclination of the curriculum and its other components. **[B, 4, 11-18].**

> **MEP#2:**
> As long as they [university physicists] do not approve of this project- as you told me and based on your interviews with them- to have them with us will be like a burden or obstacles. **[D, 6, 3-4].**

> **Ahmed:**
> How about if we can convince one of them, or someone who is willing to....

> **MEP#2:**
> That will be great. No doubt that will be to our benefit. That will strengthen our position, and perhaps he might influence his colleagues too. But other than that, I can't see any point in involving them. **[D, 6, 6-9].**

Similarly, the modification of the decision making process has implications for the PTS innovation itself. It is perhaps evident by now that the innovation referred to by the ministry officials in their discussions is not quite the same innovation I had in mind when I approached the ministry with my proposal. Of course, the idea of the PTS is still maintained. However, at this stage, we are not talking about a complete physics curriculum that will be developed and implemented in schools as usually was the case. In fact, at this stage the innovation has become a pilot and, more specifically, a few units to be implemented in two schools. This is another transformation that the innovation has undergone in the course of negotiation and networking. Of course, one can attribute this transformation in the innovation entirely to the ministry; that is, it was the ministry's decision to pilot a few units in two schools first and not to take the innovation through the 'normal' procedures. But, obviously, that decision was made in consideration of the various constraints imposed by the views of the various actors and the existing obligatory passage points.

A surprising aspect reflected by the ministry decision was the need for the network to be constructed rather slowly and deliberately. From my previous experience in the ministry and on several projects, we were never as cautious

in adopting and implementing an innovation as the quotes from my colleagues now suggest. In this case, however, the careful construction of the PTS network seems necessary for the successful enrollment of as many teachers, students and parents as possible (but, of course, does not ensure). Such need also arises because these actors are already enrolled in the existing school physics actor-network, and for them conventional school physics has been established as an obligatory passage point (OPP). In short, there are many black boxes and several obligatory passage points, which means that the opposition to the PTS innovation could spring from various sources. However, the greatest opposition recognized by the ministry, comes from university physicists who appear to be the "most powerful" of all opponents. By now we know that this power is a result of the current network in which physicists occupy a central position. In other words, this power is derived from all the actors (including human and non-human, such as physics and the physics curriculum) which physicists were able to mobilize and speak on behalf of. Therefore, in their plan for promoting a PTS curriculum, ministry educators see the need to start from the bottom and build their position by recruiting as many allies as possible. The larger the list of allies and the stronger their links to the innovation, the greater is the negotiation power of the ministry and the more likely it can withstand the academic opposition.

> **MEP#2:**
> The real danger or the crises might occur when the whole physics curriculum is designed according to the PTS emphasis and fully implemented. Thus, I believe this

> curriculum will eventually have some serious impact on the society. *But if we secure the support of the ministry, of the higher authority and get some sectors of the society with us, get them to support this curriculum project, then the university will surely review its position and sit with us and negotiate till we convince them.* **[D, 5, 6-10].**
>
> **MEP#3:**
> See Ahmed, as I have told you before, such a project requires good marketing. We need to sit with these [university] people and with teachers for a longer time, on several occasions, discuss with them, *and show them that we are serious about this. The whole ministry. Perhaps, if we all sit together and discuss, and get them actually involved in the process some of them might change their position.* **[C, 12, 17-21].**

The politics of physics curriculum in Bahrain that I have sketched so far might appear to overemphasize the role of the university; there are only two universities, and more importantly, the political system gives the ministry leadership a higher position in the hierarchy than that of the universities. Besides, in Bahrain, physics was taught in secondary schools even before establishing any local college or university. This, however, suggests another important aspect of the network that university physicists (in Bahrain) are able to mobilize and which provides them with their power and ability to control the physics curriculum. This aspect is the extended nature of their network. Although the ministry is concerned with students, parents and teachers in Bahrain, it cannot see physicists and university education as a localized and confined network; it extends all over the world. Hence, the goals and interests of potential scientists and engineers (students), their

parents and most teachers are linked to universities and physicists not just in Bahrain, but worldwide. In addition, when it comes to making decisions or giving an opinion about secondary physics education, the link between university physicists in Bahrain and their colleagues elsewhere is so strong that they may speak on their behalf and mobilize them in making their claims. Accordingly, the ministry does not only have to face the university in Bahrain, but practically all universities. Physicists participating in this study recognized this fact very well and, indeed, used it frequently:

> **Uph#1:**
> But not all [students] will decide and come to our university, in Bahrain. Some will go abroad and you have to keep with the international standards so that our students can catch up and compete with their peers from elsewhere. Check the content and level of the [physics] curriculum in the *International Baccalaureate* and think about our students who might take half of their physics curriculum as a PTS, think about how would they compete and perform as compared to those who will study that solid curriculum. Think about the reputation of our curriculum or our schooling. **[C, 12, 13-20].**

The mobilization of this extensive, international network by physicists intensified particularly in the last phase of negotiation and whenever they felt that the ministry might appeal to its "political" power to enforce the implementation of a PTS curriculum. In the following excerpts, successive layers of actants are mobilized and linked to the claims made by this university physicist. To be sure, these actants do not alter the quality of the claim per se, but they certainly make it stronger.

Uph#1:
The universities admit students on the bases that in school they have done the standard physics. For example, you have the international baccalaureate or the A-level physics, and so on, and universities know that a student who has done physics in school must have covered the fundamental things, things that are required. Otherwise, how do you think students are accepted? So, if you adopt a PTS curriculum and later on some of our students went to a university in *India, Europe or America* what can these students say about the physics they have done. Would they say we learned physics according to a PTS? They will be dismissed. No such curriculum is known. It is not recognized or approved. **[D, 8, 3-12].**

Ahmed:
Students, if asked, would simply say we learned physics in high school. They will be learning physics, of course. But, they don't have to give the details about the approach and the curriculum, whether a PTS or other. **[D, 8, 14-15].**

Uph#1:
That will be exposed. You can't hide that. It will become evident that these students lack in the fundamentals. What would be your situation or position then. *Imagine what would be said about the Government of Bahrain, about the Ministry of Education, about the standard of education in our country.* That is why I say that this is a serious matter and has huge consequences. **[D, 8, 16-19].**

A deep realization, but not necessarily acceptance, of this position seems to have been underneath the ministry's responses and decision since the beginning, and clearly accounts for the long term, deliberate plan to construct a counter network.

MEP#2:
I fear the quick jump in changing the curriculum. Such transition will face numerous problems and the consequences might be disastrous. That is, if we suddenly move and implement a PTS curriculum. Because the society

> at large, as you know, many parents would push towards [pause]... you know they will be concerned about their children's' future, whether they will be accepted at universities. Most universities might not be ready to accept such curriculum, [accept it] as a physics curriculum. Our high school certificate must be acknowledged or approved by universities. **[B, 4, 22-26; 5, 1-3].**
>
> **Ahmed:**
> But at the ministry we don't need to get the approval from any external agents regarding our projects. We do not need an approval from the university. If the ministry decides to change or adopt a new curriculum, we just do it.
>
> **MEP#2:**
> That may be true. But do you recall when the ministry adopted the credit-hour system [for secondary level], and we developed new science curricula? Later on, there was a rumor about not accepting our secondary students in certain universities abroad. And we had to compare the new curricula with the previous ones and send detailed reports to several universities abroad, just to assure them that our curricula are still up to the known standard. Perhaps you forgot that. This is a very important point. We should not undermine such incidence. **[B, 5, 5-7].**

Reflecting back, I can see changes gradually bringing the physics curriculum in Bahrain to the international "standard" and giving it its "academic" shape. More importantly, all that effort was accomplished with little or no interference from physicists in Bahrain because the ministry operated within the boundaries of the existing network and worked to further its goals. It had not violated any of the obligatory passage points, and so interference from other actors was unnecessary. Because of this previous experience of working within the network to enhance the goals of actors, I embarked on this project with great enthusiasm expecting to achieve quick results in changing the

physics curriculum; I found the task more difficult than expected, and that it takes more than the ministry, and certainly more than myself, to achieve it.

Summary

This chapter discussed the ministry's efforts to construct a PTS actor-network in Bahrain. The challenges brought by PTS demonstrated that the ministry could not be treated as a black box. Actor-network analysis views decision making as a complex process involving negotiation with various actors and sensitivity to their relative significance and positions in the overall network. Ministry officials adopted the proposal; nevertheless, they recognized that major changes would accompany such curriculum change in relation to the various actors. The network sustaining the conventional physics curriculum would be reconstructed, but not from the top down as usually was the case. Its decision and strategy shows the need for a long term plan to translate the interests of various actors, especially teachers, students and parents, in establishing PTS as an obligatory passage point that incorporates the various goals of students, parents and teachers. To do so, it needs to weaken the links and alliances that tie these actors to the existing physics and reestablish new links with PTS; if it succeeds, the ministry would have established its power over the curriculum.

CHAPTER 7

CLAIMS, IMPLICATIONS, AND FURTHER RESEARCH

This chapter is divided into three sections. In the first section, I provide a summary of the claims across the three analysis chapters. The presentation of these claims is organized around the three research questions, followed by a discussion of the focus question related to the issue of power in curriculum. Next, I present some theoretical and practical implications of the study, focusing on three areas of education: power in curriculum, curriculum making or change, and STS in science education. Finally, I suggest some implications for further research.

7.1 Claims

The analysis focused on the responses and actions of the various actors in the school physics actor-network in Bahrain to a PTS innovation. The positions of these actors fall into two categories. In the first, there were actors (Ministry of Education personnel, the university physics educator, some students, and industry representatives) who regarded PTS as an innovation with a potential to remedy many problems facing physics education, and consequently were in favor of mobilizing for the construction of a PTS

network. In the other, there were actors (physicists, most university and secondary students, and most physics teachers) who rejected the PTS innovation for various reasons, although for some of these actors PTS units or topics could be enrolled in the existing network. The responses of these actors, furthermore, reflected their efforts to maintain the secondary physics network in Bahrain.

1. <u>What are the elements of the school physics actor-network in Bahrain</u>?

The purpose of this question was to explore the constituent elements of the school physics actor-network. *Secondary school physics in Bahrain is a heterogeneous actor-network in the sense that it combines human, non-human, and spiritual elements*[1]. Human actors included physicists, students, parents, teachers, and ministry personnel. Non-human actors were physics, mathematics, the dictionary, textbooks, assessment strategies, goals of physics education, physics problems, and physics curricula in places other than Bahrain. Finally, spiritual elements were God and moral values in Bahrain. These elements come together to construct the physics curriculum characterized by abstractness, an emphasis on mathematics and problem solving, and unrelatedness to students' lives, which curriculum theorists normally identify with academic curricula (e.g., Bernstein, 1971; Young, 1971; Goodson, 1987; Apple, 1990). In other words, *these features are*

[1] In this section, I use italics to highlight the claims pertaining to the research and focus questions.

heterogeneous constructs as material, social and spiritual elements were important in constructing and maintaining them. What we normally refer to as the physics curriculum is the result of the interactions among these many and diverse elements or actors.

Actor-networks are rarely stabilized as fixed configurations of related elements, and, furthermore, these elements are not necessarily visible at all times. The controversy about the curriculum and the articulation of a plan to reconstruct the network allowed me to identify "hidden" elements and to observe *the emergence of new actors and the redefinition of existing actors.* Although not previously noted, God, moral values in Bahrain, parents, and curricula in other places were examples of actors identified and linked to the school physics network. Industry was an example of an actor attempting to connect itself more strongly to the curriculum and redefining its role in the network. Previously it had weak links to the network or was passively enrolled. The identities and roles of secondary students and their parents were also negotiated and redefined during the controversy. For instance, actors who were in favor of mobilizing for PTS, such as the ministry personnel, assigned a more active role to students and parents in reconstructing the network and the decision making process. The reshuffling of actors and the emergence of new actors were not restricted to humans; there also emerged new goals for physics education, new assessment strategies, and new content for the curriculum. Traditionally, the content of school physics came from the

disciplinary knowledge of physics, whereas content related to technology and society was ignored. In the reconstruction of the network, ministry and university educators, industry representatives, and some secondary students and teachers considered the technological and social aspects of physics as important as the "pure" or textbook physics itself. School physics in its reconstructed form would include technology and society and their interactions with physics as significant elements.

Finally, *actors in the school physics network are themselves complex, heterogeneous entities and as such can also be viewed as actor-networks.* Nevertheless, *many of these complex elements are simplified and mobilized as black boxes.* This was evident in the case of several actors including physics, assessment, goals of physics teaching, students, and teachers. For example, physics (that is, the discipline of physics as practiced by physicists) is a complex entity in the sense that it comprises many human and non-human actors interacting with each other. Academic science, as Ziman (1984, p. 2) has shown, is social, material, cultural and educational, and plays a role in human affairs. Yet, as this study shows, in the secondary physics actor-network, physics is simplified, enrolled and mobilized as a black box. In this process, physics becomes a study of the "physical world" or "the study of energy and motion and their interactions." The human, cultural, and technological aspects of physics are removed, and what is left is a content "product" for students to learn.

Similarly, assessment is simplified to mean written tests, and reduced to testing students' ability to solve standard physics problems entailing extensive use of mathematical expressions. The content of physics curriculum, assessment strategies and teaching practices reduced students to "physicists or scientists in the making." With their identities so simplified, students' role in the network is to learn physics the way deemed appropriate by physicists.

According to Callon (1987) a necessary condition for the stability of an actor-network is the durability of the elements themselves as simplified networks (i.e., black boxes). One cannot challenge, say, the assessment techniques employed in the network without disturbing the taken for granted nature of the goals of physics teaching, the content of the curriculum, or students' identities and roles. The network holds together as long as these elements remain as black boxes.

2. <u>How does school physics link the various actors to their goals</u>?

The challenges brought by the PTS units and the proposal to redefine the physics curriculum proved useful in exploring and testing the links between the various actors and school physics. More importantly, it allowed me to explore how school physics links the various actors to their goals. The analysis revealed that *university physicists and students, most physics teachers, and a few secondary students, were strongly linked to the existing school physics.* This was

evident by their rejection of any change in the curriculum that would result in redefinition of its basic features and their mobilization to maintain the existing network. Although these actors saw some merit in the PTS materials and recognized their potential to remedy some of the problems identified with existing physics curriculum and teaching, they did not link themselves to these materials as they did with the existing physics. *For these actors, the physics curriculum was an obligatory passage point (OPP) along various trajectories leading to their goals.*

Physics teachers strongly associated themselves with the elements defining the existing physics curriculum: physics, assessment, the content, and students. They accepted the simplified definitions of these elements as sanctioned by physicists and mobilized them in their practice, thereby contributing to the maintenance of these elements as black boxes. However, they did so for reasons that did not always coincide with those given by physicists. In the case of assessment, for example, physics teachers believed current strategies were desirable because these were a convenient way to allocate marks to students, practical in terms of preparation and correction, and appropriate for emphasizing and conveying knowledge (i.e., scientific 'pure' physics) considered more worthwhile than other knowledge (e.g., technology, social issues, applications of physics). Whether we describe the teachers' links to assessment as beliefs (ideological) or material interests does not matter as long as they accept the simplified notion of assessment

and mobilized it in their classroom practices. In other words, it is the strength rather than the nature of the links that contributes to the maintenance of the network.

Similarly some physics teachers viewed their role in terms of helping students prepare for post secondary education, whereas others saw their role as teaching "good" physics for its own sake and to help students view the world from a scientific perspective. In either case, the curriculum and the network are the same, and physicists (or academic physics) were seen as the major source for the content and organization of physics curriculum. Teachers' goals were different from those of physicists, but they shared a common interest in maintaining the existing school physics, which linked them to their different goals. It is in this sense that school physics becomes an OPP for physicists and physics teachers alike.

University and some secondary students (especially potential scientists and engineers) were also strongly linked to the existing school physics. They wanted to maintain an academic version of school physics. Moreover, for university students, the reason for this extended beyond receiving an "adequate preparation" in secondary school; for many the first year in university was particularly critical, as they had to cope with language difficulties (English becomes the medium of instruction in science and engineering at this level), new subjects, and different teaching and learning styles. Therefore, the fact that most of what is covered in secondary physics is

repeated in the first year physics courses was considered an added bonus because that helped them "catch up well, and made it possible to devote more time to new subjects." In other words, the interests of these students were also translated into the existing curriculum, which they saw as an OPP to success in university and to future careers.

In contrast to these groups, *ministry personnel, the university science educator, some students, and industry were not strongly linked to the existing school physics*; they attached themselves more strongly to the PTS innovation. This was evident in their arguments in favor of mobilizing for PTS and the persistence of their views in the light of the challenges from other actors. The Ministry and university educators were committed to a broader student audience than "potential scientists and engineers." They emphasized contextual learning and real-life problem solving, and considered students to be active participants in society. Furthermore, they argued for a need to relate the content of school physics to technology and society, and rejected the notion that physics should primarily be taught for its own sake. In short, these actors linked themselves more strongly to aspects and elements of PTS than the existing school physics. During the negotiation, industry's interest was translated into PTS in that it became supportive of, and involved in mobilizing for, this innovation. Like the ministry and university educators, industry linked itself more strongly with PTS than the existing school physics, although its goals differed to some extent: a PTS curriculum would provide them with

students who were better qualified to join the workplace. While physics was considered important by industry, its view highlighted conceptual understanding of the subject and its applications in technology and society, rather than mathematical manipulation and problem solving.

In short, actors who linked themselves with PTS saw this version of school physics as a potential OPP. They no longer considered the existing school physics as an OPP and therefore attempted to mobilize for constructing an alternative network in which PTS would be an OPP for many actors and not just themselves.

3. How is the PTS innovation negotiated?

The PTS innovation was described as a Category 6 in the "Categories of PTS Physics" adapted from Aikenhead (1994, pp. 55-58). Three units—Light Sources, Ionizing Radiation, and Water For Tanzania, adopted from the Netherlands' PLON project—were provided to actors as exemplifying a PTS curriculum in which 30% of the content would be "pure physics" and 70% would be PTS. Contextual learning and the interactions of physics with technology and society were highlighted as major aspects of this innovation. Moreover, broader goals, such as developing decision making skills and promoting scientific literacy were made explicit in the course of proposing and negotiating the innovation.

The PTS innovation was conceptualized variously by the different actors. In the course of negotiating the proposal, actors in the school physics network did not simply accept or reject the innovation; they modified it and shaped it to their interests. The PTS units could not be incorporated into the existing network without introducing a substantial change in its basic structure. Thus, actors interested in maintaining the *status quo* in physics education modified the proposed innovation and shaped it to their interests. University physicists, for example, defined the PTS approach as "the applications of physics in technology and society" and, consequently, regarded it as "a supplementary part to the core physics curriculum." They gave serious consideration to incorporating this modified version in order to motivate students to learn physics and encourage them to specialize in the subject. Defined as such, inclusion of PTS topics would enhance the stability of the existing network and maintain the curriculum as an OPP for a wider population of students, not just the university-bound students. In short, physicists defined the innovation in Category 1 (motivation by PTS content) or Category 2 (casual infusion of PTS content) terms.

University students (with the exception of one) and some secondary students conceptualized and defined PTS in a similar way as did physicists, thereby arguing to maintain the *status quo* in school physics. Although all university students criticized the school subject for lack of "relevancy" and "usefulness," they did not consider this to be sufficient grounds for significant

change in the curriculum. Like physicists, they argued that incorporating some PTS topics into the existing curriculum would be desirable (Categories 1 and 2); however, the goal of these actors was to match the secondary curriculum as much as possible with the first year university physics course.

Unlike university students and physicists, physics teachers were not as uniform in terms of their goals and positions with regards to the innovation. Dealing with a wide range of students' abilities and interests, some (but not most) physics teachers felt committed to all students and not only those who would go to university. These teachers focused on two of the units, Light Sources and Ionizing Radiation, modifying them to incorporate more physics content and problems. They situated the innovation in Category 4 (physics through PTS content), much like the PLON curriculum itself, and whereby PTS content would constitute about 20% of the curriculum content. Other teachers, however, argued for an "add-on approach" in that some PTS topics could be incorporated into the existing curriculum to motivate students and soften the subject. Like physicists, these teachers redefined the innovation such that it could be enrolled in the existing network.

Although I proposed the innovation hoping that it would be mobilized for wider implementation, the ministry's decision was that two or three units would be piloted in two schools. Although the goal of the ministry is to eventually implement a full PTS curriculum, such curriculum differs from the one I proposed initially; during my negotiation with the ministry and in the

process of decision making concerning the future of the innovation, it was situated within Categories 4 and 5. In other words, the proportion of "pure physics" was increased. Still, the extent to which this goal can be realized can't be known at this stage for that depends on how the actors will react to it and to each other. Whether it becomes an established "truth" in the secondary curriculum and in what form, or becomes an "inappropriate" idea, depends on the actions of the actors involved. At this point, this modification seems to resonate with how industry representatives and some secondary students defined the innovation. These actors, as discussed earlier, were supportive of PTS but modified it by giving more weight to physics itself while maintaining the significance of technology and social issues related to physics. Their version of PTS, which they described as a balanced curriculum in that it will fulfill the goals of most actors, was similar to that of the ministry.

Finally, *the PTS innovation has resulted in some changes in the existing network in that it shaped some of the actors and resulted in structural changes.* For example, not all actors who supported PTS were ready to accept it the moment it was introduced. Being members of the existing network, the innovation did not seem to fit with their initial views and goals. But, as they interacted with the PTS units, they began to question some of the taken for granted aspects of this network, and emerged with different views, priorities, and identities. They were no longer the "same actors." I discussed this in the

analysis when analyzing the views of industry, some of the teachers, and it is also true for myself. Being engaged in this project, has resulted in some significant changes in how I conceptualize the goals, content and organization of school physics, how I perceive my own role as the "physics curriculum specialist" in the ministry, and how I intend to go about working with the physics teachers.

Changes in the decision making process were also noted. For example, the process of changing the physics curriculum is not carried through the "traditional channels" but through a slow process of constructing a network. In this process, actors (e.g., teachers, students, and parents) other than those originally known (e.g., physicists) are involved, and their views are considered important.

How is power manifested in the school physics actor-network in Bahrain?

In a stabilized network, it is easy to assume that an actor (or a group of actors) "has" or "possesses" power without understanding the process and the strategies whereby this power was achieved and how it is maintained. It is also easy to confuse causes with effects once the interactions and the network that produced these effects have (temporarily) stabilized into a given configuration. That is why controversies, such as the curriculum controversy examined in this study, provide ideal situations to explore and understand how effects such as power are generated. The actors in this curriculum

controversy were engaged in constructing power as they attempted to influence and shape the physics curriculum. The study highlights some of the strategies they employed in this process.

The actors in this curriculum controversy attributed power to each other; for example, physicists attributed power to the ministry, and the ministry attributed power to physicists, physics teachers, students and parents, while the industry people attributed power to the ministry. Also, university students attributed power to physicists, and the teachers attributed power to physicists and the ministry. However, since the controversy is not yet settled, we do not know what the final attributions of power will become. Nevertheless, the process of attribution is illuminating in that it points to an important characteristic of power: it is inherently unstable. In addition, while these different attributions indicate that there may be multiple centers of power, none of them was taken for granted by all actors although they were members of the same network. From an actor-network perspective, this is not surprising because power is manifested through networks, and these are not permanent; the identities of the actors and their relationships (alliances) are constantly negotiated as they interact with one another. Therefore, we can understand the dynamics of power through the ways in which actors engaged with one another.

To begin with, the responses obtained during the first and second sets of interviews, particularly with the ministry officials, were surprising to me. Like

one of the teachers (i.e., T2) in this study, I thought that the hardest challenge to PTS was to convince the ministry. Her advice "to focus on those on the top of the hierarchy" and "secure their support" resonated with my initial view of the politics of physics curriculum making in Bahrain and the distribution of power. In effect, the ministry was perceived as "having" both "power over" other actors and the "power to" implement change if it deemed necessary. Power itself is perceived as a cause in that it could be invoked to account for the ministry's ability to initiate and maintain change. This power was, in part, acquired from the constitution and the political system that assigns the role of curriculum policy formation and change to the Ministry of Education, and was consistent with my previous experience with the ministry in the various projects. Such a view, which attributes power over the curriculum to governments and ministries of education in centralized systems, however, is not entirely personal and specific to the context of Bahrain. In fact, it is common to think of educational change as applied by ministries of education (Za'rour, 1987; Markee, 1998), as policies issued by authority (Za'rour, 1993), or as "steering mechanisms applied by the state" (Calgren, 1995). This portrays a simplistic view of power, and in my case did not explain the way in which the ministry approached the innovation.

Contrary to the conventional theories of power, this study showed that *authority, expertise, access to resources, and occupying a position in a hierarchical system were only part of what constitutes power; they were not themselves*

"power," but were *enrolled and mobilized to support the views and strengthen the claims of other actors and in furtherance of their interests.* For instance, ministry educators claimed that the political and educational leadership in Bahrain placed trust in them (i.e., in the Directorate of Curriculum Development) to propose and implement curricular change. Physicists also appealed to their own expertise and knowledge and mobilized other physicists, textbooks, and universities to claim that they should be the final arbiters of school physics. Physics teachers also appealed to physicists' and their own expertise and knowledge to further their claims to maintain the conventional curriculum, and so forth. What is important, however, is that actors in this study recognized these appeals but they did not always take them for grated nor did they equate them with power.

The ministry's position put it in conflict with its traditional allies and raised the need for new ones. In their efforts to promote a PTS curriculum and reconstruct the network, ministry actors were engaged in problematization, interessement, enrolment, and mobilization. More specifically, their plan defined human and non-human actors, assigned roles and identities, forged alliances, realigned groups, and created new groups. Moreover, in these activities neither the innovation nor its (social or material) context was assumed fixed, but capable of being reshaped. At the heart of these activities was an attempt to establish a curriculum as an obligatory passage point (OPP) which implies that the interests of many actors including teachers,

students, parents and physicists must be translated into this curriculum. In other words, these actors need to see a PTS curriculum as the most appropriate door leading to their own goals. If the ministry succeeds, it would establish its centrality and power in the network. But, *that power would be the result or the effect of these translation activities and can only be obtained from the collective human and non-human actors as they come together in one place.* More importantly, although the interests of these actors may converge into a particular OPP, their goals need not; actors may have and pursue different goals. At the moment, however, the ministry has relatively few allies. These include industry, secondary students, and perhaps a few teachers, and their task, as I have argued, will be difficult.

Earlier in this thesis I quoted Markee (1997, p. 63) who argued that in a centralized system "the power to promote educational change rests with the small number of senior ministry of education officials who are at the center of the decision-making process." As for teachers, Markee (1997, p. 63) argued that they "merely implement the decisions that are handed down to them." This, of course, looks more like the "diffusion model" described by Latour (1986, 1987, 1996). Yet, as we have seen, the fact that the ministry of education was considered the official authority responsible for directing the educational system at all levels was not sufficient for the ministry to make a decision to adopt a PTS curriculum and require teachers and others to simply implement it. Instead, their approach illustrated networking activities and as

such was an example of the "translation model." What is interesting to note, is *that the mechanism of power in this context is similar to that in other, more "democratic" societies.*

The complexity of the task of translating interests to bring about change in school physics arises because the existing physics curriculum has become an OPP for many teachers, students, parents and, of course, university physicists. The links between physics teachers, university and secondary students, and parents on the one hand, and the conventional physics curriculum on the other, were strong because the interests of these actors have been translated into the existing curriculum. It should be emphasized that I am not claiming here that either the physicists who participated in this study or their colleagues in Bahrain have historically played a major role in defining the physics curriculum, or that they were the ones who translated the interests of other actors into the traditional version of physics. At some point in time the ministry enrolled them and they have participated along with others. The question of who enrolled whom at that point in time is irrelevant; what matters is that a particular version of physics was established and black boxed, and this version which we now recognize as "academic" continues to serve the interests of university physicists and other actors as well. What also matters, however, is that in the existing network, many actors (especially teachers and students) recognize physicists as spokespersons, and that in turn allowed them to occupy a central position in the network. The links

between physicists and disciplinary knowledge, physicists and curricula in distant places, and the recognition by many actors of these links, create this centrality. Furthermore, the fact that physicists were able to define and assign roles for the various actors who accepted them for a variety of reasons was also significant in creating this centrality. Indeed, the goals of many students (potential scientists and engineers, in particular), parents and teachers are linked to universities and physicists not just in Bahrain, but worldwide. Obviously, physicists who engaged in this controversy were aware of this and frequently and extensively mobilized these actors to support their position on the need to maintain an academic version of school physics. Therefore, while the ministry's main concern was with students, parents and teachers located in Bahrain, it could not see physicists as a localized and confined network because their allies extend over the world. It is in this sense that the power of physicists is seen to be distributed in the network, to be residing in many actors. Indeed, without the cooperation of students, parents, and teachers, and without the physicists being linked to a wide international network, physicists could not have spoken with such authority as they did in this controversy. The main point is that the ability of physicists to speak for school physics, define its goals and shape, mobilize actors and assign roles is, in fact, what we describe as power. But this power is an effect or an achievement and, like all "network effects" (Law, 1994), they only remain as long as the networks that created them remain in place.

In the instance of change that I explored, the role of physicists as spokespeople was temporarily challenged. While attempting to maintain their version of school physics, *physicists were thus involved in constructing power and used strategies—problematization, interessement, enrollment and mobilization—similar to those of ministry educators and their allies*. Although the fact that the existing version of physics was an OPP for many actors put physicists in an advantageous position, that could not be assured. To maintain it, they did not simply call upon their "power." Instead, they had to call upon human and non-human allies, enlist resources, define and redefine actors, create barriers between actors, and so forth. In brief, they were practicing translation and networking, which if successful would reconstruct power relations in the network. However, the maintenance of the academic version of physics as an OPP is neither in the hands of physicists nor the ministry, but in all actors.

Although some actors are highly engaged in the networking process, one should not conclude that others are therefore passive. Actors who lend their support to others do so for reasons related to their own goals. This, in fact, is a key point in the notion of establishing an obligatory passage point. University students and most teachers, for instance, aligned themselves with physicists because that version of physics was an OPP towards their goals. This was also true for the industry representatives who aligned themselves with the ministry to achieve change that they perceived possible and in their

interests. For this reason, the distribution of power relations within a particular actor-network depends on the behavior of all actors.

In short, by focusing on the physics curriculum in Bahrain, it was possible to study power in action and highlight some of the strategies employed by actors as they attempted to construct and maintain power relations. By reconstructing networks to introduce or hinder the innovation, actors simultaneously were engaged in constructing power relations. Both curriculum and power were in the making as opposed to being ready-made. Power is unstable and is made manifest in the activities that network builders engage in as they attempt to put forward a project. The details of these activities may vary, as do the potential actors to be enlisted and enrolled, depending on the project under construction. But the form of these activities remains the same: problematization, interessement, enrollment, and mobilization, and the universe for possible actors includes the social, material and spiritual. Finally, in this process, certain actors may achieve both "power to" and "power over." But that power does not reside in these actors themselves; instead, it is a characteristic of the network that creates and maintains such an effect and is distributed in the human and non-human actors.

7.2 Implications

The findings of this research have theoretical and practical implications pertaining to several areas in education. In this section, I discuss some of these implications with particular attention to power in curriculum, curriculum making/change, and STS in science education.

Power in curriculum

This study illustrates how actor-network theory can be used to explore and theorize about power in curriculum. The focus is on "power-in-the-making" or power in action. The results of this study show that the "power" of any actor or a group of actors can be understood and analyzed in the same way and using the same language, irrespective of who these actors are or what position they occupy in society or the network. What matters is the activities of these actors and how they interact with each other. For instance, the physicists, the ministry officials, and teachers were all treated methodologically in the same way, and their strategies were analyzed using the same analytical concepts. When power is studied in action, the strategies employed by actors in order to construct power relations become highlighted. Using ANT, I found that the strategies employed by actors involved in this curriculum controversy were similar to those employed by network builders, namely problematization, interessement, enrolment, and mobilization.

Political curriculum theorists (e.g., Apple, 1993; Giroux, 1992; McLaren, 1989) frequently seek answers to fundamental questions like whose knowledge? Or who decides what? A more direct way of phrasing these questions would be: who has power? This research, however, shows that other questions are important and need to be addressed if we wish to understand how power is enacted in curriculum. Such questions include what actors were involved? How are controversies settled? How do certain actors appear to be "powerful" and what does their power consist of? These questions are different in kind because they do not take power as given, but seek to explore and explain how it comes to be in a particular curriculum setting. In essence, they go to the heart of the matter and, therefore, help us understand the origin of power.

As discussed in Chapter 2, sociopolitical analyses of curriculum often invoke power as a cause that determines the outcome of the struggle and compromises over curriculum and to suggest whose knowledge or whose views become legitimate and accepted. Actor-network theory provides a different perspective in which power—whether it is "power over" or "power to"—is an effect rather than a cause. The implication of this for researchers, as this study illustrates, is not to start with power, and certainly not to take it for granted when attempting to understand how a particular form of curriculum stabilizes and dominates. This is equally important for educators seeking to introduce educational changes. In fact, there is no reason to start

with power as given when the actors themselves do not do so. For instance, although the actors who were involved in this curriculum controversy recognized the existence of certain power relations (due to the established network), they did not take these relations for granted; instead, they attempted to redefine them as they mobilized for either maintaining or restructuring the school physics network. Neither university physicists nor physics teachers conformed to the "established" power of the ministry although they were well aware of it. Similarly, although the ministry educators recognized that university physicists and secondary teachers would play a significant role in promoting or hindering any innovation, they did not take the fact that these actors mostly rejected the PTS innovation as an indication that it was deemed to fail. Instead they planned to translate the interests of these actors into this new project.

By treating power as an effect of an heterogeneous network, curriculum scholars may also gain a broader perspective of how power is enacted in curriculum. As emphasized by ANT theorists and shown in this study, power is better seen as distributed in the network. In other words, power does not reside in the actors whom we identify as "powerful," but in all the (human and non-human) actors who are incorporated in the network and act collectively to create this effect. For example, the power of physicists can be seen as a result of the cooperation of students, parents, physicists elsewhere, universities, and teachers, as well as the dictionary, mathematics, physics problems, and

textbooks. All these elements are then important if one wishes to understand the power of physicists. Therefore, when exploring power in a particular setting one has to look carefully for the various elements being associated and how they are associated such that they give the effect of "power."

Political and sociopolitical models of curriculum making often conceptualize power in terms of resources, authority, knowledge, status, etc. (Bush, 1987; Carlson, 1996; Cooper, 1984; Wetoby, 1988). The results of this research suggest that these "elements" are important in understanding power, but they are not to be equated with the power. More specifically, they need to be treated as "actors" that are mobilized and linked to other actors who engage in constructing network. To equate these elements with power is to lose sight of the strategies employed by the actors who utilize them to settle a controversy. The focus on strategies is theoretically significant because it provides a better understanding of the dynamics of power. It is also practically important because of its implications for those involved in curricular innovation as discussed in the following subsection.

Finally, the notion of obligatory passage point and its relation to establishing power in a network are significant, and have a direct implication for scholars exploring power in curriculum as well as those seeking to promote educational change. An OPP may be an artifact, a person, or a group of people. It could also be a question or an idea. In general, it is a point along the trajectories leading to the goals of the various actors. As shown in this

research, actors who wanted to influence the physics curriculum and get their views established were actively engaged in establishing their version of school physics as an obligatory passage point. That is to say, they attempted to translate the interests of the various actors in order that they see this version as the most appropriate door leading to their various goals. Consequently, actors who can establish themselves as spokespersons for that OPP will be perceived as powerful and influential.

It should be noted that in the process of establishing networks, there might be several intermediate obligatory passage points. In this research, we can understand the insistence of the physicists on formulating the controversy about the physics curriculum in terms of students' preparation for higher education as an attempt to establish a specific question as an OPP. In particular, they constantly argued that the main issue to be addressed was whether or not PTS prepares secondary students for university education in physics and science related areas. The idea then was to make this question an OPP such that all actors would agree that it is necessary to answer such question if they were to settle this curriculum controversy.

The implication of this for educators who explore power or engage in curricular innovation is twofold. The first is the need to closely examine how OPPs are established and who the spokespersons are. The second implication is that specific attention needs to be paid to the goals of the various actors

involved to see where they converge and how they are modified or translated into a particular project.

Curriculum making/change

The results of this study broaden our understanding of what constitutes a curriculum or a school subject and, consequently, provide a unique way to conceptualize curriculum making. First, this research suggests that school subjects or curricula are networks of heterogeneous actors. In other words, the curriculum is not simply a "social construct" as often claimed, but a combination of human and non-human actors. Therefore, the non-human actors (e.g., materials, texts, spiritual elements) need to be included and recognized as an integral part of the curriculum, along with the human actors. The decision to include or exclude elements is in the hands of the interacting actors themselves. In this study, we found textbooks, mathematics, physics problems, the dictionary, God, moral values, along with the physicists, students, parents and teachers. All these actors (and many others) come together to define what we refer to as a physics curriculum. Consequently, a change in curriculum requires a change in the network, and not just the curriculum materials to be used. The shift from traditional school physics to a PTS version, for instance, entails a redefinition of the existing actors' roles, identities and practices. It also entails a redefinition of their relationships, and may also require linking them with new actors. That is why I say that

curriculum making entails a construction, or a restructuring, of a network and, hence, could be viewed as a networking process.

Educational researchers have observed that fundamental changes in curricula are rare (Cuban, 1988; Fullan, 1991, Sarasson, 1990). The findings of this research further support such an observation, and suggest some reasons for it. Secondary school physics is a relatively stable actor-network, in which the physics curriculum itself is a simplified network or black box. In this network, there are many other black boxes and several obligatory passage points. Many actors have been enrolled in this network, and they participate in enhancing its stability by mobilizing the various black boxes and accepting the various identities, goals, and relationships agreed upon. The fact that many actors are enrolled implies that their interests have been translated into this network and that they see their goals being fulfilled as participants. The move from the existing school physics to PTS, therefore, entails the abandonment of the existing network and requires the construction of a new one, with different black boxes and different obligatory passage points. For this reason, this task is far more difficult compared to previous reforms in Bahrain. Previous reforms did not disturb the existing roles, identities and goals of the various actors, but enhanced them by updating the textbooks and curricula. In doing so, the various black boxes and the existing obligatory passage points were maintained and enhanced. In other words, those reforms have gradually resulted in a more stabilized network.

To view curriculum making as networking provides a different perspective for understanding the initiation and the fate of educational innovations. Educational innovations may spring from different sources, but government officials are often identified as a major and legitimate source, especially in centralized systems. However, authors (e.g., Za'rour, 1987; Markee, 1997) who see such innovations smoothly spreading and widely adapted in the whole country because they originate from the "authorities" or ministry officials, see the fate of an innovation as resting in the hands of these actors who initiated them. In this view, the origin of an innovation is of utmost importance. Contrary to this view, this research suggests that the fate of any educational innovation will be in the hands of all actors. That is to say, the success of any curriculum project depends on the collective activities of the actors, and not simply on the "significance" of its source or whether the project itself is "good" or "feasible." Ministry and university educators, industry representatives, as well as other actors were impressed with the quality of the PTS units that they have examined and rightfully identified many positive aspects that they attributed to these units and PTS in general. However, neither this nor the fact that the ministry officials were recognized as the official authority responsible for curriculum development in Bahrain was sufficient to suggest that the innovation can be easily adopted, let alone be successfully implemented. Therefore, actors wishing to introduce change in curriculum need to recognize that they are network builders as they

attempt to translate the interests of as many actors as possible into their projects. An important aspect in this process is to enroll not just as many actors as possible, but also different kinds of actors, including human and non-human. In fact, sometimes, these may be more important. Furthermore, it is extremely important that the network builders are clear about the different goals of the various actors to see how they could be fulfilled or modified if these actors are to be interested in that particular project.

Another implication of using ANT to understand curriculum innovation is related to how both the innovation and its context are analyzed and understood. In recent years, there has been a growing awareness for the need to socially, politically, and economically contextualize curriculum if it is to be adequately understood or substantially changed (Carlson, 1992; Cornbleth, 1990; Pinar et al., 1995). When applied to curriculum, an ANT perspective would pay equal attention to changes in both the innovation and its context. To borrow from Latour (1987, 1991, 1996), one does not follow an innovation in a context, rather one needs to follow the simultaneous construction of both because the innovation and the context co-evolve. ANT thus offers a useful perspective where the divides between "external context" and "internal forces" are eliminated. The notion of a "token" (Latour, 1986) is useful here in that an innovation, such as PTS, can be regarded as a token that shapes the various actors who take up the token and interact to form a network. The actors, in turn, redefine the token and shape it to their interests. These ideas have not

been widely used in education. An exception to this is the research conducted by Gaskell and Hepburn (1998). The researchers used an actor-network perspective to follow the development of an applied physics course in two different settings in the province of British Columbia, Canada. They introduced the notion of a "coursenetwork" to emphasize the simultaneous construction of the course and the network that defined and sustained that course. The introduction of PTS in Bahrain is another example. Although the story of PTS is only starting, and hence we do not know whether or not a new network will be constructed, this research supports the findings reported by Gaskell and Hepburn (1998) and allows for a different understanding of how we interpret the way actors interact with an educational innovation. The focus here is on the changes that are generated by the innovation as well as the changes it undergoes in the hands of these actors. As this study shows, actors who supported PTS were not uncritically adopting a new innovation; they modified the innovation, and were aware of the fundamental changes it calls for and, consequently, planned to mobilize to achieve these changes. Although these actors focused more on the context of the innovation (people, educational structure, decision-making process) they still modified the innovation itself. Similarly, actors who were not supportive of PTS did not simply reject or resist the innovation; rather, they modified, and attempted to enroll, the innovation to fit the existing network.

STS in science education

In the Arab world, interests in directing science education towards STS in order to promote scientific and technological literacy for citizens have emerged during the late 1980s. The literature on the subject, however, is rare and mostly is in the form of dissertations prepared as part of university graduate work, or unpublished papers written by university science educators (e.g., Matter, 1994; Fathel, 1994; Seliem, 1993). Furthermore, these studies are generally quantitative in nature focussing on surveys and textbooks analyses. These studies and reports suggest that those who are surveyed are generally supportive of including STS topics in school science and, consequently, conclude that science education needs to be reformulated to emphasize STS issues. These studies and reports are often directed at policy makers, to convince them of the significance of STS and of the need to issue policies that would encourage the adoption of this approach in school science. Although these studies and reports are important, the implication of this research suggests that it takes a lot more than convincing policy makers to achieve a fundamental change in science education. Indeed, the discussion above regarding curriculum making and the difficulty of achieving educational change applies specifically to STS and science education.

This study suggests, above all, that policy makers and ministry officials who are interested in promoting STS in science need to reconceptualize and redefine their roles such that they become active participants in the

construction of the network that would define and sustain STS. The "policy-practice gap" in STS science education has been well recognized in the last decade (Bybee, 1991; Kummar & Berlin, 1993), but the view has been that those who issue policies have accomplished their parts and the problems lie in those who fail to implement such policies. The results of this research, however, suggest that the gap exists, in part, because of the divide between "policy makers" and "implementers." From an ANT perspective, the links between these two groups and their links with the "policies" were weak. As shown in this study, ministry officials attempted to overcome this shortcoming when they realized the need to work closely and continuously with teachers, students and parents if the innovation is to be successful.

It is not useful to blame teachers for not implementing STS or for not being willing to move away from the disciplinary-oriented science courses that have dominated secondary schools for several decades. Teachers, as shown in this research, are members of the existing disciplinary network and consequently their roles and identities are defined in relation to the other actors. Compared to conventional school science, STS is an entirely different network. Therefore, it is not realistic to expect teachers to change their priorities and practices when everything else, except perhaps the policy or curriculum document, remains the same. Those who intend to initiate fundamental changes in school science must pay close attention to all aspects

of the network, and not just the teachers; for example, the goals of students and their parents, and how these can be translated into the proposed change.

Finally, this study shows that those who seek to introduce fundamental changes in school science must think beyond the borders of their own countries, because school science is part of an international network. This was certainly the case for school physics, and is probably true for other sciences elsewhere. School physics in Bahrain is strongly linked to school physics, physicists, and universities elsewhere. From an ANT perspective, this network is relationally strong and is difficult to counter unless a similar counter network is constructed.

7.3 Further Research

Using an ANT perspective, this study has highlighted several aspects of the existing school physics network as well as the articulation of a plan to construct a PTS network. However, because the curriculum controversy is not yet settled it would be useful to continue to explore whether a new network will be constructed or whether the existing network will solidify. At present, preparation and mobilization for the pilot continues and I expect that it will be implemented during the next academic year. The pilot, as described in Chapter 6, is an essential step in the networking and mobilization for PTS and, therefore, promises to provide a rich context for further research. In particular, it would be interesting to explore how some of the translation

strategies—problematization, interessement, enrollment, and mobilization—articulated by the actors in this study would be enacted during the pilot and how the controversy would be settled.

Although the focus of this study has been on power in curriculum, it also demonstrated, albeit partly, the usefulness of using an ANT perspective to explore and understand curriculum making. Further research in this area would throw new light on the complexity of curriculum making and reveal other ways in which ANT can be used to theorize about curriculum and curriculum making.

Finally, this study suggests that science educators in the Arab world who are interested in promoting STS need to move beyond quantitative research in order to gain a broader view of the complexity of the task of putting this approach into practice. Although qualitative educational research has become widely used, this is not yet the case in most of the Arab World, especially in science education. Further research in other Arab countries would be fruitful, for example, in terms of revealing the similarities and differences between the existing school physics networks and, consequently, might help create links among interested individuals and groups.

Bibliography

Aikenhead, G. S. (1996). Science education: Border crossing. *Studies in Science Education*, *27*, 1-52.

Aikenhead, G. S. (1994a). What is STS in science education? In J. Solomon & G. Aikenhead (Eds.), *STS education: International perspectives on reform* (pp. 47-59). New York: Teachers College Press.

Aikenhead, G. S. (1994b). Consequences of learning science through STS: A research perspective. In J. Solomon & G. Aikenhead (Eds.), *STS education: International perspectives on reform* (pp. 169-186). New York: Teachers College Press.

Al-Hammer, A. (1969). *Development of education in Bahrain: 1940-1965*. Bahrain: Oriental Press.

Al-Khalifa, L. (1994). Science education in a science, technology, and society perspective-1. *The Science Newsletter*, 2 (March), 11. (Arabic).

Al-Khalifa, L. (1995). Science education in a science, technology, and society perspective-2. *The Science Newsletter*, 3 (February), 8. (Arabic).

Al-Khalifa, L. & Mattar, W. (1996). *Enhancement of scientific and technological literacy and science education for all, especially for girls and women in Bahrain*. State of Bahrain (Arabic).

Anderson, G. L.; Herr, K. & Nihlen, A. (1994). *Studying your school: An educator's guide to qualitative practitioner research*. Thousand Oaks, CA: Corwin Press, Inc.

Apple, M. W. (1990). *Ideology and curriculum*. (2nd edition.) New York: Routledge.

Apple, M. W. (1993). *Official knowledge: Democratic education in a conservative age*. New York: Routledge.

Apple, M. W. (1996). *Cultural politics and education*. Teachers College, Columbia University, New York: Teachers College Press.

Apple, M. W. (1998). Mechanisms of differentiation: A response to Roth and McGinn. *Journal of Research in Science Teaching*, *35*(4), pp. 423-425,

Apple, M. & Weis, L. (Eds.). (1983). *Ideology and practice in schooling.* Philadelphia, PA: Temple University Press.

Archer, M. S. (1979). *Social origins of educational systems.* London: Sage.

Arendt, H. (1986). Communicative power. In S. Lukes (Ed.), *Power* (pp. 59-74). Washington Square, N Y: New York University Press.

Arons, A. B. (1990). *A guide to introductory physics teaching.* New York: John Wiley & Sons.

Barnes, B. (1988). *The nature of power.* Cambridge: Polity Press.

Bernstein, B. (1971). On the classification and framing of educational knowledge. In M. F. D. Young (Ed.), *Knowledge and control: New direction for the sociology of education* (pp. 47-69). London: Collier-Macmillan.

Beyer, L. E. & Apple, M. W. (Eds.). (1988). *The curriculum: Problems, politics, and possibilities.* New York: State University of New York Press.

Blades, D. W. (1994). Procedures of power in a curriculum discourse: Conversations from home. *Journal of Curriculum Theorizing, 11* (4), 125-155.

Boulding, K. E. (1989). *Three faces of power.* Newbury Park: Sage Publications.

Bush, T. (1986). *Theories of educational management.* London: Harper and Row Ltd.

Bybee, R. W. (1991). Science-technology-society in science education: The policy-practice gap. *Theory into Practice, 30*(4), 294-302.

Bybee, R. W. (1998). National standards, deliberation, and design: The dynamics of developing meaning in science curriculum. In D. A. Roberts and L. Ostman (Eds.), *Problems of meaning in science curriculum* (pp. 15-165). New York: Teachers College.

Callon, M. (1986). Some elements of a sociology of translation: Domestication of the scallops and the fishermen of St. Brieuc Bay. In J. Law (Ed.), *Power, action and belief: A new sociology of knowledge* (pp.196-233). London: Routledge & Kegan Paul.

Callon, M. (1987). Society in the making: The study of technology as a tool for sociological analysis. In W. E. Bijker, T. P. Hughes & T. J. Pinch (Eds.), *The social construction of technological systems: New direction in the sociology and history of technology* (pp. 83-103). London, England: The MIT Press.

Callon, M. (1991). Techno-economic networks and irreversibility. In J. Law (Ed.), *A sociology of monsters* (pp. 132-161). Routledge: London.

Callon, M. & Law, J. (1997). After the individual in society: Lessons on collectivity from science, technology and society. *Canadian Journal of Sociology, 22*(2),165-182.

Caramaza, A.; McCloskey, M. & Green, B. (1981). Naïve beliefs in sophisticated subjects: Misconceptions about trajetories of objcts. *Cognitin, 9* (2), 117-123.

Carlgren, I. (1995). National curriculum as social compromise or discursive politics? Some reflection on a curriculum-making process. *Journal of Curriculum Studies, 27*(4), 411-430.

Carlson, D. (1992). Education as a political issue: What is missing in the public conversation about education? In J. Kincheloe & S. Stenberg (Eds.), *thirteen questions* (pp. 263-274). New York: Peter Lang.

Carlson, R. V. (1996). Reframing & reform: Perspectives on organization, leadership, and school change. N.Y, USA: Longman Publishers.

Cheek, D. W. (1992). *Thinking constructively about science-technology and society education*. Albany: State University of New York Press.

Clement, J. (1982). Students preconceptions in introductory mechanics. *American Journal of Physics, 50*(1), 66-71

Cooper, B. (1985). *Renegotiating secondary school mathematics: A study of curriculum change and stability*. London: The Falmer Press.

Cooper, B. (1984). On explaining change in school subjects. In I. Goodson & S. Ball (Eds.), *Defining the curriculum: Histories and ethnographies* (pp. 45-63). London: The Falmer Press.

Connelly, F. M. Irvine; I. G. & Enns, R. J. (1980). Stakeholders in curriculum. In F. M. Connelly; A. S. Dukacz & F. Quinlan (Eds.), *Curriculum planning for the classroom* (pp. 44-55). Ontario, Ca: OISE Press.

Cornbleth, C. (1990). *Curriculum in context.* London: The Falmer Press.

Costa, V. B. (1995). When science is "another world:" Relationships between worlds of family, friends, schools and science. *Science Education, 79*(3), 313-333.

Cuban, L. (1988). *The managerial imperative and the practice of leadership in schools.* Albany, State University of New York Press.

Dahl, R. (1986). Power as the control of behavior. In S. Lukes (Ed.), *Power* (pp. 37-58). New York: New York University Press.

Directorate of Statistics. (1996). *Statistical abstract 1996.* Bahrain, Directorate of Statistics, Central Statistic Organization.

Driver, R.; Guesne, E., & Tisweghien, A. (Eds.). (1985). *Children's ideas in science.* Keynes: Open University Press.

Dyrbeg, T. B. (1997). *The circular structure of power: Politics, identity, community.* London, U.K: Verso

Educational Documentation Section. (1996). *Development of education in Bahrain: 1994/95-1995/96.* A report submitted to the 45th session of the international conference on education held in Geneva from 30 September- 5 October 1996. Ministry of Education, Bahrain.

Eckert, P. (1990). Adolescent social categories—information and science learning. In M. Gardner, J. G. Greeno, F. Rief, A. H. Schoenfield, A. diSessa, & E. Stage (Eds.), *Towards a scientific practice of science education* (pp. 203-217). Hillsdale, NJ: Erlbanum.

Eijkelhof, H. (1983). Ethics in science classes: Goals, experience and implications. Invited paper to the Workshop on Science Education and Ethics. Free University of Amsterdam.

Eijkelhof, H. (1994). Towards a research base for teaching ionizing radiation in risk perspective. In J. Solomon & G. Aikenhead (Eds.), *STS education: International perspectives on reform* (pp. 205-215). New York: Teachers College Press.

Eijkelhof, H. & Kortland, K. (1982). The context of physics education. Paper presented to the 2nd symposium on World Trends in Science Education. Nottingham.

Eijkelhof, H. & Kortland, K. (1988). Broadening the aims of physics education. In P. Fensham (Ed.), *Developments and dilemmas in science education* (pp. 282-305). London: The Falmer Press.

Eijkelhof, H. & Lijnse, P. (1988). The role of research and development to improve STS education: Experience from the PLON project. *International Journal of Science Education, 10* (4), 464-474.

Eisner, E. W. (1990). Who decides what schools teach? *Phi Delta Kappan*, (March), 523-526.

Englund, T. (1985). *Curriculum as a political problem*. London: Chatwell-Bratt Ltd.

Englund, T. (1997). Educational discourses and creating a democratic public: A critical pragmatic view. In R. F. Farnen & H. Sunker (Eds.), *The politics, sociology and economics of education: Interdisciplinary and comparative perspectives* (pp. 211-227). London: Macmillan Press Ltd.

Eylon, B.-S. & Linn, M. C. (1988). Learning and instruction: An examination of four research perspectives in science education. *Review of Educational Research, 58*(3), 251-301.

Fathel, N. (1994). Evaluating and improving science teching from psychoepistemological perspective. A paper presented to the 3rd Scientific Conference of College Education (May 3-5)-The University of Bahrain. Bahrain (Arabic).

Fay, B. (1987). *Critical social science*. New York: Cornell University Press.

Fensham, P. J. (1985). Science for all: A reflective essay. *Journal of Curriculum Studies, 17*(4), 415-435.

Fensham, P. J. (1988a). Approaches to the teaching of STS in science education. *International Journal of Science Education, 10*(4), 346-356.

Fensham, P. J. (1988b). Physical Science, science and technology: A Case study in the sociology of knowledge. *Australian Journal of Education, 32*(3), 375-386.

Fensham, P. J. (1992). Science and technology. In P. W. Jackson (Ed.), *Handbook of research on curriculum* (pp. 789-829). New York: Macmillan Publishing Company.

Fensham, P. J. (1993). Academic influence on school science curricula. *Journal of Curriculum Studies*, *25*(1), 53-64.

Fiske, J. (1993). *Power plays, power works*. New York: Verso.

Foucault, M. (1977). *Discipline and punish: The birth of the prison.* (Translated by Alan Sheridan). New York: Vantage Books

Foucault, M. (1980). *Power/Knowledge: Selected interviews and other writings.* New York: pantheon Books.

Foucault, M. (1994). *Ethics: Subjectivity and truth*. (Edited by Paul Rabinow). New York: The New York Press.

Fountain, R.-M. (1998). Sociologics: An analytical tool for examining socioscientific discourse. *Research in Science Education*, *28*(1), 119-132.

Fuchs, S. & Ward S. (1994). What is deconstrcutionism, and where and when does it take place? Making facts in science; building cases in law. *American Sociological Review*, *59*, 481-500.

Fullan, M. G. (1991). *The New meaning of Educational Change*. (2nd ed.). Toronto: OIES Press.

Gaskell, P. J. (1992). Authentic science and school science. *International Journal of Science Education*, *14*(3), 265-272.

Gaskell, P. J. (1994). Assessing STS literacy: What's rational? In K. Boersma, K. Kortland & J. Van Trommerl (Eds.), *Science and technology education in a demanding society*, part 1 (pp. 309-320). Enschede, Netherlands: National Institution for Curriculum Development.

Gaskell, J. & Hepburn, G. (1998). The course as token: A construction of/by networks. *Research in Science Education*, *28*(1), 65-76.

Giroux, H. (1981). *Ideology, culture, and the process of schooling*. Philadelphia, PA: Temple University Press.

Giroux, H. (1983). Theories of reproduction and resistance in the new sociology of education: A critical analysis. *Harvard Educational Review*, *35* (3), 261-293.

Giroux, H. (1992). *Border crossings: Cultural workers and the politics of education*. New York: Routledge.

Glesne, C. & Peshkin, A. (1992). *Becoming qualitative researchers: An introduction*. New York: Longman.

Goodlad, J. I. (1991). Curriculum making as a sociopolitical process. In M. F. Klein (Ed.), *The politics of curriculum decision-making* (pp. 9-23). Albany: State University of New York Press.

Goodson, I. F. (1987). *School subjects and curriculum change*. London: The Falmer Press.

Goodson, I. F. (1988). *The making of curriculum*. London: The Falmer Press.

Goodson, I. F. (1997). *The Changing curriculum: Studies in social construction*. New York: Peter Lang Publishing, Inc.

Guba, E. G. & Lincoln, Y. S. (1989). *Fourth generation evaluation*. Newbury Park, CA: Sage Publications.

Hart, E. P. & Robottom, I. M. (1990). The science-technology-society movement in science education: A critique of the reform process. *Journal of Research in Science Teaching, 27*(6), 375-588.

Hindess, B. (1996). Discourses of power: from Hobbes to Foucault, Oxford, U.K: Blackwell Publishers.

Hodson, D. (1988). Science curriculum change in Victorian England: A Case study of the science of common things. In I. Goodson (Ed.), *International perspectives in curriculum history* (pp. 139-178). London: Croom Helm.

Hodson, D. (1987). Social control as a factor in science curriculum change. *International Journal of Science Education, 9*(5), 529-540.

Hoyle, E. (1988). Micropolitics of educational organizations. In A. Westoby (Ed.), *Culture and power in educational organizations* (pp. 255-269). Philadelphia: Open University Press.

Hunt, A. (1988). SATIS approaches to STS. *International Journal of Science Education, 10* (4), 409-420.

Hurd, Paul D. (1986). A rational for science, technology, and society theme in science education. In R. W. Bybee (Ed.), *NSTA Yearbook: Science-*

technology-society (pp. 94-101). Washington, DC: National Science Teacher Association.

Janesick, V. J. (1998). Stretching exercises for qualitative researchers. Thousand Oaks, CA: Sage Publications.

Jain, J. L. (1986). *A brief history of education in Bahrain*. Bahrain: Arabian Printing & Publishing House.

Keeves, J. P. & Aikenhead, G. S. (1995). Science curricula in a changing world. B. J. Fraser & H. J. Walberg (Eds.), *Improving science education* (pp. 13-45). Chicago, Illinois: The University of Chicago Press.

Kincheloe, J. L. (1997). Introduction. In I. Goodson, *the changing curriculum: Studies in social construction* (pp. ix-xl). New York: Peter Lang Publishing, Inc.

Kumar, D. D. & Berlin, D. F. (1993). Science-technology-society policy implementation in the USA: A literature review. *The Review of Education*, 15, 73-83

Latour, B. (1986). The powers of association. In J. Law (Ed.), *Power, action and belief: A new sociology of knowledge* (pp. 269-280). London: Routledge & Kegan Paul.

Latour, B. (1987). *Science in action*. Cambridge, MA. : Harvard University Press.

Latour, B. (1988). *The Pasteurization of France*. Cambridgem MA.: Harvard University Press.

Latour, B. (1991). Technology is society made durable. In J. Law (Ed.), *A sociology of monsters* (pp. 103-131). Routledge: London.

Latour, B. (1993). *We have never been modern* (Catherine Porter, Trans.). Cambridge, MA: Harvard University Press.

Latour, B. (1996). *Aramis, or the love of technology* (Catherine Porter, Trans.). Cambridge, MA: Harvard University Press.

Latour, B. (1997). On actor-network theory: A few clarifications. Published on the web at http://www.keel.ac.uk/depts/stt/ant/latour.htm.

Lave, J. (1990). Views of classroom: Implications for math and science learning research. In M. Gardner, J. G. Greeno, F. Rief, A. H. Schoenfield, A. diSessa, & E. Stage (Eds.), *Towards a scientific practice of science education* (pp. 251-263). Hillsdale, NJ: Erlbanum.

Law, J. (1986). On the methods of long-distance control: Vessels, navigation, and the Portuguese route to India. In J. Law (Ed.), *Power, action and belief: A new sociology of knowledge* (pp. 234-263). London: Routledge & Kegan Paul.

Law, J. (1991). Power, discretion and strategy. In J. Law (Ed.), *A sociology of monsters* (pp. 165-191). Routledge: London.

Law, J. (1992). Notes on the theory of actor-network: Ordering, strategy, and heterogeneity. *Systems Practice*, *5*, 379-393.

Law, J. (1994) *Organizing modernity*. Cambridge, Massachusetts: Blackwell Publishers.

Law, J. (1996). The manager and his powers. A Paper presented to the Mediaset Convection, Venice, 12th November, 1996: Published by the Department of Sociology at Lancaster University at: http://www.lancaster. ac.uk/ sociology/ stslaw1.html

Layton, D. (1994). STS in school science: A movement undertaken by history? In J. Solomon & G. Aikenhead (Eds.), *STS education: International perspectives on reform* (pp. 32-44). New York: Teachers College Press.

Lukes, S. (1974). *Power: A radical view.* London and Basingstoke: Macmillan.

Lukes, S. (Ed.). (1986). *Power.* Washington Square, N Y: New York University Press.

Lukes, S. (1986). Introduction. In S. Lukes (Ed.), *Power* (pp. 1-18). Washington Square, N Y: New York University Press.

Markee, N. (1997). *Managing curricular innovation*. Cambridge, UK: Cambridge University Press.

Martin, B. & Brouwer, W. (1991). The sharing of personal science and the narrative element in science education. *Science Education*, *75*, 707-722.

Matter, W. (1994). *An analytical survey of the priorities of social issues related to science and technology as reflected in unified science curricula of the Arab*

Gulf States. Unpublished Masters Thesis. The University of Bahrain. (Arabic).

McLaren, P. (1989). Life in schools: An introduction to critical pedagogy in the foundations of education. New York: Longman.

McLaren, P. (1995). *Critical pedagogy and predatory culture: Oppositional politics in postmodern era*. London, U.K. Routledge.

McLaren, P. (with Giroux, H.). (1995). Radical pedagogy as cultural politics beyond the discourse of critique and anti-utopianism. In P. McLaren, *Critical pedagogy and predatory culture: Oppositional politics in postmodern era (pp. 29-57)*. London, U.K. Routledge.

McMillan, J. H. & Schumacher, S. (1993). *Research in education: A conceptual introduction*.(3rd ed.). USA: Harper Collins College Publishers.

Merriam, S. B. (1988). *Case study research in education*. San Francisco: Jossey-Bass Publishers.

Morrow, R. A. and Torres, C. A. (1995). *Social theory and education: A Critique of theories of social and cultural reproduction*. Albany: State University of New York Press

Nespor, J. (1994). *Knowledge in motion: Space, time and curriculum in undergraduate physics and management*. Washington, D C: The Falmer Press.

Olsen, M. E. (Ed.). (1970). *Power in societies*. London: Collier-Macmillan Limited.

Osborne, R. J. & Freyberg, P. (Eds.). (1985). *Learning in science: The implications of children's science*. London: Heinman.

Pinar, W. F.; Reynolds, W.; Slattery, P. & Taubman, P. (1995). *Understanding curriculum: An introduction to the study of historical and contemporary curriculum discourses*. New York: Peter Lang.

PLON. (1983). *Water for Tanzania*. The Netherlands: State University of Utrecht, PLON.

PLON. (1984a). *Light sources*. (Arthur E. Witmans, Trans.) Saskatchewan, Canada: SIDRU, University of Regina.

PLON. (1988). *Ionizing radiation*. (Monash University, Faculty of Education, Trans.)

Rafea, A. (1987). *The need for out of laboratory experiments in the Bahraini physics program: A trial implementation.* Unpublished Masters thesis. McGill University, Canada.

Roberts, D. A. (1988). What counts as science education? In P. Fensham (Ed.), *development and dilemmas in science education* (pp. 27-54). New York: The Falmer Press.

Roberts, D. A. (1998). Analyzing school science courses: The concept of companion meaning. In D. A. Roberts & L. Ostman (Eds.), *Problems of meaning in science curriculum* (pp. 5-12). New York: Teachers College.

Roberts, D. A. & Ostman, L. (Eds.). (1998). *Problems of meaning in science curriculum*. New York: Teachers College.

Rose, N. and Miller, P. (1992). Political power beyond the State: problematics of government. *British Journal of Sociology*, *43*(2),173-205

Rosenthal, D. (1989). Two approaches to science-technology-society (S-T-S) education. *Science Education*, *73*, 581-589.

Roth, W.-M. & McGinn, M. K. (1997). Science in schools and everywhere else: What science educators should know about science and technology studies. *Studies in Science Education*, *29*, 1-44.

Roth, W.-M. & McGinn, M. K. (1998). >unDELETE science education:/lives/work/ voices. *Journal of Research in Science Teaching*, *35*(4), 399-421.

Roth, W.-M. (1996). Art and artifact of children's designing: A situated cognition perspective. *The Journal of the Learning Sciences*, *5*, 129-166.

Rowell, P. M. & Gaskell, P. J. (1987). Tensions and realignments: School physics in British Columbia 1955-1985. In I. Goodson (Ed.), *International perspectives in curriculum history* (pp. 74-105). London: Croom Helm.

Rubba, P. (1987). Perspectives on science-technology-society instruction. *School Science and Mathematics*, *87*, 181-186.

Saboor, M. (1992). *Knowledge and authority in the Arab society*. Beirut, Lebanon: Center for the Study of Arab Unity. (Arabic).

Sarasson, S. (1990). *The predictable failure of educational reform*. San Francisco: Jossey-Bass.

Schrag, F. (1992). Conceptions of knowledge. In P. W. Jackson (Ed.), *Handbook of research on curriculum* (pp. 268-301). New York: Macmillan Publishing Company.

Selim, M. S. (1986). Teaching bioethics in a developing country: A case study. The CBE/ 1UBS, Helsinki.

Selim, M. S. (1993). Scientific literacy and curriculum development. Faculty of Education, Ain Shams University (Egypt). Arabic.

Siskin, L. S. (1994). Realms of knowledge: Academic departments in secondary schools. Washington: The Falmer Press.

Solomon, J. & Aikendead, G. (Eds.). (1994). *STS education: International perspectives on reform*. New York: Teachers College Press.

Stodolsky, S. & Grossman, P. L. (1995). The impact of subject matter on curricular activity: An analysis of five academic subjects. *American Educational Research Journal*, *32*(2), 227-249.

Treagust, D.; Leggett, M.; Glasson, P. & Wilkinson, W. J. (1990). Improving physics teaching through collaborative research. *Research in Science and technology Education*, *8*, 93-101.

Van der Valk, T. (1989). Waves or particles? The cathode ray debate in the classroom. In R. Millar (Ed.), *Doing science: Images of science in science education* (pp. 160-179). London: The Falmer Press.

Ware, S.; Heikkinen, H. & Lippincott, W. (1987). Industry and technology: The CHEMCOM philosophy and approach. In D. Waddington (Ed.), *Education, industry and technology* (pp. 145-150). London: Pergamon.

Wartenberg, T. (1990). *The forms of power: From domination to transformation*. Philadelphia: Temple University Press.

Wartenberg, T. (Ed.). (1992a). *Rethinking power*. Albany, NY: Sunny Press.

Wartenberg, T. (1992b). Situated social power. In T. Wartenberg (Ed.), *Rethinking power* (pp. 79-101). Albany, NY: Sunny Press.

Weber, M. (1970). The types authority and imperative coordination. In M. E. Olsen (Ed.), *Power in societies* (35-39). London: Collier-Macmillan Limited.

Weber, M. (1986). Domination by economic power and by authority. In S. Lukes (Ed.), *Power* (pp. 28-36). Washington Square, N Y: New York University Press.

Werner, W. (1991a). Curriculum and uncertainty. In R. Ghosh & D. Ray (Eds.), *Social change and education in Canada* (pp. 105-110). Toronto: Harcourt Brace Jovanovich.

Werner, W. (1991b). Curriculum integration and school cultures. Burnaby, B.C.: Tri-University Integration Project.

Westoby, A. (Ed.). (1988). *Culture and power in educational organizations.* Philadelphia: Open University Press.

White, B. Y. (1983). Sources of difficulty in understanding Newtonian mechanics. *Cognitive Science, 7*, pp. 41-46.

Whitty, G. (1985). *Sociology and school knowledge: Curriculum theory, research and politics.* London: Methuen.

Wierstra, R. (1984). A study on classroom environment and on cognitive and affective outcomes of the PLON-curriculum. *Studies in Educational Evaluation, 10*, 373-383.

Woolnough, B. E. (1988). *Physics teaching in schools 1960-1985: Of people, policy and power.* London: The Falmer Press.

Yager, R. E. & Tamir, P. (1995). The science/technology/society (STS) curriculum viewed through a state model. *The Journal of Technology Studies, 21*(1), 33-47.

Yin, Robert K. (1994). *Case study research: Design and methods.* (2nd ed.) Thousand Oaks, CA: Sage Publications.

Young, M. F. D. (Ed.). (1971a). *Knowledge and control: New direction for the sociology of education.* London: Collier-Macmillan.

Young, M. F. D. (1971b). An approach to the study of curricula as socially organized knowledge. In M. F. D. Young (Ed.), *Knowledge and control: New direction for the sociology of education* (pp. 19-45). London: Collier-Macmillan.

Young, M. F. D. (1976). The schooling of science. In G. Whitty & M. Young (Eds.), *Explorations in the politics of school knowledge* (pp. 47-61). Driffield: Nafferton.

Za'rour, George I. (1987). Forces hindering the introduction of STS education in schools. In K. Riquarts (ed.), *Science and technology education and the quality of life -Vol. 2* (pp. 731-741). Kiel: Institute for Science Education.

Za'rour, George I. (1993). New trends in the development of teaching science and technology. Paper presented in the First Conference on the Future of science and mathematics education and the needs of the Arab society (October). Beirut, American University of Beirut.

Ziman, John. (1984). *An introduction to science studies: The philosophical and social aspects of science and technology*. Cambridge: Cambridge University Press.

Ziman, J. (1994). The rational of STS education is in the approach. In J. Solomon & G. Aikenhead (Eds.), *STS education: International perspectives on reform* (pp. 21-31). New York: Teachers College Press.

Appendices

Appendix A- Interview Protocol for Phase One

1. What do you think of each of these units?
2. What is your general impression about these units?
3. What difference, if any, do you see between these units and the physics materials we currently use in Bahrain?
4. What aspects of these units do you particularly like? Why?
5. What aspects of these units you don't like? Why?
6. How do you feel about replacing one or two of our courses, say the Spectra, with the unit Light Sources? Why? Why not?
7. How do you feel about using these or similar units as exemplars for developing a secondary physics curriculum?
8. What do you think are the strength and weaknesses of the current secondary physics curriculum in Bahrain? What changes you would like to see?
9. In your opinion, what constitute a good secondary physics curriculum? Why?

Appendix B- Sample Interview Excerpts From Phase One

Excerpts from an interview with a university physicist (uph#4)- Phase One interview
Date: December 1st 1996.

Ahmed: First of all, I would like to thank you for your time and participation in this project, and I hope that we all benefit from and learn from this discussion and negotiation.

Uph#4: You are welcome.

Ahmed: So, let us begin with your general impression about these units. Is there anything you wish to say about them?

Uph#4: Well, first let me be frank and say that I spent several hours examining two of the units: Light Sources and Water for Tanzania. I looked into these two in details. But I scanned through the third one, Ionizing Radiation, but still looked at the kind of questions used and what problems and formulas are highlighted in the unit. Perhaps the reason for this was that this is not my area of specialty.

Ahmed: You mean nuclear physics?

Uph#4: Yes. I am not a nuclear physicist, and others might be able to judge this unit better, in terms of suggesting what topics in this field are important and what need to be focused on. Any way, do you have any specific questions?

Ahmed: Yes, I do. And we may start with you general impressions as I said.

Uph#4: Well, initially I began to think about what constitutes a good secondary physics curriculum.

Ahmed: Good, in fact that is one of my questions.

Uph#4: When I think about secondary students, and especially those who opt for the science stream, I assume that they are wishing to continue into university education. Leaving university education for now, let us focus on secondary level of education. This is a very crucial stage. No doubt about it. At this stage, the student's mind is fresh and flexible, and he

begins to decide for himself if he likes physics or other subjects. So, if we look at the secondary level of education, we note that it serves several purposes. At this stage students' thinking abilities and skills are developed and shaped. Also, students begin to develop interests in pursuing certain subjects in the future. Thirdly, this stage prepares students for further education at university level. So, a curriculum should be designed to fulfill or facilitate these three aspects.

Ahmed: These three aspects or purposes are your focus then?

Uph#4: Yes, exactly. And when you think about university physics education you note that the discipline of physics, as you know, has become so deep and wide that eventually we have to set priorities and settle on certain topics and areas to be taught to students in university. One of the consequences is that we don't have a lot of time to help students fully develop their thinking and reasoning abilities and skills in dealing with problems. We expect them to acquire that during their first two years in the physics program and, hence, we assume that similar practice has been followed in secondary school as an initial preparation. They should be able to handle and solve physics problems. Problem solving is crucial.

Ahmed: By problem solving you are referring to the kind of problems we are familiar with in physics courses?

Uph#4: Yes, and when we emphasize problems and problem solving that means mathematics; formulas and equations. I don't think you can separate math from physics. This is not an opinion, it is a fact...Whenever we tackle a physics problem we prefer to do that mathematically Instead of writing twenty pages we write one equation...Math is the language physicists use to tackle problems in physics. That is why teaching physics in secondary school should be based heavily on math. This is a fundamental criterion of a physics curriculum. Next to that we have the content coverage or what topics to include. We must include the important things, because we do not have the time to include everything.

Ahmed: What would these important topics be in your opinion?

Uph#4: Let me explain. The most important area that should be covered well in the physics curriculum is mechanics because, after all by definition, and you may consult any dictionary for that, physics is the study of motion and energy and their interactions. Naturally, this is a simplified

definition but it provides us with basic ideas as to what to include in a curriculum and how to judge the units you are proposing.

Ahmed: You began by setting some criteria.

Uph#4: Yes. And I want to see if your proposed units or curriculum do or do not fit with my ideas. So, first of all, the students should study mechanics thoroughly and strongly over the three years of secondary schooling. Then comes electricity and magnetism, both are important areas and could be covered over a span of two years. Also we have waves and light, although less important than the other topics but nonetheless should be covered to some extent. And, of course, the curriculum should include something about heat and electronics. It will also be nice if we could teach students something about the computer.

Ahmed: In physics you mean or programming, I am not clear on that.

Uph#4: I mean in physics. It will be nice if we can incorporate and use the computer in physics, for instance to solve problems. But in any case, as far as the physics curriculum is concerned, it should focus on mathematics. Also, the curriculum should be pedagogically consistent, and I am sure you know what that term means. It means that the content must be logically organized such that students progress from learning the simple concepts and move to the more advanced and complex ideas and so forth.

Ahmed: Fine. What else do you see as important in any secondary physics curriculum?

Uph#4: Then we come to evaluation. I mean Exams. Exams should focus on problems. The mathematical type physics problems.

Ahmed: Entirely? Should we base our evaluation entirely on problems?

Uph#4: Not entirely, but say 80% (of the questions).

— — — —
— — — —

Ahmed: How about these [PTS] units. How did you find them?

Uph#4: I looked at the unit LS first. From the title you can tell that it deals with sources of light. The focus is on the sources and I assumed that students have learned about the light and now come to apply what they have learned about the physics of light to some useful appliances. And

in the introduction you can sense the approach used. You can get a sense of the STS philosophy or approach here and also in the unit Water for Tanzania. The philosophy underling these units can be clearly seen from the start. In the unit Light Sources, they talk about the importance of light sources to people and society. That is the starting point. Then after some historical introduction the units put forward several questions: what kinds of lamps are appropriate for the given situations? What is the efficiency of the lamp? How much does it cost? Then comes the scientific question: What happens when a lamp gives off light? You note that they ask the social questions first and leave the scientific questions to the end. This is a general approach in these units. The social, technical, or economic questions are tackled first and later on the scientific questions.

Ahmed: What is the problem with that? What is wrong with beginning with these questions and then discussing the scientific issues?

Uph#4: The problem is with how you deal with them, and which one is given the priority? So, my general conclusion is that the applications, the social aspects are given priority in these units, and this is evident in the way the topics are dealt with and in the titles. For example, if I want to write a book about or discuss light, then the title should be "The Light," but obviously for them light sources are more important than 'the light' itself. Therefore, [the authors] discuss light through light sources.

Ahmed: Wouldn't that make it more attractive to students?

Uph#4: No, I don't think so. If we want to study or learn about light, we isolate it and study its properties. This is the scientific method, the method used in physics. When we study a phenomenon, you isolate it from its background, from the distracting or cumbersome factors. Thus, if I want to teach students about light, I focus on its nature, its characteristics, like interference, reflection, diffraction, and look into its speed and how it diffract and interact with matters. Once I have done all that I can now ask about the applications and teach something about the microscopes, telescopes, or even electric lamps and light bulbs. But the situation is reversed in this unit [LS]. They focused on the applications and later on devoted few pages to the nature and characteristics of light. Here, the unit deals with the topic scientifically, as an isolated phenomenon but even then the formulas and equations are omitted.

Ahmed: They are not omitted but reduced. Perhaps because they not relevant here. They are not necessary for understanding the topics discussed.

Uph#4: But these are very important. And I am certain that they are not ignored in our physics curriculum in Bahrain, for example, in the [courses] Spectra and Waves. So, if this [i.e., the unit Light Sources] is the only unit on light then it will not do. This unit deals sources of light and their kinds. Normally, I should consider the science first, then I may look into the appliances or the device which is an application of science. Not the other way around. This is my point of view. Also, [in this unit] when they want to discuss the properties of light I noted that they select those properties that are needed for the topic being discussed, for example, illumination. But there are other properties of light, which are even more important than these discussed.

Ahmed: More important, in what sense?

Uph#4: In a theoretical sense. From a theoretical point of view. When I want to talk about light and its properties, then I ask: What is light? Is it a particle or a wave? If it is a wave then it has certain characteristics, like interference and diffraction. And so on. But her [in the unit] the authors chose to focus on other secondary properties from a utilitarian point of view. The chose whatever is useful for applications and technology.

Ahmed: Well, they focus on technology and things that are useful and relevant to students. In other words, the unit emphasizes or takes a utilitarian approach to physics.

Uph#4: Exactly. This is the main idea that underpins these units, and I wanted to keep it until the end.

Ahmed: And you don't seem to be happy with that.

Uph#4: No. I don't [approve such utilitarian approach] because there is more to science than mere utilitarian. I don't want to give students the ideas that the main purpose of science is to serve us, that science simply is something useful to us. No, I philosophically object to that. We should not select from science what is useful to us and say that something else is not useful.

Ahmed: O.K What else?

Uph#4: In general science has two purpose. It is not just for the benefit of humans in society, in economics and technology. No. Not just that. God created us and bestowed upon us the ability to think and find out and

ultimately become believers, to ultimately have faith in God. Naturally we have to look into that.

Ahmed: I don't think that I object to that.

Uph#4: But if you take science from a perspective of what is useful, then first you put the human in the center of the universe, because you say what important in science is what is important or useful to me [the human]. Who benefits from knowing why the sky is blue? This knowledge has no use in technology. It has no applications. But answers to such questions must be sought, to fulfill our desire to learn and understand, and which God created in us. So, in physics, when I want to discuss and understand a natural phenomenon I do that in its natural setting, irrespective of or in an isolation from the observer. This is the scientific method that is used, at least up until now. While this [PTS] approach attempts to involve us, the observer, with the natural setting and it does so by invoking one's interests, the usefulness of the knowledge or by taking a selective utilitarian stance. So, there is no neutrality. Such philosophy is not useful and students should not be encouraged and trained to follow it. Also, there is a heavy emphasis on economic aspects, and this you can deduce from the kind of questions asked and highlighted in these units..... This, I believe, ultimately promotes a materialistic point of view. This curriculum is written by people for students functioning in a capitalist society an its purpose is to promote capitalist ideology..... We live in a different kind of society, we are governed by religious and moral values, not materialistic.

.....

.....

Uph#4: As I said before, in this unit [LS] only 6 pages are devoted to discussing the properties of light in a scientific manner. Not much else.

Ahmed: Well, in these pages the students learn about interference and diffraction. Of course, there are other topics, and these will be dealt with or they have been covered earlier either in other courses. So, we don't have top cover everything about light in this unit.

Uph#4: Are you suggesting that students have already covered the other important topics about light somewhere else.

Ahmed: Yes, or they may cover some of it later on.

Uph#4: And here they deal with light sources and the applications.

Ahmed: Yes.

Uph#4: Then I think this is a waste of students' time. If the purpose of the unit is not to teach about light per se, then that is a waste of students' time and efforts. Why should I teach then about lamps or other light sources. They are hundreds of other appliances and technologies. Why should I choose lamps.

Ahmed: That is not a problem really. We may select another applications, another equipment.

Uph#4: I am against the teaching of appliances or instruments per se. What is important to me is to teach the science itself. To discuss lamps or other appliances will be kind of specialized, very specialized topics. Students who will go into sciences, medicine or engineering are better off learning the physics rather than these specialized and unimportant topics.

Ahmed: O.K. Anything else about this unit? Is there anything you liked about it.

Uph#4: No. That's about a summary of my general impression about the units although we focused on this unit [LS].

Ahmed: How about the other ones. Say the unit Ionizing Radiation?

Uph#4: As I said, I did not focus much on this unit. I am not sure what is the point behind it. Can you tell me more about it.

Ahmed: Sure. This unit focuses on acceptability and risks involved in the applications of ionizing radiation. As you can see [some pages are highlighted to illustrate] basic scientific knowledge about radiation, atomic physics are discussed to provide the necessary background for students. But the focus is on the use of this knowledge to help students gain insight and to be able to involve in discussion about economic, political, medical social impacts of ionizing radiation. As you can see, the unit talks a lot about radiation and risks involved in a variety of settings, such as hospital and factories. And students are thoroughly engaged in discussion and evaluation of risks involved in these situations.

Uph#4: But aren't these topics discussed in our curriculum?

Ahmed: No. However, our textbook briefly mention about dangers of radiation and something about the applications of atomic and nuclear physics, but not to the extent done in this unit. The students are not, for example, involved in any kind of discussion or investigation where they explore in details the social and economic aspects of radiation and its applications.

Uph#4: I think that is enough. As long as we tell students that radiation involves risks. In teaching about radiation we give students some general information about the various risks involved in dealing with radiation and what procedures or precautions we need to guard ourselves. Anything more than that is not necessary for students. Instead, why not teach about 'nuclear properties' itself. What happens [when radiation is emitted?] That would be physics. The physics is the study of nature as it is, and this unit [I R], like the other, attempts to put us in the picture. In my opinion, and as I said before, physics deals with isolated natural phenomena and events to understand their nature, their properties. Later on, I can talk about the applications of that science and I may consider my interactions with these applications.

Ahmed: You emphasized a given definition of science or physics, and how it is done according to your view as a university physicist. You also talked a lot about university physics. Are you implying that the secondary physics curriculum should necessarily reflect all these points?

Uph#4: Yes. School physics should be an image of university physics, but perhaps not a perfect one. Not 100%. I might include a bit of other things. But you have to keep in mind that those who will in the future specialize in physics must learn physics in schools in the same way we teach it in university. This is also important for those who will study engineering, medicine and other science branches, such as biology and chemistry. At this stage I have to prepare all students who are light dough. I can shape their minds, and I have to prepare them such that they will be good receivers in university. I don't want to make a container with no holes.

Ahmed: Are you suggesting that this [PTS] approach will leave many holes?

Uph#4: Naturally, because you can't deal with all these details about technology and social aspects without overlooking other things. This will be done at the expense of the depth of the scientific knowledge.

Ahmed: How about the last unit, Water for Tanzania.

Uph#4: This unit, Water for Tanzania, is the worst because it does not contain one single equation. You look for yourself, there is no mathematical analysis whatsoever, it is all descriptive. So, I would expect that the exams would solely test memorization. I became truly depressed when I read this unit. At first, I did not really understand what is behind all these letters, the problems in Tanzania, and the company who studies the problem of water there, and so forth. I did not understand this presentation or style until I got a whole picture about this approach, which usually begins by introducing a need, something that we need to do.

Ahmed: Yes.

Uph#4: The beginning is always like that. We need water, or we need light. Then it offers the available solutions or alternatives. These are the different kinds of light sources, or the different kinds of pumps and so forth. Then we they go into the details, asking about these equipment and how they work. But they focus only on the scientific content necessary or needed for these equipment or devices, and ignore the rest of the scientific concepts and principles. So, let me summarize what I see as problems with this [PTS] approach. First, the simple definition of physics is that it is the study of motion and energy and their interactions of the two, and to achieve that, to understand the physical phenomena we isolate nature from the observer. Other aspects or social and economic details are not part of that definition and don't fall in the realm of physics.

Ahmed: Are saying that consequently they should not be included in a secondary physics curriculum?

Uph#4: Yes. Otherwise you may call that [curriculum] anything else, some other names, but not a physics curriculum. And I don't support that. Another problem is the emphasis on materialistic or capitalistic views. .... Also, in this approach, the physics concepts and content are watered down or diluted considerably. Physics is a difficult subject. No matter how you look at it, it is a difficult subject and many of its ideas can't be simplified without actually giving up on scientific details and accuracy. Naturally, we can teach it properly and teach it well, by following the right steps, and taking it one step at a time, but not by saying that we will omit the difficult content or ignore the details. That will result in diluting the subject. Because, as I said, physics is and can't be but a difficult subject.

Ahmed: What else do you see as problematic with this approach?

Uph#4: The fact that the units did not include solved problems also means that the students are not participating in learning. They just listen.

Ahmed: Well, I don't think so. As far as being participants and being active, I think the units are very successful in engaging students in learning. There are many activities and a lot of thought provoking exercises and discussion. Even there are many experiments. In fact, students are far from being listeners in these units. How could you say so?

Uph#4: This is your point of view. For me, as long as there are not (physics) problems for students to work on and practice, it is no use. Students must take the pen and write, solve equations and so forth. This is what I mean by active learning. Any ways, this is my view. And my last objection to this approach is that it does not prepare students for university education.

Ahmed: Fine. Now let us say that we wanted to maintain the core physics courses that we currently have as they are now, how about if we replace the elective courses with units like these. As you know, students may, in addition to the core courses, select one or more physics courses as elective. Such units could be offered to them instead of, or in addition to, the existing ones.

Uph#4: These same [PTS] units?

Ahmed: Yes, but not necessarily. Other similar units could be designed and prepared in Bahrain.

Uph#4: Well, that depends. Of course, it is ok to include some applications in the curriculum. If you have a good, mathematically oriented physics curriculum that covers the fundamentals well, then it is fine to include a bit about applications and technology. I think at least 95% of student's time in the curriculum should be devoted to learning the actual physics, the fundamentals, and perhaps 5-10% to examples of the sorts found in these units..... Of course, a student will be attracted to technologies, to learn about racecars for example. To say that is not to contradict my previous statements, so I repeat that no more than 5% of the time need to be spent on these things. Basically, to motivate students' and attract their attentions to the content. A good teacher will do that any way even when the curriculum does not include such examples. The teacher will draw students' attentions to some real life examples, will mention some applications, but naturally that will not be on the expense of working on physics problems. The idea is not to tell students stories.

Ahmed: O.K. is there anything else you wish to add.

Uph#4: No. That is all what I have.

Ahmed: Thank you very much. I will get back to use with the transcript, so that you can comment on it and perhaps we can talk more then, if you think of anything else or if I have other questions.

Uph#4: You are welcome.

Appendix C- Sample Interview Excerpts From Phase Two.

Interview Excerpts from an interview with a physics teacher (T2). Phase Two interview.
Date: January 23rd 1997.

Ahmed: In this interview, we are going to discuss the views of other participants regarding the PTS units and this curriculum emphasis in general. Please feel free to comment on these views, whether you agree or disagree with them.

T4: Fine. No problem.

Ahmed: I found a spectrum of views regarding these units and the significance of this curriculum emphasis. On the one hand I found university that university physicists rejected these units while ministry and university educators strongly supported this approach and liked the units. The views of other participants fall in between, and there are differences among each group, as we will talk. With whom shall I start?

T4: How about the university physicists. Let us begin with them.

Ahmed: Sure. Let me say that in general they rejected these units. They based their objection on the following points. First, physics includes certain fields or areas, and its content is well known worldwide while these units do not reflect this content. Rather, the units contain general information. Second, while physicists believe that math is the language of physics and a school physics curriculum should reflect that very well, the PTS units had downplayed or ignored the mathematical treatments, like formulas and problems. They argued that school physics should be mathematically oriented and ....

T4: (interrupts) For sure, otherwise the units will remain mainly descriptive.

Ahmed: Well that's what they said. That is why they rejected the units. What do you think?

T4: I agree with them [university physicists] in that the curriculum should cover the fundamentals of physics, including the appropriate and necessary laws, formulas, and skills. All this will consequently help students understand and explain natural phenomena, and even

acquire skills like designing.... For example, what makes me certain or confidence of my explanation of a given phenomena or event? Through the laws of physics and calculations. A [physical] law that does not change and gives the same result every time you apply it. We don't want to turn school physics into mere description or speculations, which are not and can't be supported by experimentation, equations or calculations. That will not be physics.

Ahmed: It seems that you are in agreement with them.

T4: Yes. You see perhaps the unit Water for Tanzania, and as I said before, is like a method to teach technology, and could be used in physics in order to teach physics that is. To some extent that will be acceptable in order to help students apply and use the physics they cover and learn practical problem solving. But without the foundation, the content of physics itself, the unit is useless. For example, when it comes to the pumps if the students did not actually study and learn about properties of liquids, pressure, and fluid low, there is not point ion teaching them about design and problem solving.

Ahmed: How about that some physicists, but not all of them, refused to teach such units even when the students have covered the fundamentals of physics elsewhere. Say in another unit or course.

T4: Not to that extent. I mean, I agree with them in that we should focus on physics, but the kind of activities I saw in the units is also useful and some of them might find a place in the physics curriculum.

Ahmed: One of them mentioned that the unit Light Sources and the PTS in general promotes a utilitarian approach to physics. He stated that it encourages students to select from science what is useful for them instead of taking and learning science as a whole and the way it is, irrespective of whether it is useful or not. He also argued that if such approach is adopted then the number of people who would actually understand physics will...

T4: (interrupts) will diminish. I agree with him. Frankly he has a good point here. And when I teach physics I discuss lots of things that are not even part of the curriculum and has no applications, but it is good physics. He is very concerned about physics and worried that the number of physicists will diminish. Actually I agree with him.

Ahmed: On what basis? Why do you agree with him?

T4: From the perspective that you don't pick and choose from science. A student should acquire the basics, get a scientific base and not to choose from science what ever he likes or thinks useful or practical, No. A student will learn all that to understand science and explain what surrounds him. So, in general, in share physicists in their views but I would like to add some applications and technology to make the physics more exciting. The sugar coating that you mentioned last time (with laughter).

Ahmed: University physicists argued that one of the reasons why they emphasize problem solving in a physics curriculum because it promotes critical and analytical thinking in students. What do you think of that?

T4: True, but let us look at it from another angle. When students learn physics whereby he uses laws and formulas [to solve physics problems], that will also give them self-satisfaction and confidence in their explanation. That is in addition to developing their thinking skills.... In physics, a student begins with solving simple problems, requiring one or two concepts, then gradually gets into solving more complex problems. As such, his mind develops too. This is an important gain. Of course this point is important.

Ahmed: Do you wish to add anything concerning what the physicists said?

T4: No. Let us move to another group.

Ahmed: How about the ministry university educators, whose views concerning the units were very much alike?

T4: OK. What did they think of these units?

Ahmed: As I told you earlier, they liked the units a lot and supported the idea of designing the school physics such that it will reflect the approach emphasized by these units. They criticized the existing curriculum for being abstract and irrelevant to students' lives. They also argued that this curriculum is not helpful for the vast majority of students who will not opt for university education, especially in physics. They also noted that the existing curriculum does not promote scientific and technological literacy and the skills needed for students to function well in society. Consequently, these educators argued that a PTS curriculum as exemplified by these units is a better approach to teach physics because it will overcome these shortcomings.

T4: What shall I say. I agree with them that the existing curriculum does not fulfill these goals and does not help students develop these nice skills. That is why if we modify the curriculum by adding some of these topics, then it will be great because we will solve those problems.

Ahmed: But they don't think that adding 10% PTS to the existing physics, as you suggested before could solve these problems. No. They think that PTS should be the priority. However, I should emphasize that they did not suggest that we would ignore the formulas or the physics content. Rather, that content will be used as needed and as necessary, depending on the issues or applications being discussed. In other words, that content will be socially and or technologically contextualized. So, if the issue at hand requires students to examine and understand a particular formula that will be done of course, but these will not be forced into the curriculum for their own sake. Not most of the time at least.

T4: No. No. If you adopt this approach and disregard the academic style curriculum, eventually perhaps in 10 or 20 years we will not have any scientists. They will disappear.

Ahmed: Do you really think so?

T4: Yes, I do.

Ahmed: Let us go back to our discussion regarding what ministry and university educators think of the PTS units.

T4: Yes. Perhaps we deviated a lot.

Ahmed: That is ok. Now one of the aspects of these units that these people liked was their interdisciplinary nature. As you might have noticed, the existing curriculum draws its content from the discipline of physics, while a PTS curriculum will still draw upon physics but will also include technology as well as other fields of knowledge. In other words, they found that a PTS curriculum would bridge the gaps between various fields or area of knowledge including the sciences, technology and society.

T4: Perhaps this is a positive aspect if you are considering an industrial society, where they have a lot of technology and factories. Still, if this approach is followed we will run short of academic scientists. Think

about it in a different way. We have many Arab scientists, academic scientists who do not find the suitable environment and the encouragement and support to pursue their research, to be creative and produce results. These people graduated from our schools, they learned the traditional curriculum and went abroad. Many of them stayed in the West, where they found an appropriate environment and stayed there and became distinguished scholars and researcher. These people learned the traditional way, the traditional curriculum, and they went to the west with a solid background in science and succeeded.

Ahmed: But so many students learn this curriculum every year, they are all exposed to the same content. Why only those? Does not that imply that their success could be attributed to other factors, and not just the curriculum?

T4: Well, I said that the environment was appropriate for them were they went.

Ahmed: But think of the many classes you have taught over the years. How many in each class actually get their physics the way you wish them to. You do recall what we used to find in students' papers when correcting them each year in past? The vast majority don't do well, right?

T4: Some students are talented, or have special skills for physics. Only very few.

Ahmed: I think I am trying to say, and some people actually believe so, that those examples, I mean people who actually become successful or distinguished in science, that their success is due to their hard work and probably other factors, and not simply because the curriculum was solid or academic as you implied. Students who are "good" will do well in university whether they learn the PTS or the traditional physics.

T4: No. No way Impossible. Are you telling me that someone like.... who went to the university and became an engineering student and got A+ in all his courses, do you want to say that he could have done that without the kind of preparation he had in school in physics and mathematics? No. That is impossible.

Let me tell you something too. I've met with few students who graduated from technical school. The courses they have done in school, of course, focused on technology. Right? These students are

now having a hard time at the university. They are not doing well at all, because they lack the fundamental skills and knowledge in physics and math. Even good students among them would need a lot of time and work to catch up with what they have missed. Far more than what any regular student from the science would need. In fact, do you know that one of the physics courses, that is, Force and Motion [physics 215], has helped so many first year university students. I have met with some of these students too and they were so grateful that they have taken this course in school because they found it helpful.

Ahmed: Let us talk about secondary students' views.

T4: yes, maybe we will find something different.

Ahmed: [summarizes students vies]. What do you think?

T4: I think I have a way out this conflict. If students liked this approach, them maybe we can adopt such units and at the same time assign one physics textbook as a reference, something like Fundamentals of Physics, or any other similar book. The PTS units will deal with applications and that kind of stuff, but at the same time the teacher will use this reference to cover the content and the fundamentals of physics.

Ahmed: Which one will be the required curriculum? Which one of them is the base?

T4: We can assign certain chapters each year through the secondary cycle to accompany the units. The students must cover that content each year along with the units.

Ahmed: So, the actual curriculum is still the traditional one, right?

T4: Yes [laughs].

Ahmed: But this is not what many secondary students suggested.

T4: I know [with a smile].

Ahmed: So how about their views? How do we deal with them?

T4: Perhaps students don't actually realize [pause]. You see the applications and technology-as I have had said before- interest and attract students, but students do not realize the significance of learning the fundamentals and to go deeply into the mathematical

manipulations and problem solving. Compared to technology and social applications, students definitely would find these harder and troublesome.

[No specific reactions after that]

Ahmed: Based on these views, how do you think we ought to decide?

T4: It is hard. [Pause].

Ahmed: I mean we have different views with regards to adopting PTS. How do you suggest we can decide now?

T4: I think, to form a committee consisting of specialized physicists, industry representatives, and educators. Together, these parties can work towards putting what students called 'a balanced curriculum.' Of course, 'balance' does not mean that everything will have equal share or given equal weight. It means teaching the minimum requirement of knowledge, which students need to have in order to succeed in their future endeavor. I can't see how would they disagree on that.

Ahmed: But we don't all seem to agree on what the term minimum requirements mean. Is it all what students learn now? Is it something else?

T4: They can come to common point. If all these parties get together and pick a book like college physics or university physics, then these people can work as a committee and will find in each chapter what are the fundamentals and what the students need to learn in physics.

Ahmed: If you suggest that we take such a textbook as a reference, then you have already made a decision that is biased towards yours or the physicists. In other words, this implies that the committee will adopt the views of physicists and those who agree with them, because you have taken the traditional physics content for granted.

T4: Of course. This is the basic, the fundamental, and it has to be in the curriculum.

Ahmed: But I am talking about school physics, not university physics. And we found that PTS is one way of designing a physics curriculum. In addition, we had conflicting views with regards to this curriculum. Some like it and some don't. But how can we decide? How can the ministry, for example, make a decision?

T4: Pause. Perhaps you think I am a traditional person who does not change his mind. But I believe that students must learn all the basic physics. They must cover a bit of each field: properties of matter, electricity, heat, mechanics, and so forth. If we can reduce a bit to make room for some PTS that will be nice, but no more. That's all.

Ahmed: That's ok, all what I am saying is that you settled the issue in the benefits of certain groups, people, or views and kind of ignored the others; for example, students, industry, the ministry educators.

T4: Students, we have to consider that fact that they don't find physics attractive, we have to look into their view that physics is dry and we try to do something about it. We can't do much, but the add-on approach will help, as I said before, or last time. Also, the students at this stage are not mature enough to decide on these things, they don't know what is good for them, and I have talked about that in the last interview I think. As for the industry people, their views mostly count when dealing with technical education. But we should not give much weight to their views when deciding matters of curriculum in the academic, science stream. It is quite natural for the to adopt a PTS approach, because it provides the kind of background they want for students who would work with them after graduation. So these people have vested interest.

Ahmed: But don't we all have some kind of interest, perhaps not necessarily personnel?

T4: Yes. [Laughs].

Ahmed: So, if it is a matter of vested interest, then we can say that all have that.

T4: Yes, but I think that the physics curriculum should be kept as is, with some modifications. That's all.

Ahmed: Good. Do you have anything else to add?

T4: No. I can't think of anything now. Perhaps later if I think of something we can continue to talk about it, some other time.

Ahmed: Thanks a lot, this was an interesting conversation.

T4: Thank you.

Appendix D- Sample Interview Excerpts From Phase Three

Excerpts from an interview with a ministry personnel (MEP#2)- Phase Three interview
Date: September 22nd 1997.

Ahmed: I would like today to focus on the decision, on what we intend to do and what is it that you think we might be doing. I know that we have been talking about this all along, now and then, but I would like to be clear about a few things. For example, do you think we should aim for a PTS curriculum or is that we use an "add-on" approach, as some of the participants have suggested.

MEP#2: In fact, you know that I am convinced of this approach. I am fully supportive of PTS, which emphasizes scientific and technological literacy, and depends on linking scientific concepts with society. However, because this is a new trend for us, and given what you found from your interviews with teachers, who are particularly important when it comes to implementing this curriculum, these teachers did not seem sympathetic with this proposal, perhaps not all of them were straight forward in rejecting it, but it was clear. For instance, when they wanted to include more formulas, more problems, etc.

Ahmed: Yes, most of them wanted to maintain the traditional physics, perhaps with some addition of PTS topics.

MEP#2: Exactly, they want the traditional physics and insist on the traditional trend. Therefore, and based on al this, I think we should move towards implementing this curriculum slowly, through different phases. In the first phase, we have to familiarize ourselves, as curriculum developers, more with this curriculum. This can be done while implementing a few units. We begin with a pilot. We select teachers who are convinced and supportive of this approach. We prepare the environment and the necessary support system and material to ensure proper implementation. This is also important in order to get feedback on this type of curriculum. To be able to evaluate it. That is how I think about it, especially that no such change was ever proposed in science education in Bahrain.

Ahmed: When you say, we pilot and when you talk about evaluating the pilot. How do you see that being done? Who will be involved?

MEP#2: Of course, we will continuously follow and evaluate the pilot. The curriculum specialists will be involved in this process, but so will the teachers themselves. And I would like to see parents whose children will be learning this new curriculum participating with us. I believe we need to get then involved and learn about their views.
We also need to follow the students carefully, to see how they develop, and what they learn in these trial units. Perhaps we might see a considerable improvement in student's achievement such that we can stand up firmly and announce the result to society. The public and media are both important, and that is why I insist on involving parents in this pilot.

Ahmed: Do you mean to involve them in following and evaluating the pilot?

MEP#2: Yes, and to have a say in approving this new curriculum. It is possible that students may find this curriculum rather difficult, or their peers, those students who will not be involved in the pilot and continue with the traditional physics curriculum, those students may devalue the new curriculum and make participating students feel that they are doing a watered down or soft curriculum. I don't want such factors to affect or jeopardize the success of the project. We need to pay attention to them and prepare the environment. And as you can see, the pilot might be for two years, not just one year, and we would pilot perhaps two units.

Ahmed: Ok, so you don't feel that a year is enough.

MEP#2: No, we need two years. As I pointed out earlier, there are those who oppose this trend. Even some people here in our department. So, the whole process needs careful studying and time. We also have to implement in two schools, or more. We need at least one boys school and a girls school where we can pilot a unit or two.

Ahmed: I don't think that we can actually show this approach through one unit. I mean, perhaps one unit is not enough to fully reflect the PTS approach, nor does it allow us to see the consequences in terms of learning and the impact on teachers and parents.

MEP#2: Well, probably you are right. I agree that more than one unit is necessary. So, we might begin with two units and expand in the next year. Hopefully, the pilot will be successful, and we will do our best.

Ahmed: When you say successful, or if the pilot succeeds, what do you mean by that? How do we decide if it is or it is not a success?

MEP#2: We certainly have goals. Every project has goals. Based upon these goals, we will see how much it affects the student, because students are the key factor here. We need students' opinion as well as the opinions of the parents. Based on their feedback or input we can find out if the project has been successful and whether or not people have accepted this curriculum approach. For example, did the students accept it.

Ahmed: Students' acceptance of the curriculum? Is this an important criterion?

MEP#2: Of course, whether or not they eventually accept the PTS curriculum is important. Yes. How they accept it and make use of it. Of course, it is also important that students learn what we expect them to learn from this curriculum. The idea is not to release them from the burden of solving problems or equation. The point is not to replace the traditional curriculum with a softer one. No. Here we are talking about actual problem solving, about active learning and practical situations. So, I want to see students achieve these.

Ahmed: So, in other words, we will also judge the success of this curriculum on the basis of its goals, or learning outcomes. And these, as you have said, are different from the goals of the traditional or existing physics curriculum. They are different from the goals that other participants have emphasized.

MEP#2: Yes. These [new] goals are not emphasized or ignored in our curriculum and in the teaching practice. Achieving these important goals is among the criteria we will use to judge the curriculum and in evaluating it.

Ahmed: What other criteria do you think are important in evaluating the pilot?

MEP#2: The acceptance of this project by the teaching staff and parents. Frankly, this is very important because I am thinking about the expansion of the project later on. Therefore, we need the support of a strong base. It is difficult to be held responsible for the future of all students. We need at least to involve others in sharing the responsibility with us

Ahmed: From what you have said, I think you are particularly concerned about involving parents.

MEP#2: Yes, as well as teachers. You have to be aware that a major change in the curriculum might be associated with a great resistance or opposition. Parents are concerned that their children eventually join the university, to study medicine and engineering. So, they might resist this strongly if they feel that goal is in jeopardy. ... We need the support of the Director of Curriculum Development, we need his backing.

Ahmed: Let us say that the pilot was a success. That is, we found that the students attained those learning outcomes, that they learned the concepts and were able to relate these to real life situations, that they could relate physics to technology and discuss the issues involved. In other words, the goals that are more PTS or STS in character. What then?

MEP#2: Then we move to the next phase. We expand to many schools. We implement the curriculum in other schools and introduce more units, and so on.

Ahmed: Do you expect that the university would be convinced? In particular, do you expect them to accept our evaluation and judgment on the project?

MEP#2: We will, of course, follow those students in the university. However, note that the problem with the university will not occur at the beginning. The students in the pilot will be those who has done the traditional physics plus two PTS units. That will not be noticed. The real danger or the crises might occur when the whole physics curriculum is designed according to the PTS emphasis and fully implemented. Thus, I believe this curriculum will eventually have some serious impact on the society. But if we secure the support of the ministry, of the higher authority and some sectors of the society, get them to support this curriculum project, then the university will surely review it's position and set with us and negotiate, till we convince them. We can also wait and monitor those students who graduate and go to university to see how they function in the university courses. At the present, university professors complain about the high school students and their weaknesses, despite the amount of physics that they study in school. So, the whole thing needs time, needs deliberations and negotiation to convince them.

Ahmed: Fine. What other problems do you expect the project to face in the expansion phase?

MEP#2: The teachers, as I said, because if they were not convinced they will resist the implementation.

Ahmed: How about if we take this as a two-stage piloting. After piloting with two courses, we then move in the next stage to piloting a complete or mostly PTS curriculum in two schools. Of course, then it will make more sense to follow students after their graduation from school to join university.

MEP#2: Yes. That is a good idea. Not only that will facilitate the process of following students, but it has been done before in other subjects as well. So, we implement a PTS curriculum in a school or two first. That sounds good.

Ahmed: When talking about evaluating or following the pilot, you mentioned teachers, students and parents, but did not mention university physicists.

MEP#2: As long as they [university physicists] they do not approve of this project- as you told me and based on your interviews with them- to have them with us will be like burden or obstacles.

Ahmed: How about if we can convince one of them, or someone who is willing to....

MEP#2: That will be great. No doubt that will be to our benefit. That will strengthen our position, and perhaps he might influence his colleagues too. But other than that, I can't see any use or point in involving them.

Ahmed: Anything else, we wish to tell me or discuss about the pilot?

MEP#2: I believe we need to prepare the Bahraini society through a media campaign which educates people towards the importance of achieving and acquiring the goals and skills that are advocated in this curriculum trend. This, of course, in addition to persuading ministry officials to stand by and support us. The materials and that sort of things must be all ready and prepared, we don't want the project to fail because of these reasons. Because there are no materials or enough support for the teachers. I also recall that you talked to me about action research. I think this is important and can be done during the trial implementation [of the PTS curriculum] to gain a deeper

understanding about what students learn and the teaching-learning process as a whole.

Ahmed: It is my understanding that you are for the decision to go for a PTS curriculum, and not just to add a few PTS units to the existing curriculum.

MEP#2: Yes. We want to adopt the [curriculum] emphasis as it is, only with some modification to suit our society. Although we are starting with implementing certain units, our goal is to reach a stage where we implement a full curriculum based on PTS.

Ahmed: Great. Now in the next stage of this research I will negotiate and discuss this decision with the other participants. I want to talk to them about our decision. Therefore, it is important for me to be clear about what to say and what not to say, especially I am concerned about teachers and physicists. Of course, they know that we are for this project, that we support PTS and STS and have our reservation on traditional science, but I didn't talk to them about any decision. Can I now say that we have a decision?

MEP#2: Yes, and why not. It has been more than seven years now since the present science [physics, chemistry and biology] curricula have been developed and implemented, and the ministry has requested us to re-evaluate them. Therefore, among some of things we are considering are the STS and PTS. But to leave the curriculum as it is and focus on the scientific content or subject matter only, this is not in fact an improvement....You may tell them [university physicists] that the ministry approves this curriculum and is going to pilot it and, if the piloting succeeds in the light of the criteria we specified earlier, then a PTS curriculum will be fully implemented.

Ahmed: In two schools.

MEP#2: Yes. Please tell them that we welcome their participation. If any of them is convinced and wishes to contribute in following this project, we will be happy. We wish to involve as many people as we possibly can.

Ahmed: Of course. In fact, I interpret this cautiousness in implementing such a curriculum, although we are convinced of its significance and usefulness, I see that as an attempt to explain it to others, to convince as many as possible and get them to back the project. Like you said.

MEP#2: Yes. No doubt. And don't forget that this is a new thing. It is not being implemented anywhere. Even the private schools, the foreign schools don't adopt a PTS or STS curriculum. They emphasize traditional science and focus on content learning. The scientific content per se. Their direction is always towards the university.

Ahmed: Fine. Is there anything else I should pay attention to or make note of as I talk to people re our decision?

MEP#2: No. Just don't make them feel that we are moving quickly towards full implementation in all school. Stress that piloting will be conducted very carefully and precisely and that we will take into consideration or pay good attention to whatever comments and feedback we receive.

Ahmed: How about university physics and science educators? You did not mention them when talking about the pilot.

MEP#2: The science educators are convinced and approve this project, and we can involve them with us. The problem is that I feel that these people [the science educators] do not have any influence on university physicists. So we will involve educators, but we still need physicists with us, that is if possible, and even if at a later stage.

Ahmed: Anything else?

MEP#2: No, that is all. And we will keep talking if anything comes up.

Ahmed: Yes. Thanks a lot.

MEP#2: Thank you.