Working the Network:
Initiating a New Science and Technology Course

by

Gary Roy Hepburn

B.Sc., Mount Allison University, 1985
B.Ed., Mount Allison University, 1986
M.A. (Education), Saint Mary's University, 1993

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Department of Curriculum Studies

The University of British Columbia
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Abstract

This study explores the introduction of a new applied physics course into a British Columbia high school during the 1994-1995 school year. The course was part of a provincial effort aimed at making science and technology education more responsive to the workplace. Data collection took place during the first year the applied physics course was being piloted at the school and focused on the pilot teacher and the applied physics classes, but also involved others inside and outside the school who had a connection to the course. A variety of methods were used in data collection including interviews, observation, and document analysis. Using actor-network theory and sociocultural theory, the focus of the research is on the networks that were constructed at the pilot school and at the provincial level where the course was conceptualized and developed. The research describes how the teacher and other network builders attempted to enroll various human and nonhuman actors into the networks they were constructing in support of the course. They did this by convincing the actors that the course was compatible with their interests. The types of actors that were enrolled, the sociocultural communities they belonged to, and what it took to convince them to support the course are shown to shape the way that the course was enacted in the classroom. In addition, it is demonstrated that the network that was constructed at the provincial level had only a minor connection to the one the teacher was constructing at the school level. The lack of contact between the two networks meant that the interests of those who were involved in organizing the applied physics pilots at the provincial level were seldom taken into account in the course at the school. Fourteen conclusions are drawn about the networks that were constructed and the network building process at both the school and provincial levels. These conclusions have implications for policy in educational change initiatives and for addressing problems that emerge when cross-subject courses are introduced. The research also develops a new theoretical approach that will contribute to advancing research on educational change.

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Chapter 1

Introduction

Courses that integrate science, technology, and society have been advocated by a variety individuals and groups in recent history (Aikenhead, 1994b) but have had limited success at making it into classrooms (Bybee, 1991). Surprisingly, there have been few researchers who have taken up the task of investigating the reasons behind this lack of impact at the classroom level. One exception is Gaskell (1989), who explores the resistance of science and other teachers to a new science-technology-society (STS) course. He explains teachers' resistance in terms of conflicts between the course and the culture of the teaching communities that the teachers participate in, as well as by pointing out that the course failed to develop its own community of support. The findings and perspective of Gaskell's research are consistent with an emerging area of study on teacher culture and, in particular, the influence of the subject community on teacher practice (Siskin & Little, 1995). Subject communities are normally associated with the departments within which teachers work, and they are central features of teachers' professional lives (Siskin, 1994). Subject communities provide the teachers who participate in them with a community identity, pedagogical methods, and an appreciation for what is, and what is not, *the subject*. By demonstrating the ways that teachers are situated within communities, this literature exposes a set of challenges to overcome in attempts to change teachers' practices. The challenges are even more daunting when the changes involve integrating different subject areas (Little, 1995b), as is the case with STS. The subject culture perspective is an important move in new directions that have been suggested in the wake of a "negative legacy of failed reform" (Fullan, 1991, p. 354). These directions involve accounting for cultural and institutional influences on reform initiatives (Cuban, 1995) as well as developing research programs that study the life history of particular reforms at the classroom, school, district, and regional levels (Cuban, 1990).

The literature on subject communities provides the beginning of a theoretical approach that is used in this research to explore the initiation of an STS course into a secondary school. This literature places the focus on the ways that existing subject communities to which teachers belong influence the development of new STS courses. The subject community focus is supported by a sociocultural theoretical perspective (e.g. Lave, 1988) that emphasizes the changing participation of actors within sociocultural *communities of practice.* Sociocultural theory, however, tends to be most concerned with participation within communities and does not usually account for the role of the larger social world beyond the community in shaping the activities and identities of community members (Nespor, 1994). Because the larger social world usually remains unaccounted for, sociocultural theory often neglects the influence of outside groups or communities on practices within a particular community. In the cases of teachers who are teaching new STS courses, these other groups include school administration, students, and policy-makers—groups that have been identified as being important in change initiatives in science education (Cuban, 1995).

Actor-network theory (Callon, 1986; Latour, 1987) extends sociocultural theory so that the roles of other groups and communities can be accounted for in change initiatives without limiting the scope of research to the community.

Actor-network theory emphasizes the ways that actors are linked to other actors in networks as projects aimed at producing new tokens are undertaken. The tokens that Latour concentrates on in his work are scientific facts or technological artifacts. When these tokens are first developed or put forward, a diverse group of actors is linked together in support of the project. Some of these actors, such as scientists or politicians, are human while others, such as tools or technological components, are nonhuman. These linked actors form a network and the more stable this network becomes, the more likely it is that the token will be successfully advanced. Networks are constructed by individuals and groups who are interested in advancing the token. The network builders enroll other actors, translate the other actors' interests into ones that are consistent with those of the project, and mobilize the other actors' in such a way that the project can proceed. In a similar way, a network must be constructed when a new course is initiated in schools and it is the network construction process that is the focus of this research. By exploring the new STS course in terms of actor-networks, the relationships between the various actors—for example, the teacher, the course materials, the school administration, and the groups in society who have a stake in the course—are the focus of the analysis. As the network builders are followed, their efforts aimed at constructing the network can be examined. Questions about who it is that is enrolled and how this is done can then be asked. This is the theoretical framework that guides the analysis that is carried out in this research.

The Study

This research takes the initiation of a new applied physics course as its focus. In partnership with several other groups, including business and industry as well as community colleges, the British Columbia Ministry of Education decided to pilot a new applied physics course. This was done to provide more students with a background in physics in a manner that emphasized the ways in which physics concepts can be applied to better understand technological systems that are found in the workplace. This type of course, which relates science and technology to the workplace, is a type of STS course (Solomon, 1993) and was piloted during the 1994-1995 school year in several schools in British Columbia at the Grade 11 level. The research concentrates upon one of the pilots of the applied physics course as well as upon the general process through which the provincial piloting initiative proceeded. The actor-networks that were constructed at the school and provincial levels were explored during a year-long ethnographic engagement in the research setting. During this time, data were collected using a variety of methods including interviews, fieldnotes, and document examination.

These data were analyzed with the general goal of accounting for the actor-networks that formed at the school and provincial levels. The actor-networks are the unit of analysis and will be explored by following particular actors or tokens, as Latour (1987) recommends. By following actors who *work the network*, a relational account that identifies the important actors and the relationships between them will be produced. By following actors who work the school and provincial networks, I will produce an account of the networks that form. As I do so, I will respond to the following research questions:

1 How does the teacher of the applied physics course *work the network* as he plans and teaches the course?

1.1 How does the teacher *work the network* outside the classroom?

1.2 How does the teacher *work the network* inside the classroom?

2 How are the interests of various actors who are enrolled in the networks that were constructed around the applied physics course at the provincial and school levels translated into the course?

The first question refers to the teacher of the new course *working the network*. Drawing upon actor-network theory, I am using this phrase to highlight the role the teacher played in *enrolling* other actors into the network that he was constructing as he planned and taught the new applied physics course. Answering the question involves following the teacher as he enrolled new actors and *translated* their interests so that they would be compatible with the project of successfully introducing the course in the school. The enrolled groups were then *mobilized* in the network in such a way as to maximize overall support for the course. The term *actors* refers to both human and nonhuman participants in the network. The human actors are the individuals or groups that are enrolled. The term *groups* refers to any identifiable group (e.g. parents) but may also be taken to refer to communities, which are more tightly associated groups organized around particular activities, such as physics teaching. The nonhuman actors are artifacts or processes that are utilized in the network in some way (e.g. applied physics textbooks). In sub-questions 1.1 and 1.2, I have distinguished between the teacher's working of the network outside and inside the classroom. I made this separation for analytical convenience and am not implying that I consider these to be separate networks. In fact, the relationship between the network inside the classroom and outside the classroom will be explored in the analysis.

The second question takes a broader perspective on the network(s) and does not focus on a particular actor at the center as a network builder. Instead of following an actor, the course itself will be followed as it moves from a general concept discussed at meetings at the provincial level to an actual course that was taught at the school of the teacher whose network building activities are the focus of the first question. Various network builders enrolled many human actors in the network that was constructed around the provincial initiative that led to the piloting of the applied physics course. The actors who were enrolled had their interests translated into the project aimed at advancing the course. This question focuses on the different interests that were translated into the project as it went from a provincial initiative to an actual course taught in a school and the nature of the translations that were made.

Contributions of the Study

This study investigates a phenomenon that has not been adequately investigated in the educational literature, yet is critical to attempts to make the changes in science and technology education that many groups desire. By developing an account of the introduction of a new STS course into a school and of the provincial initiative that led to its introduction, this study will contribute to the development of a more informed basis from which to proceed in future initiatives. It will also expand the number of relevant groups that are considered in studies of educational change, as many researchers have called for (e.g. Cuban, 1990; 1995), and provide a more complex and authentic universe of actors to take into account. Even though this study focuses on science and technology education, the contributions mentioned above will be valuable in other curricular areas as well.

This study also makes an important theoretical contribution. The theoretical perspective brought to bear is new to educational change studies and responds to several identified problems that previous perspectives have encountered. Not only does the study include groups outside the classroom that have been identified as factors in educational change, it goes further by incorporating them into networks involved in educational change so that they are actually part of the system being changed. The use of sociocultural theory and actor network theory provides an alternative perspective on educational change that has the potential to create new avenues for policy, research, and practice.

Limitations of the Study

Although this study aims to account for the networks that were constructed around a pilot of the applied physics course and the provincial initiative that led to it, many choices had to be made about which aspects of the network to collect data on and about the depth with which various linkages would be articulated. The choices that I made resulted in an emphasis on linkages that the teacher formed with some actors (e.g. other physics teachers), while placing less emphasis on his relationship which other actors (e.g. students). These choices also meant that less emphasis was placed upon a detailed accounting of the relationships between groups that were distant from the classroom (e.g. between business representatives and the provincial government). The development of a thorough account of the participation of every actor in the network was not possible in this case due to limitations of time and resources. This limitation is difficult to avoid in the study of complex actor-networks but can be overcome through further research or multiple, overlapping investigations. It is also possible that a complete account is not worthwhile as, at some point, the effort expended is likely to be met with diminishing returns in terms of the usefulness of the additional data.

Another limitation of this study has to do with the lack of a critical perspective that explores the way that power is performed in networks and the relationships between actors. Although this aspect of networks is not totally ignored in the analysis, it is an important topic that is not explored to the extent it warrants. Hopefully, this limitation will be redressed in future research.

Organization of the Chapters

Chapter 2 outlines some research and perspectives on educational change that help to situate the research that I am undertaking. Chapter 3 introduces the theoretical perspective that I will be using to analyze the data and Chapter 4 presents the research methodology. The next three chapters—Chapters 5, 6, and 7—are the analysis chapters. The first looks at the way that the teacher who taught the new applied physics course worked the network outside the classroom, while the second focuses on the way that the teacher worked the network inside the classroom. The third analysis chapter concentrates on the translations that were made as the applied physics course moved from the network that built up around the provincial initiative that led to the piloting of the course towards a classroom where the course was enacted. The final chapter reports the conclusions, implications, and suggestions for further research.

Chapter 2

Educational Change and Science-Technology-Society Education

One of the greatest challenges in education has been finding ways to bring about desired changes in education systems. Despite continual efforts to bring about changes, "few reforms aimed at the classroom make it past the door permanently" (Cuban, 1990, p. 11). Change that has been attempted in science education is no different in this respect. Curriculum reform in science education can be construed as a struggle between science education as a mirror of the scientific disciplines and science education as preparation for living (Cuban, 1995; Hurd, 1991). As a mirror of scientific disciplines, science education aims to give students a knowledge of the structure and basic principles of the scientific disciplines. The primary goal of this sort of science teaching at the upper grades is preparing students for post-secondary education in science and for careers in science. Science for living, or science-technology-society (STS), tends to concentrate more on interrelations between science, technology, and society and usually takes the preparation of students for democratic participation and careers as its general focus. Although there has been support for the development of STS (e.g. American Association for the Advancement of Science, 1989; Science Council of Canada, 1984), success at incorporating this approach at the classroom level has been limited (Bybee, 1991; Cuban, 1995). Despite efforts to introduce several variations of an STS emphasis into schools over the years, the disciplinary science emphasis has remained as the dominant approach to science education in secondary schools (Hurd, 1991).

Current pressures to make changes in science education are the latest chapter in this historical debate. Presently, demands that originate from business groups (e.g. Conference Board of Canada, 1990; Economic Council of Canada, 1992) are being echoed in concerns and efforts of governments, post-secondary institutions, parents, and students (e.g. Ministry of Education & Ministry of Skills Training and Labour, 1994). Many of these demands call for a broader range of students to receive an education in science and technology at the senior secondary level. New courses are being recommended that emphasize the application of science to provide a better understanding of technological systems and the general science and technology background that students will need to enter today's and tomorrow's technologically sophisticated workplace. The research I am reporting in this dissertation investigates an attempt to introduce such a course. In this chapter, I will situate the research by discussing perspectives on educational change and the types of approaches these perspectives have led to. The consideration of the educational change literature will be followed by a review of the literature on teacher cultures and subject communities, an emerging area of research that has important implications for how educational change is understood and approached—especially in science and technology education. I will conclude the chapter by discussing some of the implications this literature has for the introduction of an STS focus into science education.

Approaches to Educational Change

Pressures to bring about change in education often originate in the social, political, and economic milieu. Groups that are successful in being heard by policy-makers at a given time are able to have their visions for education written into educational policy (Lewington & Orpwood, 1993; Manzer, 1994). Once policy positions are formulated, there is usually a set of measures taken with the aim of translating the policy into educational practice at the classroom level. The curriculum implementation and curriculum change literature deal with this process but, for the most part, past attempts to develop a science of implementation have failed in practice (Fullan, 1991; Sarason, 1990). At the heart of most usages of the terms curriculum implementation and curriculum development is a technical view of change that is concerned with "technical methods for changing schools by means of curriculum initiatives taken by local authorities or school boards, or as a result of directives from central governments" (Barrow & Milburn, 1990). Referring to this view of educational change as the *control paradigm*, Hollingsworth and Sockett (1994) characterize it as having a "commitment to (a) generalization about contexts rather than to contexts themselves, (b) a hierarchical view of theory/theorists and practice/practitioners, and (c) agenda driven by bureaucracies rather than by teaching professionals" (p. 2). An example of this approach is found in a book called *Taking Charge of Change* (Hord, Rutherford, Huling-Austin, & Hall, 1987) in which an approach for bringing about desired change in school is based on a game plan and makes extensive use of diagnostic tools. This top-down perspective locates decision making about policy and curriculum outside schools and develops a plan of action so that the intended curriculum will become the curriculum used in schools.

The top-down orientation is softened somewhat by authors such as Fullan (1991) who recognize that the teachers and others who will be responsible for operationalizing the intended curriculum in the schools are not passive actors in the process. He points out that these individuals play a vital role and must be convinced of the merits of the proposed change and to act on its behalf. Even though this stance recognizes the importance of teacher support in change efforts, it is still based on the goal of implementing curriculum policy which comes, at least in part, from above. Fullan's technical view comes clearly through in the language and message of the following excerpt:

> We have a negative legacy of failed reform that cannot be overcome simply through good intentions and powerful rhetoric. Paradoxically, the way ahead is through melding individual *and* institutional renewal. One cannot wait for the other. Both must be pursued simultaneously and aggressively. . . . Armed with knowledge of the change process, and a commitment to action, we should accept nothing less than positive results on a massive scale—at both the individual and organizational levels. (p. 354, emphasis in original)

Fullan's position on educational change seems to represent the dominant attitude governing attempts to effect educational change as is demonstrated by many centralized and, at times, local efforts at implementation. In these efforts, proposals for change usually originate outside schools and then implementation strategies are developed to bring the desired reforms to educational practice. At times these top-down strategies may be accompanied by elements of a bottom-up strategy, where the grass roots support of teachers is considered necessary.

Some local successes have been achieved using bottom-up or site-based strategies for educational change (e.g. Baird & Mitchell, 1993) but these have been criticized by some authors. Fullan (1991) claims that site-based change "is problematic either because individual schools lack the capacity to manage change or because assessment of attempted changes cannot be tracked" (Fullan, 1991, p. 200). Despite his reservations about site-based change, Fullan looks at it as an important part of the solution he advocates. He recommends a model based upon simultaneous top-down/bottom-up approaches. Fullan's approach seems to seek a balance between two positions that are both unacceptable in themselves, but this perspective has also encountered criticism. In their reaction to a model of educational reform that is described as systemic reform by Smith and O'Day (1991), and is similar to the one Fullan puts forth, Scheurich and Fuller (1995) express concern:

> We would argue they are trying to have their cake (maintain the hierarchy with the ultimate power at the top) and eat it too (get the district to carry out the reform as if it were the district's or school's own creation). (p. 18)

Whether they argue for top-down or bottom-up approaches to educational change or a combination of the two, these authors are all interested in finding the best means to bring about change. These approaches differ in such things as the roles of the various participants in the change process and upon whether there ought to be a commitment to particular outcomes of the process. Fullan (1991) and Sarason (1990) both provide an appreciation of the many different groups involved and the very complicated nature of educational change processes. In his recent work, Fullan (1993) begins to move beyond just appreciating the complication of the process by suggesting that teachers can play an important role in it by becoming both inner and outer learners. Inner learning refers to intrapersonal sense-making and outer learning involves relating to, and collaborating with, others. Although researchers like Fullan and Sarason point out some important directions in which to move, there is no consensus on how change ought to be approached and, in many cases, despair as a result of past failures. Cuban (1990) provides a sense of this state of affairs but also suggests a way to move beyond the situation:

> It is important to policy-makers, practitioners, administrators, and researchers to understand why reforms return but seldom substantially alter the regularities of schooling. The risks involved with a lack of understanding include pursuing problems with mismatched solutions, spending energies needlessly, and accumulating despair. The existing tools of understanding are no more than inadequate metaphors that pinch-hit for hard thinking. We can do better by gathering data on particular reforms and tracing their life history in particular classrooms, schools districts, and regions. (p. 11-12)

An important contribution, in the direction that Cuban suggests, to educational change studies is emerging in the work of those who are researching teacher culture. Not only does it provide a new focus in the study of educational change but it also complements the insights that many of those more directly interested in educational reform have been writing about.

Teacher Culture, Subject Communities, and Change

Sarason (1990) attributes much of the lack of success in educational reform to the fact that those who have power in policy-making arenas have little appreciation for, or knowledge of, the systems they are trying to change. Even research focusing on change at the classroom level is beginning to try to account for the influence of the larger system. Calls are being made to expand the scope of study to include district, school, and classroom organization as factors in change (Cuban, 1995; Magnusson & Palincsar, 1995). This trend opens up the possibility of developing new approaches to working for change in education, but there is still more that can be learned from other parts of the educational literature where the interrelation between teaching and the culture in which it is embedded is the central focus.

Over the past two decades there has been a great deal of reference in the educational literature to school cultures, teaching cultures, and subject communities (e.g. Hargreaves, 1989; 1994; Lacey, 1977; Werner, 1991). Although the cultural unit has varied in this body of work, they all involve a network of strategies developed by a group or community sharing a common purpose. Hargreaves (1994) provides a description of what is meant by teacher cultures:

> In general, these various cultures provide a context in which particular strategies of teaching are developed, sustained and preferred over time. In this sense, *cultures of teaching* comprise beliefs, values, habits, and assumed ways of doing things among communities of teachers who have had to deal with similar demands and constraints over many years. Culture carries the community's historically generated and collectively shared solutions to its new and inexperienced membership. (p. 165, emphasis in original)

Hargreaves provides a sense of how teacher cultures serve as a frame of reference for practicing teachers and at the same time provide community norms into which new teachers are socialized. One of the most important cultural influences on teachers at the secondary level is that associated with the subject community (Goodson, 1993; Lacey, 1977; Little, 1995a; Siskin, 1994). Before entering teacher education, most teachers were successful students in school and, particularly in the case of secondary teachers, this success was often associated with a specific subject area. The teacher training that secondary teachers received also would have emphasized their subject specialty and this would have been followed up by a socialization into the school system that was organized by subject or discipline-centered departments (Hargreaves, 1989). The subject community or academic department that secondary teachers are socialized into involves more than just an association with a certain disciplinary content or subject matter, it also provides the professional community in which teachers become members. Teachers frequently become part of a socially cohesive community that provides support for members and a network for discussing content and sharing pedagogic strategies (Siskin, 1994).

Teachers often form their strongest bonds with members of their subject group and the differences between teachers from different subject groups can frequently result in a lack of communication or affiliation. In discussing the teachers from differing subject communities that she studied, Siskin (1994) comments:

> By virtue of the subjects they teach, these teachers bring distinct perspectives, procedures, values, and discourses of their fields into the school—and sometimes into conflict. Intellectually and professionally, as well as socially, they inhabit quite different worlds. What is evident from examining the differences among these subject cultures is that in many ways teachers have more in common with geographically distant colleagues in the same subject than they do with colleagues in the same school but an intellectually distinct department. As subject specialists, they share a sense of who they are, what they do, and what they need to do it. (p. 180)

Teachers also have an interest in the maintenance of the department as it is the unit through which they engage in political struggles within the school. It is in these struggles that teachers seek and obtain resources as well as define and maintain subject boundaries (Goodson, 1993; Siskin, 1994). The dual role of the subject department—as a community into which the teachers are socialized and a central instrument through which they maintain their practice—demonstrates why teachers identify strongly with their departments and maintain the department through their practice. The claim that comes out of much of this literature is that the "*subject* is not merely the stuff of curriculum, texts, and tests; it is more fundamentally a part of being a teacher" (Little, 1995a, p. 184, emphasis in original). Siskin (1994) points out that subjects are not "labels that can be peeled off" (p. 184) but, rather, they are fundamentally experienced by teachers as identities.

Understanding secondary teachers as being participants in subject communities and as having acquired identities has important implications for educational change initiatives. Efforts to change education often challenge departmental boundaries and this brings the other side of the subject department coin to the forefront. Subject areas do not only provide a professional identity for teachers, they also result in the construction of boundaries. These boundaries act positively to let teachers know what the subject area is, but they also tell them what the subject area is not. "Just as teachers make assertions about what is and what is not *the subject* they also make assertions about who they are, and are not, as teachers" (Little, 1995a, p. 186, emphasis in original). Based on her extensive research into the influence of subject communities and the way teachers experience divisions between subject areas, Little (1995b) writes:

> Teachers experience such separations—especially the departmental divisions of most high schools—not only as matters of structure but also in terms of the goals they espouse, the sense of identity they acquire, the student clientele to which they respond, and the professional communities in which they participate. (p. 58)

Not all educational change initiatives attempt to overcome subject boundaries. Some initiatives leave the subject structure of schools in place but call for more homework, more instructional time, more tests, and so on. The change initiatives that do challenge subject boundaries face greater challenges, particularly when they run up against some of the more pronounced boundaries.

Many researchers have explored the differences between the, so called, "academic" and "vocational" subject areas in schools (e.g. Hargreaves & Macmillan, 1995; Lewis, 1994), and, in doing so, have been able to expose one of the greatest challenges that courses that try to bridge this gap face. Academic subject areas are those which are thought of as university preparatory such as science, mathematics, and English while vocational subject areas are those which focus on occupational or domestic contexts such as technology studies, home economics, and business studies. The divide between these areas has led researchers such as Siskin (1994) and Little (1995b) to use the term *two worlds* to describe them. Lewis (1994) demonstrates the vast gap between the two worlds in his account of the historical and philosophical debates that separate the two. The two worlds differ most obviously around issues of status, with the academic subjects being seen as the route for the brightest and the best students to move into high status pursuits in the future. As for the vocational subjects, despite their apparent relevance and importance for *all* students, they remain unchosen by university bound students and are often put in the position of being marginalized and of fighting for their very survival in the face of school budget cuts (Hargreaves & Macmillan, 1995). These two subject areas differ in political power and physical location within the school and are often in competition over symbolic, human, and material resources (Hargreaves & Macmillan, 1995). When the subject areas find themselves in competition, the academic departments invariably win out. One of the greatest barriers to bridging these two areas has been the strength of the academic departments who are able resist and act as a barrier to subject integration in the name of subject integrity (Little, 1993).

This research on the differences between subject cultures tends to support the notion that departmental boundaries are frequently looked upon as a "problem" in bringing about educational change (Fullan, 1991). Little (1995b) warns that difficulty is likely in attempts to bridge the two worlds: "It would be a mistake to underestimate the power and persistence of these two worlds, and their significance for teachers, students, and parents" (p. 58). Similarly, Siskin (1994) adds that "efforts which aim at restructuring [or changing subject departments], without attending to the firmly entrenched identities of subject specialists, risk unexpected conflict and resistance" (p. 10) while Huberman (1993) describes the tendency in educational research to neglect the influence of the subject department as "goofy logic". The subject culture literature provides an important perspective upon why it is difficult to introduce new courses and, in the next section, I will show why this is particularly useful in considering some of the changes that are being attempted in science education.

Science-Technology-Society Education

As is the case with many subject areas science education has frequently been subject to demands for reform. Some of these demands aim at the intensification of science education (e.g. more time in class, more frequent testing) but many others have to do with the development of "science for living" or a type of science education that links the science content with content from other traditional curriculum areas. The most recent attempt has been the broad movement advocating science-technology-society education or STS. In general, STS is concerned with establishing inter-relationships between science, technology, society and, often, the environment but, in practice, STS is a broad umbrella for a wide variety of approaches. As various writers such as Solomon (1993), Layton (1994), Ziman (1994) and Hepburn (1993) point out, STS has many approaches which include: (1) the cultural approach in which the nature of science and technology are explored along with their relation to society; (2) the political action approach in which future citizens are educated to take appropriate action on controversial issues involving science and technology; (3) the issue-based approach where specific contemporary and controversial problems that are interdisciplinary in nature are explored; and (4) the vocational approach where students are prepared to participate effectively and critically in vocations that require a background in science and technology. In the vocational approach, the societal component comes about from attempts to situate science and technology related knowledge and skills in societal activities. This array of approaches that fall under the label STS are being advocated by a number of groups including university based researchers/teachers, environmental groups, and employers. In policy arenas, there has been some interest in STS and in a move away from disciplinary science as a result of the *science for all* movement which has surfaced in various countries (Fensham, 1985). The development of this movement has been aided by conditions such as concern about falling student enrollments in science, an increasing awareness of the social nature of science and technology, greater awareness of the relationship between science and technology education and economic development, and concern about environmental problems (Aikenhead, 1994b).

One of the questions that remains underappreciated in the STS literature is the extent to which it has been successful in being initiated into schools. Many cases of successful STS programs have been highlighted by STS advocates (e.g. Solomon, 1993), but there are still questions about the general receptiveness of teachers to STS courses. Aikenhead (1994a) points out that many teachers are worried about students missing out on science content when an STS approach is taken, while Fensham and Corrigan (1994) comment that it is harder to convince teachers that STS content is worth teaching than it is to establish new strategies for improving traditional science instruction. Bybee's (1991) review of research on the extent to which STS is incorporated into classroom instruction demonstrates that success in this area has been limited and there are still many barriers to overcome if STS is to avoid becoming "a passing fad" (p. 300). Bybee's summary highlights questions that are crucial for those interested in STS to address: What are the barriers to initiating STS in the classroom and what occurs in attempts to initiate STS courses?

Although there has been little research done on the process of initiating STS courses, Gaskell (1989) has made an important contribution in his study of the introduction of a new STS course to high schools in British Columbia. Science teachers in the province were not supportive of the course because they did not see it as "real science". In general, science teachers and teachers from other areas tended to avoid the course in favor their own specialties. Gaskell attributed this lack of support for the new STS course to its failure to develop an identifiable community of teachers to argue for, support, and teach it. Recognizing the strength of the communities that science teachers already belonged to and the commitments that this implied, such as commitments to exams and university preparation, he explained their resistance as "rational decisions about the way to act based on their perception of their own and their pupils' best interests" (1989, p. 271). Gaskell's work begins to position subject communities as a central entity in understanding the introduction of this STS course in a way that resonates with the subject community literature. As the subject community literature suggests, courses like this STS course which cross subject boundaries are bound to encounter problems because they also challenge teachers' identities and community interests. This is particularly true where the boundaries crossed correspond to the academic-vocational divide as is the case with many STS courses.

There is a clear need to continue with the sort of research that Gaskell has initiated in the area of educational change in STS education, and this corresponds with the new directions that are emerging in the more general educational change literature. Recalling Cuban's call for "gathering data on particular reforms and tracing their life history in particular classrooms, schools, districts, and regions" (1990, p. 12) as well as other recommendations for including more about organizational structure and teacher culture in these studies, it would seem that a direction for research is indicated. A challenge that remains is establishing a powerful theoretical basis for studying educational change in STS that situates change at the classroom level within its social, cultural, and institutional context. In the next chapter, I develop the theoretical framework that is used in this study. This framework provides a new way of studying educational change that takes into account many of the requirements that are highlighted in this chapter.

Chapter 3

Educational Change in Actor-Networks

Valuable as they have been in exposing many issues that must be taken into account in educational change studies, the perspectives on educational change discussed in the last chapter seem to be lacking in their ability to provide an adequate theoretical basis from which to proceed. While the technical perspective does theorize how change occurs, it separates those within the classroom, who are to be changed, from those outside, who usually decide upon the changes to be made. The teacher culture or subject community literature points to the inseparability of the teacher and the system within which they work and suggests why change is difficult to achieve, but it is unable to suggest how change can occur. In this chapter, I draw upon two theoretical perspectives that have rarely, if ever, been used to explore educational change. As I do this, I begin to map out the theoretical perspective I use in this study.

Sociocultural theory

Sociocultural theory moves beyond simply recognizing the influence of group culture on the actions of the individuals who participate in the group. This position emphasizes that human action is situated in the context within which it occurs and cannot be separated from it if the action is to be understood. Analysis, then, must take into account *both* the acting individual(s) *and* the activity setting(s) within which they are acting (Lave & Wenger, 1991; Wertsch, 1991).

Both of these elements are accounted for within the concept of the *community of practice* (Lave & Wenger, 1991). A community of practice is usually taken to refer to an identifiable group within which there are general ways that participants relate to each other and do things, ways that everyone in the group either is or is becoming familiar with. These communities of practice can be professional groups or other groups that have developed historical means of participating in a particular activity. Examples of communities of practice that have been researched are tailors (Lave & Wenger, 1991), navigators (Hutchins, 1993), midwives (Jordon, 1989), and construction workers (Carraher, 1986). As the subject community research discussed in the previous chapter indicates, teachers also work within communities of practice and it is this interconnectedness between the acting teacher and the community she or he works within that sociocultural research assumes.

Communities of practice consist of groups of practitioners who share similar goals and ways of achieving them. The knowledge, tools, values, and ways of interacting associated with that community become mediational means because they are the means by which communities carry out their activity (Wertsch, 1991). Coming to be a full practitioner entails coming to share, at least to some extent, the goals and mediational means of the community. The movement of a participant in a community of practice towards becoming a full participant is not so much a change within the individual as it is a change in the individual's relationship to the community's activities and with the social group.

> As an aspect of social practice, learning involves the whole person; it implies not only a relation to specific activities, but a relation to social

> communities—it implies becoming a full participant, a member, a kind of person. . . . Activities, tasks, functions, and understandings do not exist in isolation; they are part of broader systems of relations in which they have meaning. These systems of relations arise out of and are reproduced and developed within social communities, which are in part systems of relations among persons. (Lave & Wenger, 1991, p. 53)

Participation in communities also involves the development of identities—that is, how individuals view and understand themselves and also how they are viewed and understood by others (Giddens, 1979)—because participation, in part, involves defining relations between persons (Lave & Wenger, 1991). The community of practice is a type of activity and a social system that both acquires persons and is acquired by the persons.

Much of the sociocultural research and scholarship related to education focuses either on the ways that newcomers are socialized into a community of practice (e.g. Rogoff, 1993) or the ways that the actions of community members are mediated by and tied to the mediational means of the community (e.g. Saxe, 1988). This work contributes to an understanding of the inseparability of the acting agent and the community they are participating in as well as the ways that communities reproduce themselves by acquiring new members. An additional facet of sociocultural theory that has received less attention is the way that new community practices are produced. Lave (1988) highlights both the reproductive and productive functions of communities by incorporating a theory of practice. A theory of practice gives primacy to neither the human agent nor the community in which they participate (Giddens, 1979), but instead considers there to be a dialectical synthesis in which both factors are constitutive of practice (Lave, 1988; Ortner, 1984). A theory of practice takes seriously the role of human action in producing sociocultural communities of practice. As agents act in ways that are outside the usual ways that practice is carried out in their communities, they have the potential to contribute to a re-definition of what it means to practice within the community. This new practice may take the form of new ways of accomplishing the same goals, or it may even involve contesting the goals of the community. Contesting community norms, however, is a complex process as many other considerations come into play, such as the varying influence of different practitioners and the strategies that individuals use to effect change. For an individual or group to bring about change in a community, a degree of negotiation is required so that they can both act differently and still be part of the community of practice upon which their identity is based. The practice perspective makes processes of change and resistance to change central questions and avoids simply trying to develop a description of a static sociocultural community which masks the roles of individuals who participate in both reproducing and producing the community.

In this research, I focus upon the way that a member of a community of practice produces new practices. Changing participation in communities involves developing a new identity but there is an important difference between identity construction for newcomers to a community and for more experienced participants who produce new practices. The sorts of relationships that characterize participants in particular sociohistorical communities pre-determine the general sort of identity a newcomer will develop. This is not the case, however, when new practices are being developed. In these cases, new relationships must be negotiated, ones that are not already set out by the historical community. This is where the community as a unit of analysis appears to be less useful. These new relationships could only arise as a result of an outward movement away from the relationships that are associated with central practice within the community. The larger social world beyond the community must be included in the analysis to account for these new relationships. Critics of Lave and Wenger's community focus, such as Nespor (1994), have claimed that they neglect the larger social world in their work but, to be fair, it should be noted that they do comment on its importance at several points (e.g. Lave & Wenger, 1991, p. 98). Lave and Wenger, like many other sociocultural theorists such as Rogoff (1993), tend to concentrate on the reproduction of communities of practice and, in doing so, have less need to account for the larger social world. It is when the focus is placed upon the production of the new practices that the need to account for the world beyond the community becomes most apparent. Actor-network theory provides a way of doing this that enables some of the important contributions of sociocultural theory to remain in place and, at the same time, allows the limitations created by the bounded community focus to be overcome.

Actor-network theory

Actor-network theory provides a resource that can be used to study educational questions in a way that, like sociocultural theory, emphasizes relational aspects of activity, but it is also able to move beyond the bounds of the community. Actor-network theory has primarily been used by researchers working outside education, but a few inroads into educational research have been made. Several researchers (e.g. Callon, 1986; Latour, 1987) who are working in the area of the sociology of science and technology have been using actor-network theory to study the relations between various actors that become linked together in technoscientific projects. This theoretical position has been used in the area of curriculum studies by Nespor (1994) as he investigated how the disciplinary areas of physics and management are structured in a way that allows them to initiate new students into the discipline. Fountain (1995) has also used the theoretical stance as a way of investigating student discourse with regard to socioscientific issues. The varying contexts in which these researchers have used actor-network theory illustrates its potential to make contributions to diverse research foci, including studies in education. The use of actor-network theory also entails some important departures from other approaches that have been taken in sociological research and I will discuss some of these below.

Networks

Actor-networks are constructions in which actors link themselves with other human and nonhuman actors. The linking occurs as projects are undertaken in efforts to have some kind of *token* accepted or established. I am using the term token to describe the aim of a project. In Latour's work, for example, the token could be a scientific fact or technological artifact that scientists or engineers are trying to put forth and gain wide spread acceptance for. In this research, the token that was being put forth was a new applied physics course that required the support of many different groups if it was to be accepted as a credible component of high school course offerings. For these projects to be successful, they require the involvement of a diversity of actors that must act together in support of the project. These actors become linked together in the project and constitute the network. The particular actors involved in the network, as well as the nature of the links between them, will vary from project to project. An example will help to illustrate what actor networks are as well as some important concepts that are related to them.

In his recent book *Aramis or the Love of Technology*, Bruno Latour (1996) investigates the failed development of a new guided transportation system in Paris. He shows that for this project to be undertaken, networks of support had to be constructed. These networks contain both human and nonhuman actors who had to be enrolled into the project as supporters of the work that was being done. In this excerpt, Latour describes the network that was being drawn together in the project to develop the transportation system as well as the fragile interdependence of the linkages between the actors.

> 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. (1996, p. 58)

The actors that must be linked in the network of the project Latour describes range from the technological artifacts that will become part of the train, to the customers and politicians who must support the project if it is to continue. Managing a project like this requires actors who have a strong interest in the success of the project to become network builders so that the other actors whose participation is required can be convinced to participate in the network. Actors must be *enrolled* into the project and *mobilized* in such a way that allows the project to go ahead. To enroll actors, their interests must be *translated* by the network builders so that they become consistent with the goals of the project. Actor-network theory concentrates on the process of building and maintaining networks; it is a "study of methods of association" (Latour, 1986, p. 264) and looks upon the linkages between actors in a network as "ongoing accomplishments" (Nespor, 1994, p. 12).

One aspect of actor network theory that is immediately apparent is that it groups human and nonhuman actors together in the analysis and treats them in a similar way. In doing this, a division that Latour associates with modernity is challenged. In the excerpt below Latour describes two sets of practices: one that is illustrated in actor-network theory and another that is characteristic of modernity.

> The first set of practices, by *translation*, creates mixtures between entirely new types of beings, hybrids of nature and culture. The second, by *purification*, creates two entirely distinct ontological zones: that of human beings on the one hand; and that of nonhumans on the other. . . . The first set corresponds to what I call networks; the second to what I call the

> modern critical stance. The first [when discussing the depletion of the ozone layer], for example, would link in one continuous chain the chemistry of the upper atmosphere, scientific and industrial strategies, the preoccupations of heads of state, the anxieties of ecologists; the second would establish a partition between the natural world that has always been there, a society with predictable and stable interests and stakes, and a discourse that is independent of both reference and society. (Latour, 1991, pp. 10-11)

Latour and his colleagues use practices of translation in their research to avoid the limitations of accounts of technoscientific projects that result from treating nature and culture separately. Latour (1986; 1987) describes researchers who keep nature and culture separate as they attempt to explain projects aimed at producing a token as subscribing to a *diffusion* model. In a diffusion model, the token is endowed with an inner force and is governed by a principle similar to that of inertia in physics. Just as the principle of inertia would apply to a mass, once the token is put in motion it will continue to move unless it encounters an obstacle. Examples of tokens are found in accounts of "technological progress" which is frequently explained using a diffusion model. New technologies are given a sort of force that sets them in motion towards general acceptance and use. From this deterministic perspective, people who resist or slow the spread of new technologies are characterized as being backwards thinking or closed minded. A societal or cultural explanation is used to explain resistance to new technologies, but is not required to explain technologies that are faithfully adopted. (Note that the successful or unsuccessful introduction of new courses into schools has often been explained in similar terms.) This asymmetrical explanation of successful and unsuccessful technological projects results in a distorted view that cannot account for how technologies, especially successful ones, are shaped by people. The natural or nonhuman side of the explanation is treated separately from the cultural or human side. A translation model overcomes this asymmetry and results in a more balanced account that recognizes the ways that token promoting projects involve hybrid mixtures of human and nonhuman elements.

A *translation* model does not endow the token itself with motion or force. From this perspective a token moves in the hands of people who actively transform, reject, deflect, or appropriate it (Latour, 1986; 1987). Rather than only involving human elements to explain problems, as the diffusion model does, it is the relationships that are formed in mixtures of people and things that need to be explained if the fate of any particular token is to be understood. Even if the rare case appears in which people accept a token without changing it, this too needs to be explained. As the token moves through different hands, networks that join human and nonhuman actors are constructed. Researchers who are interested in the plight of the token must examine the nature of the associations between the actors that make up the network. Rather than treating the various actors in the network differently for the purposes of analysis, a common language to describe associations between the actors, no matter what type they may be, is used (Callon, 1986). The language of translation is used to do this and, shortly, I will set out the specific terms that I will be using in this study.

In addition to the symmetrical treatment of human and nonhuman actors, actor-network theory takes a very different ontological stance than many other sociological studies. Latour (1986; 1996) describes the approach most often taken in "classical sociology" as an *ostensive* one, where the sociologist stands outside society and seeks to determine its nature once and for all. The classical sociologist uses the actors as informants yet knows more that they do. A metalanguage is used to explain the actions and perspectives of the informants involving such concepts as classes, roles, cultures, and goals. The classical sociologist is caught in the contradictory space of being inside the society she or he is explaining and, at the same time locating themselves outside it to construct the explanation. In an attempt to minimize this contradiction, methodological precautions are taken to escape the inescapable. Latour (1996) acknowledges the value and accomplishments of classical sociology but also points out its limitation in studying projects that are aimed at bringing a token into existence. These projects "go too fast" (p. 200) and society shifts as networks are formed and new relationships are negotiated. Instead of providing a basis for explaining the projects, society is made through these projects and their local practices of network building—society is an effect rather than a cause of the project.

Actor network-theory is able to account for these projects and the construction of networks by taking a *performative* approach which relies on a relative or relational sociology (Latour, 1986, 1996). Relational sociologists do not know what society is made of and depend upon the actors to show them as it is constructed through the actors' projects. Relational sociology does not hold a privileged interpretive position in relation to the actors it studies as the actors are the ones who are making society through their actions. By mapping associations that are made as networks are constructed, the relational sociologist tries to account for a society of human and nonhuman actors as it is being performed. Relational sociology "adds its own interpretations to those of the actors whose fate it shares" as it, too, tries to construct a stable network around its version of the project. Actor-network theory, and the performative approach it assumes, provides an effective way of studying projects that involve the construction of networks to advance new tokens, be they scientific facts, technological artifacts, or high school courses.

Studying networks

A necessity in using actor-network theory to study projects is to capture the process of network construction. In his work, Latour tends to focus on projects that involve network building to support the development of new scientific facts or technological artifacts. He has normally looked retrospectively at *science and technology in the making* by either exploring how successful projects managed to construct stable networks (e.g. 1988) or by looking at how failed projects were unsuccessful in their efforts to do this (e.g. 1996). Nespor (1994) takes a different tact in his research on the disciplinary areas of physics and management. He is not looking at *disciplines in the making* in the same sense that Latour studies the establishment of new tokens in technoscience but he does, nonetheless, capture the reproduction (or re-making) of the disciplines. Disciplinary areas are relatively stable networks that are already in existence. Unlike scientific facts, which are relatively maintenance free once the relevant people have been convinced they are credible, disciplinary areas require maintenance. Nespor captures disciplines in the re-making by focusing on the initiation of new participants or students into the disciplinary areas. This is done through mobilizations of actors that are already within the networks (e.g. teachers and textbooks) and by translating the interests of the students so that they become consistent with those held in the disciplinary network. While Latour's networks are constructed by network builders, Nespor's sociohistorical networks are maintained, renewed, and, sometimes, transformed by those participating in the network.

Although Nespor manages to find a point of network construction in an otherwise stable network, the nature of the linkages that make up stable networks of, for example, established facts, artifacts, or courses are normally hard to see. These networks become what Latour (1987) calls *black boxes*: the uncontroversial and generally accepted tokens that are the result of successful network construction. When the black box forms, it is as if it exists on its own, rendering the network somewhat invisible. The networks fall out of sight largely because they are no longer being openly constructed, often making it appear as if there never was a network formed in the process of completing the successful project. The problem with looking at established tokens to learn about how they became that way is that they frequently do not reflect the process that made them that way. This is why in actor-network theory the *token in the making* is the focus. In this research, the focus is the *course in the making*.

Analytical concepts

In this research, I describe a project aimed at introducing a new course into the school system by using actor-network theory and some elements taken from sociocultural theory. A few terms that others who use these theoretical positions have used, and that I have used above, will be utilized in the analysis, so I will take a moment to review them here. Because *communities* have been rather central in the subject community/teacher culture literature, I will employ the concept of community that I discussed earlier. Rather than assuming to know how communities work though, I will explore how they are performed during the period of data collection. Another important concept that is used in both the sociocultural and actor-network literature that I will use in this research is that of *identity*. Lave and Wenger (1991) use identity to describe relationships within communities in a useful way and Nespor (1994) suggests that the notion of identity is also important to describe relationships that extend beyond the bounds of the community. Callon (1987) points out that identities can be shifted at any time as relationships are redefined or new elements, human or nonhuman, are brought into the network. Actor-network theory provides a powerful basis for investigating the shifting of identities as a process of network construction.

As discussed above, the network construction that is the focus of actor-network theory involves linking human and nonhuman actors. The problem with the term *actor* is that it is commonly used in reference to humans while not usually being seen as applicable to nonhumans. I use the term to refer to *both* human *and* nonhuman participants in the network and remind the reader of this at several points through the analysis. As network builders construct or maintain the networks in which they participate, several strategies are employed. One of these is the *enrollment* of other actors. Actors are enrolled as they are woven into the actor-network (Nespor, 1994). Enrollments are accomplished through a process of *translation* where the interests of actors that are to be enrolled are interpreted by network builders in a way that makes the actors' interests consistent with the interests of the network (Latour, 1996). The network builders try to reconcile the interests of the actors they want to enroll with those of the network by convincing the enrollees that they should adopt the position of the network and/or by changing the position of the network to make it more like that of the enrollee. As network builders enroll actors, they are also engaging in the process of *mobilization*. Mobilization refers to "making a maximal number of allies act as a single whole in one place" (Latour, 1987, p. 172) and in support of the positions of the network. These terms will provide some basic concepts that are used in this research to discuss the actor-networks that are created in the attempt to introduce a new applied physics course into schools.

A framework for studying educational change

Latour's work demonstrates the value of actor-network theory for explaining how technoscientific innovation occurs. One of his emphases is to demonstrate that science and technology are social activities and research that attempts to keep the social aspect separate leads to a distorted perspective of the activities. Actor-network theory allows Latour to present a view of science and technology which highlights the work of network builders who weave networks of humans and nonhumans together. The theoretical position allows him to overcome some of the separations that have led to a limited appreciation for how technoscientific developments take place. In education, separations between groups such as teachers and policy-makers as well as between these groups and objects, like textbooks, have been a limitation of theories of educational change. The use of actor-network theory will allow many of these separations to be overcome while clearly maintaining a focus on how change does occur. The addition of the concept of sociocultural communities of practice will allow a further emphasis on the ways that communities of practitioners deal with change and what it means for communities to change. These communities, though, will be located within the larger social world where individual and community identities are forged as new community practices are produced. This theoretical framework will facilitate the study of change in science and technology education and will provide a better understanding of how it occurs. This understanding is not so much intended to help particular groups control educational change but rather to help diverse groups learn to effectively participate in the process.

Chapter 4

Methodology

This study utilized an ethnographic methodology designed to explore the actor-networks that were constructed around a new applied physics course during a pilot project that was sponsored by the British Columbia Ministry of Education. This chapter begins by providing background on the general strategy employed in the research as well as an account of how access to the research site was negotiated and how data were collected. I then describe the transformations that took place during data analysis before moving on to discuss the value of the long term engagement that characterized this research.

The Study

Just as Latour (1987) took on the task of following scientists and engineers as technoscience was being made in order to develop an account of the network(s) that they were creating, I followed a teacher of a new applied physics course as it was being piloted. In doing so, I sought to develop an account of the network in which the teacher participated. As a secondary yet closely related focus, I followed the applied physics course from the initial discussions of developing such a course to its actualization in the classroom in order to explore the network that was constructed around the provincial pilot of the course. Accounting for these overlapping networks meant that I had to identify other actors that maintained a connection to the teacher and/or the piloting initiative as the new course was piloted and to investigate the nature of these associations. This was done by developing a description of which actors were enrolled into the pilot project, what the actors' interests were, how these interests were translated into the positions of the network, and how the actors were mobilized in the network. This strategy of tracing the construction of actor-networks recognizes the socially constructed nature of the networks and, therefore, a qualitative research approach was adopted (Denzin & Lincoln, 1994).

Negotiation of access and data collection

The first of the two foci of this research involved an exploration of the network a teacher was working as he planned and taught a pilot of the applied physics course. The purpose of following the teacher was to learn about the network by finding out about who the actors were and what the relationships were between them. This part of the research was conducted at a school that I will refer to as Lower Mainland Senior Secondary, or LMSS. The school based part of the research involved interaction over one full school year with the teacher of the pilot course and with others from the school. When I first contacted the teacher, who I will call Gordon, about doing this research, he immediately indicated a willingness to allow me into his classroom. He was open to having me spend between one to three days a week in his class and to allowing me to conduct interviews with him regarding the progression of the course at several points throughout the school year. Gordon had taught physics at the school for sixteen years, but he had no previous experience with applied science or technology education. For this reason, we were both aware that he had a great deal of work ahead of him in preparing the course for use in the classroom. Because of my own science teaching background and my graduate work in science and technology education, I felt that I could be of assistance to him in the preparation of the course. I offered this assistance to Gordon and he accepted, indicating that any help I could give him would be appreciated. The assistance I gave him over the school year primarily involved helping him to prepare student activities such as labs, but occasionally involved assisting him in the classroom. The help that I did give him was in the form of assistance rather than giving him advice on how the course should be taught. All instructional decisions were made by Gordon.

During the year I spent in Gordon's classroom, he agreed to let me observe, take fieldnotes in, and audio-record the applied physics classes. The discussions that I had with Gordon about the classes and the course in general were also audio-recorded. Gordon also consented to several formal interviews for the purposes of collecting background information and talking with him about issues that emerged as the research progressed. In addition, Gordon provided me with some copies of the print materials and lesson plans he used for the course. From time to time during the school year, Gordon met with teachers and others who were interested in the applied physics course. I attended these meetings and took fieldnotes and/or audio-recorded them.

There were many other people, such as students and school administrators, who were involved with the applied physics course at LMSS in some way. After gaining their consent, I interviewed many of these participants. I also collected documentation relating to the opinions and/or the involvement of some of these groups.

All of the data sources referred to above along with the form the data were collected in is summarized in Table 1.

Table 1. Data sources and the form of the data collected

data source	form of data collected
teacher	• audio-recordings of teacher-researcher conversations • fieldnotes concerning teacher-researcher conversations • audio-recorded interviews concerning research issues • copies of teacher's lesson and course plans • copies of teacher-produced course materials • audio-recordings and/or fieldnotes of presentations or meetings with to other teachers
classes	• audio-recordings of the classes • fieldnotes taken during the class and reflective notes made afterwards
students	• audio-recorded interviews
school administrators	• audio-recorded interviews
others with a connection to the course	• audio-recorded interviews • documents related to provincial pilots of the course

In the analysis section, I will be referring to data collected from the sources listed above. When I do so, I will use a letter to designate the data type and follow this with the date the data were collected. This designation system is outlined in Table 2.

Table 2. Data designation in references

data type	designation	reference format	example reference
interview	I	[I-yy-mm-dd]	[I-95-02-25]
conversation	C	[C-yy-mm-dd]	[C-95-02-25]
fieldnotes	F	[F-yy-mm-dd]	[F-95-02-25]
presentations	P	[P-yy-mm-dd]	[P-95-02-25]

The second focus of my data collection strategy was developing a description of the network that was constructed around the provincial piloting initiative for the applied physics course. Rather than concentrating only on how the local network developed around the course at a school, this part of the analysis follows the course from the point at which it was conceptualized at the provincial level to the point that it was enacted in Gordon's classroom. Before the course came to LMSS, the data consisted mainly of a document trail which I was able to gain access to because most of these were in the public domain. In situations where the documents were not readily available to the public, I obtained the documents from the particular groups involved after gaining their permission. Where the people from LMSS are involved, data were drawn from the same sources that I used for the first research focus as described above. The LMSS data will be designated in the same way that was described in Table 2.

Data Analysis

The units of analysis were the networks that were constructed at the school and provincial levels. Although these networks both involve to what may, at first glance, appear to be the same token—the applied physics course—differences in the networks lead to different versions of that token or, simply, different tokens. The analysis will develop a description of the two networks as well as explore any relation that exists between them.

The process of moving from raw data towards an account of actor-networks, was accomplished through several steps of data transformation and reduction that were similar to those used in other research aimed at describing actor-networks (e.g. Latour, 1996). Three general phases of transformation were used in the development of the account: the production of transcripts and fieldnotes, linkage analysis, and linkage articulation.

With the exception of the data that were already in print format, the data were in the form of audiotapes or hand-written field notes. The audiotapes of interviews, conversations, classes, and presentations were transcribed verbatim with only minor editorial changes made to improve the readability. As close to the time that they were taken as possible, the handwritten fieldnotes were typed in a more organized and focused format. In addition to the typed version of the fieldnotes, analytical memos were created from time to time which were notes about emerging themes and events that helped me identify issues that needed to be followed up at some point.

The next step of data transformation was linkage analysis. Linkage analysis involved identifying the human or nonhuman actors that were participating in the networks. Where the local LMSS network was concerned, this meant using the original data to determine which other actors had some connection to what the teacher was doing as he planned and taught the course. With respect to the provincial piloting initiative, linkage analysis involved determining which groups were involved with the initiation and piloting of the applied physics course at various points along its development. This step was partly carried out during the data collection because it had implications for further data collection, but it was also carried out once data collection was completed.

The final phase, linkage articulation, involved describing the nature of the linkages that were identified in the second transformation. A linkage was an indication that a particular actor had been enrolled but matters of mobilization and translation still remained to be described. This phase involved using available data to describe the linkage and/or collecting additional data when possible.

Locating the Researcher

In this brief account of my own involvement in this research, I will provide a sense of how the research ended up taking the shape that it did. I came to the research with particular interests and commitments which shaped my choice of topic and approach. I made other choices as the research progressed which also contributed to the research account that I am reporting in this dissertation.

I came to this research with experience teaching science. I had taught science at the senior secondary level for eight years and was very familiar with how traditional discipline-based science courses, such as chemistry and physics, were approached in schools. In my graduate studies I became interested in how discipline-based science courses could begin to emphasize the interrelationships between the scientific subject matter, technology, and society. It was my commitment to exploring the introduction of STS courses into classrooms and how these courses impact on student learning that led me to pursue this research. After hearing that a teacher in a local school was going to be piloting a new applied physics course, I arranged to be present in his classroom on the first day he met with students. It was apparent from the outset that Gordon's transition from physics teaching to applied physics teaching was going to be complicated. At times, it was difficult to see how the applied physics course was different than Physics 11 although Gordon appeared to be open to and interested in the idea of emphasizing applications. After attending the first few applied physics classes, I decided to focus my research on the development of the new course in the classroom. Because Gordon's classroom was my entry point into the research setting and because he was centrally involved in the introduction of the course into the classroom, I decided to concentrate on Gordon's role in introducing the new course. It was by exploring Gordon's role that the role of others involved in the introduction of the new course, such as the technology education department head, become visible.

At the beginning of the research, I used sociocultural theory in order to explore the way in which Gordon changed his practices within the physics teaching community from ones that were consistent with the historical practices of the community towards ones that were new to the community. As I began to develop the research story, though, it become apparent that the role of other actors who were located outside the physics teaching community, such as school administrators and the Ministry of Education, had to be accounted for if Gordon's approach to the new course was to be understood. Sociocultural theory was not very useful in articulating the involvement of groups beyond the bounds of the community so I began to search for an additional theoretical perspective. Actor-network theory allowed me to produce a relational account of the way in which the new course developed at the school and at the provincial level. Gordon was re-situated as someone who was *working the network* and, as Bruno Latour does in his work, my task became one of following a particular actor in the network in order to gain a perspective on which actors were included in the network and what the relationship between them were. Focusing on the relationships that constituted the network is different than focusing on the dispositions of Gordon himself. Consistent with Latour's (1996) approaches the task of following actors, in this research Gordon was neither a hero nor a villain, neither guilty nor innocent, neither a resistor nor a radical innovator. Gordon was working towards a particular sort of goal and the network he constructed to do this is the focus of the research.

My involvement with Gordon and other actors during the data collection period was an important aspect of the research. From the theoretical perspective the research employs, I was enrolled into the network. My interests were easy for Gordon to translate: by letting me do my research, I agreed to support his work. In supporting him, though, I did not attempt to direct his approach to the course. Instead, I tried to facilitate his efforts by assisting him as he worked out the lab program and by offering support at times when he attempted to emphasize applications. Occasionally, when we met with other teachers who were interested in the course, Gordon appeared to highlight my—a university-based researcher and science educator—involvement to bring greater credibility to his version of the applied physics course. Overall, I was mobilized in a rather peripheral way compared to the positioning of other actors.

Engagement in the Research Setting

The partnership that I established with the teacher, the primary focus of the study, was initiated largely on ethical grounds. I was uncomfortable being present in the classroom only as an observer when I was aware that he was going to have a difficult time preparing and teaching the new course. I felt a sense of relief when Gordon immediately agreed to a partnership, because I felt that I could compensate him for the time I would be asking him to devote to helping me with my research. I was aware of the methodological standpoint that would result from my helping the teacher with the course, and this has introduced an interesting dimension to the research. It is important to point out, however, that this is not collaborative research. I did offer Gordon the opportunity to collaborate on the research but he declined on the grounds that he did not think he had time to do anything beyond just getting the course ready for the classroom.

Goodlad (1988) describes partnerships by referring to the concept of symbiosis: when unlike organisms—or institutions or individuals—are joined in mutually beneficial relationships.

> For there to be a symbiotic partnership, presumably three minimum conditions must prevail: dissimilarity between or among the partners; mutual satisfaction of self-interests; and sufficient selflessness on the part

> of each member to assure the satisfaction of self-interests on the part of all members. (p. 14)

This perspective on partnerships provides a useful framework from which to consider the partnership that was established in this study. Goodlad's first condition was clearly met; there was a great deal of dissimilarity between the teacher and myself in our purposes for being involved in this work, the reward structure we work within, and the types of resources we bring to the partnership. Although I was interested in the applied physics course and wanted to assist the teacher in course preparation, my primary concern was the research I was conducting. The teacher made a commitment to facilitating my research, but his main goal was to prepare and teach the course to the high standard he set for himself. These differences provided both the teacher and myself with some opportunities we would not ordinarily have had, and this is the main reason why Goodlad considers university-school—or researcher-teacher—partnerships to be so promising. In this working relationship we were also able to meet Goodlad's conditions two and three.

The year I spent engaged in the research setting also provided me with several opportunities to increase the credibility of the data that was collected. Credibility, taken as the match between my interpretation of the data and the ways that my sources claimed they saw things relating to the networks I was researching, were enhanced through prolonged engagement and persistent observation (Guba & Lincoln, 1989). I was also in a position to have ongoing conversations with many of my major data sources and I was able to check back with them regarding events and their thoughts throughout the research. In addition, the analysis chapters were returned to the teacher, who was the major source of data, so that he could decide whether the data was a fair representation of events, conversations, and interviews.

An important source of validity through the study was catalytic validity which involved the extent to which the research account that was fed back to the research participants during the study was valuable to them and enabled them to re-orient themselves in productive ways (Lather, 1991). I had several opportunities to feed interpretations back to the participants through informal discussions, meetings, conference presentations, and reports. Many of these feedback opportunities came about because I was involved in a project that was funded by the British Columbia Ministry of Education in which I worked with another researcher to provide a report on the process through which applied physics and mathematics courses were being piloted in the province. I had many opportunities to feed my developing interpretations back to research participants ranging from the teacher of the applied physics course, who was the primary focus of the study, to Ministry of Education officials, who were also represented in the data. These feedback sessions appeared to provide the participants with an account of the piloting of the applied physics course that they found interesting and helpful. One indication of the value they placed on the results is that several of the participants asked me to share the emerging results of the research with them and others at conferences and meetings.

The Analysis Chapters

The analysis of the data is displayed in three chapters. Chapter 5 and Chapter 6 explore the ways that Gordon worked the network as he planned and taught the new course. Chapter 5 focuses on the parts of the network that were located outside the classroom, while Chapter 6 attends to those inside the classroom. Chapter 7 examines the network that was established in the province that led to the piloting of the applied physics course and how this network is interconnected with the network Gordon was building at LMSS.

Chapter 5

Working the Network I: Outside the Classroom

A considerable measure of the effort that was put forth by the teacher as he planned and taught the new applied physics course at LMSS was expended outside the classroom as he managed social relations with other groups. In this chapter, I explore how the teacher worked this part of the network that he was constructing to support the new course. In doing so, I examine how he moves from being one of the actors that was enrolled in the network that was being built around the new course to becoming a network builder who was involved in enrolling others. I describe the efforts he made to enroll members of his own teaching community and how his positioning in the community made it more possible for him to do this. Finally, I explore how, in his network building, Gordon was forced to make choices regarding the sorts of translations that could be used in enrolling other groups and, therefore, the sorts of groups that could be enrolled. In all, this chapter presents a new picture of how teachers participate in initiatives involving new courses in science and technology by locating the teacher as someone who works a network outside the classroom.

Into the Network

To gain an appreciation of how Gordon worked the applied physics network, it is necessary to take a step back and consider the way that the pilot project unfolded at the provincial level and how the course was introduced at his school. More detail on the provincial initiative that led to the pilot project will be provided in Chapter 7, but a few comments are needed here as well. In response to the demands of various groups which included business and industry, community colleges, labour, and schools and school districts, the British Columbia Ministry of Education decided to launch eight pilots of a new applied physics course. The applied physics course was intended to meet the demands of business and industry by providing a physics background to a broader group of students than normally receive it in secondary schools, and by doing so in a way that emphasizes workplace related applications of the physics. School districts were invited to apply to have one of their schools pilot the new course at the Grade 11 level. The Ministry of Education selected eight schools whose proposals seemed to resonate with their purposes for the course. LMSS was one of those schools.

When LMSS received approval and funding from the British Columbia Ministry of Education to offer the pilot of the applied physics course, they purchased the *Principles of Technology* (POT) course materials and lab equipment from developers in the United States. Also, the heads of the science and technology studies departments along with the principal began to plan the way that the new course would be integrated into the school's existing program of courses. Initially, the applied physics course was presented to LMSS students as a course that would involve technical applications of physics but would not lead to credit equal to that given for the academic Physics 11 course. The school administration was counting on the new applied physics course to contribute to an effort to move the program offered by technology education department from an industrial education model towards one that was more consistent with contemporary models of technology education. Part of making this move meant including more content that had traditionally been associated with science education in response to the new demands of employers. This way of presenting the applied physics course at the school, however, was unsuccessful because few students signed up to take it in the following year. This led to changes in the type of credit that would be offered for the course. As the science department head described it:

> When it was first offered [to students] the sign up was very low and I suggested to them that what they had to do was set up a program that will also attract people who are doing academic science. To incorporate both groups in the same program, and that's how we came upon the idea to give credit for Physics 11. In other words you create opportunity to go in one direction or the other, and you don't give a watered-down version of a senior science. [I-95-06-28]

Students were told that the course would lead to an opportunity to gain credit for Physics 11. The result of this change was that enough students enrolled to fill a class of applied physics for the 1994-1995 school year.

The technology department head elaborated on the need to present a version of the course that would lead to academic credit on the basis of the expectations of students and their parents.

> I was able to sell it to students because . . . I knew that in this district I could not stand up and say that I have another alternate science course that we would like you to take. It just was not going to work. Parents were not

> going to buy it. Our parents come from a very varied background but collectively they all want the students to be at least prepared to go to university and they feel comfortable with that fact, even though the marks don't indicate the student ever will go to university or even if their interests indicate that something else will take place. [I-94-12-15]

The approach to the course was heavily influenced by what would be required to "sell" it to students and parents and, at LMSS, the only way to make the course viable was to give the students who took it the opportunity to receive credit equal to that given for the Physics 11 course. By presenting the course in a way that would allow it to be sold to students and their parents, the school administration attempted to enroll them into the network they were constructing around the course by translating their interests into it. The fact that students and their parents could be enrolled into the network in this way brings up an important point about courses and the way that various groups perceive them. The students and their parents were not making decisions about taking the applied physics course on the basis of an examination of the proposed course, *per se*, but, instead, they were more interested in the way that other groups would react to the course. Everyone already knew how other groups, such as universities, reacted to Physics 11 credit and by attaching the applied physics course to Physics 11 credit the course could be "sold" to students and their parents. The new course gained some popularity with students and their parents once they saw it as being positively situated in a stable network of relationships between various groups. Situating the course in this way amounts to presenting it as being within a particular network of relationships where, for example, universities and students who want to go there are important. Situating the course in this way was a choice made at the school to ensure its success. This choice had important implications for the sort of the network that was being constructed and, therefore, for the sorts of actors who are relevant to this research. The academic direction that was taken meant that some actors, such as academic physics teachers, are likely to be included in the network while others, such as technology education teachers, will most likely be excluded. This chapter will now move on to discuss some additional steps that had to be taken if the course was going to have a network that was similar to that of Physics 11.

Enrolling the teacher

As the administrators at the school were preparing to offer the applied physics course for the following year, they had to find a teacher to teach it. The choice to create a version of the course that could lead to academic physics credit had implications for who they could select because the teacher had to be capable of preparing the students to write a Physics 11 exam at the end of the course. A physics teacher would be the obvious choice in this case and Gordon was a good choice among physics teachers. He was the senior physics teacher at LMSS in that he had seventeen years of experience and had taught more physics than any of the other teachers [I-94-11-10]. In this excerpt, the principal explains why she thought Gordon was a good choice for the teacher of the applied physics course.

> So I think that with his academic credentials which are well known by the academic students and his interest in doing this program and doing it in the Tech Studies area and trying to blend the academics with the tech

> studies, if anyone was going to be successful we felt it was him. He's an academic teacher teaching a tech studies course. [I-94-12-12]

She refers specifically to Gordon as an academic teacher and in doing so associates him with a particular type of teaching activity and teaching community. In Gordon's case, academic physics teaching was the specific activity that she had in mind. This begins to show the role that Gordon played in the school. He had a particular social identity that he obtained as a result of having engaged in the activity of physics teaching, one that he shared with other physics teachers. Gordon's social identity as a physics teacher implies particular relationships with school administrators, students, parents, and other groups less directly involved in the school, such as universities and employers who hire high school graduates. These groups are all part of the network that Gordon had previously participated in as a physics teacher.

While it may be a relatively unexceptional claim that Gordon is seen by others and sees himself as a physics teacher—that his participation in physics teaching network has produced a particular social identity—it is an important first step in appreciating why he was selected to teach the applied physics course. The relationship between physics teaching and other groups and activities was understood by most everyone, and it was generally expected that Gordon would be able to maintain these relationships as he developed and taught the new course. This expectation was communicated to Gordon in a conversation he describes that he had with the school principal:

> And then the principal, when she heard that I was interested, came to me on a number of occasions and said that was what made this course. She said "I'm very excited that you would consider teaching it because this gives the course credibility." She said, "Often these kinds of things are just in the technology realm and it lowers everything," and she said, "by having the physics teacher teach it, and yourself teach it," she said, "it gives a very great credibility." And I felt that was sort of the encouragement that I needed, the little nudge, and I thought well this is great and then the more I looked at it and I thought, "I really want to teach this thing." [I-94-11-10]

In addition to encouraging Gordon to teach the course, the principal also made it clear that she expected him to teach it in a particular way. By showing an interest in having Gordon teach the course largely because he was an experienced physics teacher, the principal effectively communicated that she expected him to develop a version of applied physics that would be recognized as equivalent to Physics 11. The science department head was even more direct in a conversation that he had with Gordon.

> The head of our science department, he emphasized to me that he felt that [ensuring the students get a strong physics background] should be the priority and my first reaction, I didn't tell him that, but my first reaction was, "Oh no, we've got this technology and it's just better. The technology stuff is great, let's get that and just get some basic principles of physics down. Enough so that they can, you know, get by." But then as I reflected on what he said I thought to myself, "No he's absolutely right. Those

> principles of physics are really important and if they're going to get Physics 11 they have to have a great awareness of a lot of those things, especially kinematics, Newton's Laws, waves and stuff like that." So that would be a priority to get it done and they will get it done. . . . They'll get it done but they will also get the technology, hopefully. [I-94-11-10]

Again, it is clear that even though different approaches could be taken to the applied physics course, Gordon was expected to adopt one that emphasized the traditional goals of Physics 11. This would help ensure that the network that had built up around Physics 11 would be inherited by the applied physics course.

Gordon was in a position of working the applied physics network as a result of being enrolled himself by the administration of his school. In their efforts to start a viable version of applied physics at the school, they had to enroll actors that could be mobilized in such a way as to get students to sign up for the course. My interviews with the principal, the science and technology studies department heads, guidance counselors, and students indicate that Gordon was generally considered to be a very good and popular physics teacher, one who they all thought could develop a good applied physics course that would also lead to Physics 11 credit. While mobilizing Gordon in the network helped ensure that the course would be viable the following year, there was also the matter of translating Gordon's interests into that of the course in a way that was consistent with the way he was being mobilized. The administrators had to sell the course to Gordon so that he would be willing to teach it in a way that would produce both an applied physics course and a course that would prepare students for a Physics 11 exam. The administrators encouraged Gordon to teach the course and appealed to his ability to make it into a credible physics course in the process. Although the ways that power structured the relationships between Gordon and the school administrators would have given them some persuasive ability, the idea of teaching the course appealed to Gordon. This appeal is reflected in the following excerpt:

> As I looked at it I realized, "Boy, this is a wonderful physics idea here and I would really [pause]." You know, I'm half way through my teaching career. I figure, this is the time to really commit to a change, open up ideas, do things differently. [I-94-11-10]

In addition, the idea of making it into a course that would lead to academic physics credit appealed to Gordon as well.

> I thought to myself, "This is too good to just be left as a *Principles of Technology* course." So the idea that conceived in my mind was that I would try to make it a physics course and give the kids something to hold on to. Something that is just not a low level course where you're feeding them something and they're getting hands on but not understanding, but they will have physics. [I-94-11-10]

The successful enrollment of Gordon into the project as the teacher of the course solved a problem for the administrators and left Gordon to worry about the course itself. As the teacher of the course, Gordon now becomes someone who must work the network and is the person I will follow in my attempt to learn about the network he is working.

Enrolling a Community

When the school administration at LMSS enrolled a physics teacher to teach the new applied physics course, it helped to stabilize the status of the course for some groups, such as students and their parents, but it remained problematic in other ways. A major reason for recruiting Gordon as the teacher of the course was to ensure that the course would be situated within a network of social relationships that is similar to the way that Physics 11 is situated. Mobilizing Gordon in that network brought some of the necessary actors into the network but some of the others were not going to come on board so easily. One of the most visible of these other actors is the physics teaching community. This may be surprising because Gordon was, and is, a member of this community and, indeed, this was one of the reasons why he was chosen to teach the course. Gaining the support of the physics teaching community, however, turned out to be something that had to accomplished. The nature of the resistance on the part of physics teachers, and the way that Gordon reacts to this, leads to some important insights about the process of network construction.

Community resistance

As Gordon planned and taught the applied physics course, he saw himself as continuing to take the goals of the Physics 11 course into account. At the same time, he was adjusting the approach so that the same result could be achieved in a way that he thought would be more interesting to an expanded group of students. In fact, by relating the applied physics course to the historical development of physics education in the province, Gordon argued that this approach was, in a sense, a natural continuation of that process.

> In the 60s, what happened was there was a change and they did what was called the PSSC course . . . and it was so hard it limited people who would take it. Now I think some people still have the idea that that's physics. Now, then, and I'm not sure of the date, I was teaching at the time, there was a change and they brought in the new course using [the textbook called] *Fundamentals of Physics* and it is broad, and the thing I have to emphasize is that it's not that hard. If a person has basic algebra, and I'm talking basic algebra, they can pass this Physics 11 course. You don't get into complex equations, you get the whole panorama of physics. But what it's missing is any kind of practical application and also the real interesting things like the technology thing were not there. You had just a few people taking it. Now [with applied physics] you've got more. You know it's growing a bigger circle because now physics is manageable, people are learning that, yeah, they can manage. Physics is fun, it's not sitting doing equations, you're not solving this and solving that all the time. What you're getting is, yes, you're getting a basic physics thing but now you're getting a whole bunch of really neat applications. [D-94-10-26]

For Gordon, the applied physics course provided a better way of teaching physics rather than one that would produce a "watered-down" version of the normal Physics 11 course (to use the words of the science department head).

Not all physics teachers in the province, however, were convinced that a course that used the POT materials could be a legitimate physics course. For the most part, the objections of some of the other physics teachers seemed to emerge as hear-say but a few specific challenges to the applied physics course also appeared. One physics teacher had written an article for the journal of the provincial specialist association of science educators after he examined the POT materials that were being used in the provincial pilots of the applied physics course (Wootten, 1995). He was critical of the materials, and he argued that a course based upon them would neither be a suitable physics course nor an acceptable alternative to the existing Physics 11 course. Examples of his claims were that the materials provided a very superficial coverage of content, that they mixed metric and imperial measurement systems, and that the labs were too difficult. He was also concerned about the fact that a community college in the province was accepting either applied physics or Physics 11 credit for entrance into some of its programs. This controversy about the status of the applied physics course was one that mattered a great deal to Gordon and the way that he handled this situation shows the importance he placed on making sure that he had the support of members of the physics teaching community as he taught the course.

Gordon was aware that some other physics teachers were rather skeptical of the legitimacy of the applied physics course as an acceptable physics course. He thought that this was because they were worried about the rigor of the new course and, on that point, he agreed with them that the rigor should not be compromised. He thought that the new applied physics course should maintain the rigor of Physics 11, as he considered himself to have done in his version. His strong commitment to maintaining the rigor of the existing Physics 11 course in form of the new applied physics course comes across in the following statement where he is commenting on the concerns of some physics teachers he has been told about:

> [The technology studies department head] tells me that there are some people who have no interest at all in it, and I have a feeling that there are people that would feel threatened. . . . I think [some physics teachers] are thinking we're going to compromise Physics 11 and take the physics course and lessen it. And I would fight tooth and nail against compromising it myself. No, I think that ultimately you don't want to ever compromise the Physics 11 course, but you really want to supplement it so that it's richer. [I-94-11-10]

When discussing the importance of maintaining a rigorous physics course in the form of applied physics he refers to the need for appropriate preparation for Physics 12 and also for the provincial exam that Physics 12 students in British Columbia write.

> To me the final reckoning for a kid in physics will be that Physics 12 government exam. He's going to be ready. I mean, with everything I've covered, they will know everything they need for the Physics 12 exam by the time they get there. [I-94-11-10]

Because Gordon thought that his version of the applied physics course was maintaining the rigor of Physics 11, he saw the concerns of some of the other physics teachers as ones that he could put to rest by talking to them about his course. He did get such an opportunity and several days before a presentation he was going to make to teachers—many of them physics teachers—who were interested in hearing about his applied physics course, Gordon commented on his goals for the presentation:

> I think that I could do a really good sales job so that these people will see that they're not messing with the Physics 11 course, they're expanding it. The kids are going to walk out not less for it. [D-94-11-03]

The reaction of the physics teachers who would be attending the presentation was of particular interest to him.

> I would be interested in getting their opinion of saying, "Okay, do you agree that that would be the content of Physics 11?" Like I'm thinking in terms of Physics 12 teacher saying, "Hey, if a kid had that and knew it, then I would accept him." [D-94-10-17]

Gordon was clearly concerned about enrolling the physics teaching community as supporters of the applied physics course he was planning and teaching. The reasons for his concern had to do with the status of the applied physics course. At Gordon's school, there had already been a guarantee given to students that the course would prepare them for an exam they could write to receive Physics 11 credit. In a way, Gordon's course already had status equivalent to Physics 11 but having members of the physics teaching community dispute this would have created problems. If this happened, other groups, such as universities and certain employers, may begin to also question the legitimacy of the applied physics course. These groups had a stable relationship with the existing Physics 11 and 12 course and physics teaching community, making physics teachers legitimate spokespersons for them where high school physics was concerned. Having other physics teachers take a position that was for or against the course had implications for which other groups were likely to emerge as being for or against the course. Developing the course in a way that would allow it to be equivalent to Physics 11 meant that Gordon had to work at constructing a network that went well beyond the boundaries of the classroom.

It is also important, at this point, to consider why some of the other physics teachers were less than enthusiastic about the applied physics course. It was possible that this course could end up being bad for the physics teaching community in two ways. First, if other groups who the physics teaching community enjoys a stable relationship with do not accept the new course as a legitimate physics course, then there is some danger in community members being associated with it. This situation would weaken the position of the community of physics teachers in their historically established network and, therefore, alter the community's identity by changing its relationships with other groups. The community's identity is something that members have established in the history of their activity and something that they actively work to maintain. Second, if people outside the physics teaching community teach the course, as was the case at many of the pilot sites, and it is accepted by post-secondary institutions as being equal to a Physics 11 credit then the identity of the physics teaching community is, again, weakened. This would result in physics teachers no longer being seen as the exclusive providers of physics education in secondary schools. Two of the ways out of this dilemma for the community are to ensure that the course is not offered in British Columbia schools or that only non-physics teachers teach it and the course is not accepted by anyone as being equal to Physics 11. A third way is to have physics teachers teach it in such a way that other groups in the network will accept it as equal to Physics 11. This third option was the one that Gordon was interested in, but for this to be the case, he needed to enroll other members of the physics teaching community into his applied physics project. To have this support, Gordon had to convince the other physics teachers that his course would maintain the place of physics courses and the physics teaching community in the network in which they have historically participated; he had to translate their interests into his project. In the next section, Gordon attempts to enroll other physics teachers by accomplishing this translation.

Enrolling and translating

When he actually did make a presentation to physics teachers, Gordon was careful to point out that the applied physics course that he was developing was different than those underway at other pilot sites—most of which were not taught by physics teachers—where the POT course materials were being followed much more closely. He also was careful to identify himself as an experienced physics teacher. This is an excerpt from the opening remarks of his presentation:

> What I'm doing is very much different, I think, than what's happening at the other sites. I am a Physics 11 and 12 teacher and I've taught the old PSSC course and the course that's happening now in physics and, of course, this *Principles of Technology*. [P-95-11-16]

Anticipating many of the concerns that these teachers may have had, Gordon structured much of his presentation to address these directly. In doing so, he did not challenge the quality of the work that physics teachers have done in the past through courses like Physics 11, but, instead, convinced them that they could use the type of course he was developing to do what they have been doing in an even more effective way.

> Now the problem is this: if POT is the course that you taught in Physics 11, the fact is they would not be getting a Physics 11 course. It would be too low of a level and there's no way they would be able to handle Physics 12. Any student coming out of this POT 11 course, as it's taught, I would not want to have in my Physics 12 class. They simply wouldn't be able to do it. It's not mathematically rigorous enough, as we are going to find out as we're going through this [presentation]. But what I am trying to do is take this basic outline and borrow from it and add to it all the Physics 11 material so that what we have is a richer Physics 11 course. [P-95-11-16]

He immediately makes it clear that he is not simply following the POT materials. Instead he is enriching them so that students are provided with the background in physics that they would have received in Physics 11. He uses goals that are stated in a textbook that is highly regarded by most physics teachers in the province to make a case for what the course he is developing has to offer.

> Now the problem is: Am I doing something that is out of sort of line with the goals of Physics 11? And I don't think so. We use, at least I use here in the school, I think a lot of teachers use *Fundamentals of Physics*. How many use that text? [most of the physics teachers raised their hands] Well *Fundamentals of Physics*, for example if you take a look at the teachers manual, here is the very first goal that they talk about. The first goal in *Fundamentals of Physics*, "to help students increase their knowledge of the physical world and to recognize applications of physics to the world around them." To recognize applications of physics, that's technology. And I dare say that it's not in the *Fundamentals of Physics* book. They have a chapter called Energy in Society, but it doesn't really deal with the application very well. And I don't believe they are actually meeting that goal in the *Fundamentals of Physics* course. This does open up a door, if you will, for a technology component and that's what we are trying to do here. Let's take a look here at this, another goal of the *Fundamentals of Physics* course, this is right out of the teachers manual, "to provide a firm foundation of knowledge for students who may go onto a post secondary education in science or engineering". Now, again, does our Physics 11 course really prepare for an engineering background? I think that it does to some degree but we can do a far better job. [P-95-11-16]

In the presentation, Gordon positioned himself as an innovator within the activity of physics teaching rather than someone who was doing something that was located outside of physics teaching. His strategy involves reassuring the physics teachers that this course would not endanger the identity of the community and may even strengthen some of the social relationships that physics teachers consider important, such as those with engineering programs. The applied physics course was not argued for in and of itself, but rather the value of the course maintaining important relationships was highlighted. This act of translation was the focus of Gordon's presentation. As he did so, it can also be seen that Gordon is mobilizing two nonhuman actors that he enrolled into the course in different ways. To help him translate the interests of physic teachers into his course, he moves the POT course materials, items that have been problematic in the eyes of the physics teachers, to the periphery of the new course. "[I]f POT is the course that you taught in Physics 11, the fact is they would not be getting a Physics 11 course" [P-95-11-16]. He also mobilizes a Physics 11 textbook that is popular with physics teachers and uses it as a means of pointing out what a good physics course ought to be. These mobilizations were used to help translate the interests of physics teachers into his course and, thereby, strengthen the network he was building.

This presentation that Gordon gave went quite well. Many of the physics teachers complemented him on his efforts in the applied physics course and demonstrated their interest with a number of questions once he had finished his presentation [F-94-11-16]. Most of the questions were general ones about such things as the number of units and amount of preparation time he was putting in, but a few had more to do with the relationship between the new course and existing physics courses. An example of such a question and his response is:

> Teacher: How are much of the current Physics 11 are you actually going to teach in the course?
>
> Gordon: I should have actually brought a thing on that too. We will cover, what I think is what they need for Physics 12. They will know all the kinematics formulas, they will interact with them and solve problems. . . . They will do Newton's Laws, they will have done waves, they will have done momentum, work and energy, all of the essentials. Now whether I spend a week or two on relativity, no, there's no way. Maybe one hour. But I still think they're gaining much more by adding these other things in. [I-94-11-16]

In this case, Gordon reassured the physics teacher who had asked the question that the course would cover all of the material that students needed to move on to Physics 12, but acknowledged that some of the topics that were optional, such as relativity, may not be covered to the same extent as they sometimes were. Gordon appeared to have successfully convinced the group of physics teachers who were assembled at the presentation that his version of the course could be counted as a legitimate physics course without endangering the identity of the community. When I say he was successful, I mean within the context of the presentation. The interest and positive comments of the physics teachers who attended show that they thought that Gordon's version of the course had merit and that they tentatively accepted it. The strongest indicator of their acceptance, however, is that none of the teachers denounced or rejected the course as one that should not be counted as physics. The results of another presentation that Gordon gave later in the year were similar. In fact, as far as Gordon or I had heard, no physics teacher had suggested that Gordon's version of the course should not be considered a legitimate physics course. This does not equate to an unqualified endorsement, but it does show some measure of support from the proximate community and, therefore, an enrollment of a number of physics teachers into the network he was constructing around his course.

Again, the importance of mobilizing these physics teachers in his applied physics network was to develop a measure of control over their behavior and, with luck, the behavior of other physics teachers who were not present. Having these actors in the network was very important in avoiding the risk of universities rejecting his course as a legitimate physics course. By dealing directly with the physics teachers, he did not have to deal directly with other communities even though enrolling them was of concern to him. This concern comes through in the following excerpt where he discusses the possible reaction of university faculty to the applied physics course:

> It's just that I was thinking there are people up at the university who are saying, "No, no, you can't leave that out." I'm thinking, "Just a second now. They're going to get it in Physics 12 anyway." So to me, I've got my criteria, I've got my basic core and I would guess that any physics teacher anywhere would say, "I'm not going to argue with that core." I could say to them, "You should be doing this, this, and this and we're doing it as the extra with the engineering component." [I-95-06-30]

He frequently pointed out that the applied approach would strengthen the connection between university and post-secondary programs. "Well, in the *Principles of Technology* course they get real meters that they would use in university in a physics lab or in a engineering firm, I mean the real stuff" [I-94-11-16]. These relationships were clearly important to Gordon and these groups were ones that he was able to enroll indirectly by mobilizing the physics teaching community into the network.

In his efforts to enroll other physics teachers into the applied physics network by translating their interests, Gordon used some additional strategies besides reassuring them that the course would not endanger the social relationships that the community had with other groups. One of these was being very careful to locate himself as a long-standing participant in the physics teaching community and the other was to distance himself from other non-physics teachers who were teaching the course. In of the following sections, I will discuss the significance of these strategies.

The social community

Gordon was better positioned than many other physics teachers to successfully enroll members of the physics teaching community in the network he was constructing around the applied physics course. He recognized the importance of his positioning as he discussed the advantages of himself, as opposed to non-physics teachers or beginning physics teachers, trying to convince other physics teachers that the applied physics course was a legitimate physics course.

> Now, in one way it's probably good that I did it because if you're not a physics teacher, physics teachers will probably not listen. Some of the others are younger physics teachers, like they've only been there for two or three years teaching physics. I mean, I've been there for 17, 18 years teaching physics. So I can meet the other physics teachers, I know some of them already, and they're going to respect me and not say, "You're the new kid on the block." I can look at the others and say, "Well look, I've been there; I've done that; I've been to the American Physics Teachers Association meeting; I've read the literature; I've taught the course; I did the old PSSC course; I've taught this course." So I think that that lends a bit of credibility. [I-95-06-30]

Gordon's position in this community was very important and gives him "credibility" as a judge of what constitutes a legitimate physics course. His already well established identity as a credible physics teacher puts him in a better position to convince the other physics teachers of the legitimacy of the new course because his own identity is closely tied to that of the community. As was shown earlier, Gordon's identity is important in his interactions with those outside the community such as school administrators, but it also shapes interactions within his community.

Although Gordon is concerned about what the community thinks of the applied physics course he is teaching, he is aware that there are some members of the community who were less likely to challenge him. This is demonstrated in the way he responds to a question I asked him about the reaction of the other physics teachers in his school to the applied physics course.

> The teachers are very open to things. And being that I basically, I mean, I am the head Physics 11 and 12—the only Physics 12—teacher and the other Physics 11 teachers, like, they all have one block. Hey, they're totally interested and into it and supportive of anything. [I-94-11-10]

Gordon's recognition of the difference in the status he had as a physics teacher and that of the other teachers in his school underscores the social nature of the community. Just as power has already been a factor in structuring relationships that Gordon has with groups outside the community, it is also important to relationships within the community. The relative strength with which the identities of some members have become associated with that of the community leads to increased credibility. Not only does high credibility give some members more influence in proposing new ways of participating, it also influences who is best positioned to challenge the legitimacy of new ways of participating. High credibility arises from such things as amount of experience, number of physics courses taught, and getting to know other members on a personal level. Because it is a function of relationships between community members, credibility is not something that is possessed by individuals; it is partly enacted by individuals as they relate to others as, for example, community spokespersons and it is partly given to individuals by others as they, for example, accept the opinions of some members as representing the position of the community. Also, credibility is conditional because just as it is given to an individual, it can also be taken away.

This means that even the most credible members, like Gordon, must attend to and maintain their relationships with the larger community if they hope to retain their status.

This social character of the physics teaching community and the different positions that members can have within the community demonstrate how some members are more effective change agents than others. Credible members are able to speak on behalf of the community as they suggest positive changes or challenge ones that they do not see as positive. In other words, they are able to have a great deal of influence in deciding whether a given project successfully translates the interests of the community. When proposing change, as is seen with Gordon, they are also more likely to be able to enroll other members of the community and mobilize them in a way that enhances the possibility of change. Gordon's high credibility in the physics teaching community is utilized when he introduces himself as an experienced physics teacher at the beginning of the presentation that was discussed in the previous section. Gordon's credibility is also a reason why the school administration wanted Gordon to teach the course in the first place.

Networks in Conflict

The importance that Gordon placed on enrolling the physics teaching community, and other groups that were associated with the community, was not something that extended to all groups. One such group consisted of the other teachers who were piloting the applied physics course. As condition of his school becoming a pilot site, Gordon was expected to interact with these other teachers in a variety of ways but, in contrast to the way he interacted with physics teachers, he did not appear to consider these interactions to be very important with respect to the network he was constructing around his version of the applied physics course. Gordon did not know about the nature of the project that was overseeing the piloting of the applied physics course in the province until approximately six weeks into the school year, at which time he attended his first meeting with the other pilot teachers.

None of the other seven teachers piloting the applied physics course were attempting to prepare the students to receive credit for Physics 11. Instead, their successful students were going to receive a special credit for the pilot that was given the label of Physics 11A, a credit that was not considered to be equal to that given for Physics 11. Unlike Gordon's students, few students in the other pilot courses planned to go to university. Most of them planned to go directly to work, into trades or apprenticeship training, or into a technical college program. Only two of the other pilot teachers had a background that involved physics teaching but they were not approaching the course as an academic physics course. Of the remaining teachers, none of them had taught physics in the past and all but one of them, who was a science generalist, were experienced technology education teachers. Meetings of the pilot teachers had been held six times through the year. At these workshops they received training as well as discussed their approaches to the course and the merit of the applied courses in general. At times, they provided information to representatives from the Ministry of Education and community colleges who were monitoring the progress of the pilots. The teachers were also in contact with each other through an electronic mail network, although it took several months to get the system working smoothly. The discussion on the network ranged from social interaction to practical issues involving course resources and workshop planning to more political issues such as credentialing. The degree of participation on the electronic network, however, varied from teacher to teacher and substantive course discussions were difficult because the teachers taught the course at different times during the school year.

Gordon's involvement with the pilot group was limited. He attended three of six meetings and rarely participated on the electronic mail network. Gordon did not consider the training sessions that the Ministry of Education had arranged to have been very useful. In his words:

> I would say that the majority of the training was a complete waste of time. . . . Sure it's nice to be part of a group and be together with a few of the other people, that's true, but I wouldn't call it training *per se*, it was more like a gab session. Some of it was worthwhile but there were many, many hours wasted in my opinion. [I-95-06-30]

A sense of the limited contribution that Gordon felt this group could make to the applied physics course he is developing is apparent here. Some of the wasted time that Gordon alludes to involved discussion of the future status of the applied physics courses in the province and credentialing issues. Although this was very important to the other teachers who were not preparing students to receive credit in Physics 11, Gordon did not feel that this sort of discussion was important in his case. He did not have a problem with credentialing because his version of the applied physics course would lead to Physics 11 credit for most of his students—a credential that was already recognised throughout the province.

Gordon's lack of interest in the workshops did not result from personal differences with the other teachers. Indeed, as he indicated above, he somewhat enjoyed getting together with the other teachers but, in terms of the direction that was being taken with the course, Gordon did not have a great deal in common with the others. This is indicated in the following excerpt where he is commenting on the openness of the other physics teachers when it comes to providing support:

> If anything I would say that if I had a question I could easily ask any one of them by e-mail or whatever and they would be more than willing to answer. And then probably enjoy giving an answer you know. So I feel the support that way, there's no question about it. But, as for the kind of thing I'm doing, who can you talk to? I mean, none of them would be able to relate to that at this point. [I-95-06-30]

The difference between Gordon's approach to the applied physics course and that of the others was quite obvious at the meetings. Gordon frequently spoke of what was needed in the course to make it more like Physics 11 and the other teachers emphasized applications of the physics concepts they needed to develop in order to make the course accessible to students who normally would not be found in Physics 11 [F-95-06-01]. Several of the other applied physics teachers were quite outspoken in their opposition to the applied physics course becoming too much like a regular physics course. The following excerpt was taken from an interview with Bob, one of the other pilot teachers:

> The whole purpose of the course was to bring physics to a larger majority of the students that need it but aren't getting it now. And by making it too much like the standard physics course, by including all this information that is in the old physics course, a lot of which is not relevant to any industry or business or job, that's a danger because you put too much information into a course. If it's not relevant, doesn't have applications, it has no value. If it's never being used in industry or business or any occupation, it's only application is for research and science, it has no place in this course. [I-94-10-20]

The difference in the descriptions of the course that Gordon has provided up to this point and Bob's demonstrates the gap between the approaches taken by Gordon and the other teachers. The network that Gordon was trying to construct around his course is very different than the one that Bob was working on.

Gordon did not feel any pressure to justify his approach to the applied physics course to the other pilot teachers nor did he show a great deal of interest in their approach. Gordon indicated that he felt that the approach the others were taking was worthwhile, but considering a similar approach himself presented a problem. This can be seen in the following excerpt:

> I wasn't concerned about what they thought about what I was doing, it didn't matter to me at all. It's a pilot site in any event. I hope I didn't give the wrong impression to some of them. I probably did. I didn't mean to because I can be vocal on certain things sometimes and I think that I

> bothered some people in certain ways. I did not mean to but I also feel that what they're doing is fine but in the academic community it will not be accepted. [I-95-06-30]

Gordon was aware that the approach that the other teachers were taking would not be accepted in the academic community and it has already been demonstrated that it was important to him to have his version of the course accepted there or, more specifically, in the community of physics teachers.

By looking at Gordon's interactions with the other applied physics pilot teachers in terms of the network he was constructing, his lack of engagement with them is not very surprising. An important reason why Gordon did not make any great effort to enroll them into the network he was building was because these other teachers could not be mobilized in a way that would strengthen his network, and it is likely that they would have been a liability. As had been shown earlier in the chapter, Gordon was expected to make the applied physics course into an academic course and an important part of doing that was enrolling the physics teaching community. This meant he had to translate their interests into the course he was teaching by showing how it would maintain and, perhaps, strengthen the relationships they already had with other groups, such as universities. The other pilot teachers worked their own networks within which different groups, such as industry and trades programs, were important. When Gordon says that the courses the other pilot teachers were developing would not be accepted in the academic community, his words can be interpreted as pointing out a problem of translation. If he were to try to translate the interests of the other pilot teachers and the groups they considered important into his course, he would risk loosing the support of the physics teaching community. The two types of translations that would have been required to enroll both groups would be in conflict. This problem demonstrates an important difficulty with the introduction of new science and technology courses: it is problematic to fit them into both a science education network, like the one Gordon was constructing, and a technology or vocational education network, like the one the other pilot teachers were constructing. As long as these existing networks serve as a template for the ones that must be constructed around new courses, it seems unlikely that courses that bridge the two subject areas will be developed.

The effort Gordon made to enrol and mobilize members of the physics teaching community compared to his lack of concern with, and avoidance of, the other pilot teachers illustrates an important point. Not all groups are important allies to be mobilized in constructing a network for a course. In contrast to the value of having the support of physics teachers, being closely associated with the other pilot teachers may have hindered Gordon's efforts to construct the sort of network he was trying to. Recall that when he discussed his approach to the course with other physics teachers, Gordon disassociated himself from the other pilot teachers. This disassociation is an even stronger statement than simply not enrolling them; it amounts to using them as a foil. In a sense, it appears that the physics teaching community defines itself in opposition to the technology or vocational education communities, meaning that Gordon actually gains strength by not mobilizing them and maintaining a distinction between the network he is constructing and their network. This is a case of conflicting networks.

The Network Worker

In Gordon's efforts to construct a network as he taught the applied physics course, he worked to enroll several groups by using both direct and indirect approaches. After being enrolled and mobilized himself into the network that was being created around an academic version of an applied physics course, he became an active participant in the building of the network. The main task he had to accomplish to do this was to enroll members of the physics teaching community. By mobilizing physics teachers he was able to indirectly enroll a number of other groups, like universities, with whom physics teachers have historically had stable relationships and have been able to represent their interests in high schools. These other groups were important ones to mobilize because the students who took the course and their parents had been told that it would lead to Physics 11 credit. This credit implied particular sorts of relationships with other groups—the possibility of entrance into engineering programs, for example—and Gordon was stabilizing these relationships as he enrolled and mobilized the other groups. He enrolled physics teachers by translating their interests into the course he was teaching in a way that they found compelling. In this case, it was by convincing them that his version of the applied physics course would not threaten the social relationships that they had historically fostered—their network. Once he translated the interests of the physics teaching community into the applied physics course, the possibility of some other translations that would be required to enroll other groups, such as the other applied physics teachers, became limited. Given the nature of the network that Gordon was constructing, there was far more to lose than to gain by enrolling other groups who were not committed to an academic version of applied physics.

One thing that helped Gordon in his efforts to enroll other physics teachers was his own position in the physics teaching community. As a credible member of the community he was well positioned to convince other physics teachers that he was offering them a good and valuable translation of their interests in the form of applied physics. When it comes to new initiatives in science and technology education, credible community members are those who are in the best position to successfully enroll and mobilize their community. Credible members of the community play a much greater role in influencing community decisions than less credible members, making Gordon a good choice for the teacher of the new course.

The active role that Gordon played in building the network provides a picture of the initiation of a new course that involves the teacher doing a great deal of work outside the classroom. The initiation of this new course, that differs significantly from physics courses, involves the construction of a network that requires human actors to be enrolled. An interesting question emerges here about whether Gordon and the applied physics course constituted a special case or whether networks are features of all new and existing courses. Latour (1987) is helpful in suggesting an answer to this question. In his research on innovation in technoscience, Latour follows *science in the making*. The reason for this is that, at that time, he can see how technoscientific controversies are settled. He can see the social side of science as scientists construct networks of human and nonhuman actors to settle the controversy. Once the controversy is settled as a result of forming a strong network, the network itself becomes hard to see. The technoscientific controversy becomes a noncontroversial fact—a black box. At that point, the fact appears as if it were self evident and that it exists as a reflection of "nature" without requiring a network. Latour describes the perspective shift that occurs. When looking at an established technoscientific fact, that appears to exist without a network, the process of making facts appears to be one that can be described by the statement, "Once the machine works people will be convinced". However, if the fact is explored when it is in the making, and the network is still being constructed, the statement that appears to apply is, "The machine will work when all the relevant people are convinced" (p. 10). Academic physics courses that have historically been taught in high schools are black boxes as well. In this research the physics teachers reacted to the applied physics course because they thought that the black box of physics courses and teaching may be opened, requiring them to renegotiate the physics network. Returning to the question, this research suggests that all courses and teaching involve a network. It is a visible network when we have a *course in the making*, but in established courses, where the network is stable and there is no controversy, the network is less visible because it is not being actively worked.

In addition to several specific claims about the process of working the network that I will recount in the final chapter, this chapter concludes with a claim about how the new applied physics course came into existence at LMSS. The course is more than something that only occurred behind the door of a classroom, it required that a network be created. The part of the network that was explored in this chapter involved actors that are mainly found outside the classroom. The teacher enrolled various actors by translating their interests into the course he was teaching. The result of doing this was, what appeared to be, a successful mobilization of actors that gave the course strength. The course moved in the direction of becoming a stable and accepted one—a black box. The sort of role Gordon played in constructing the network is one that has not been described in the educational literature.

Chapter 6

Working the Network II: In the Classroom

In the preceding chapter, the part of the network that Gordon worked outside the classroom was the focus. This chapter focuses on how Gordon worked the network inside the classroom as he actually planned and taught the course. Although the actors that Gordon enrolled in the planning and teaching of the course are, for the most part, different than the ones that he enrolled outside the classroom, they are all mobilized into the same network. Within this network the actors are arranged in relation to each other and in such a way as to make the applied physics course successful. As a result, the preceding chapter has already provided a great deal of information about the type of network that Gordon was trying to construct. In this chapter, I will explore how he enrolled and mobilized additional nonhuman actors. Recall that actors can be either human or nonhuman. One source of these additional actors was the POT course and laboratory materials which had to be enrolled in some way as a condition of being a pilot site. Other sources of actors were ones associated with physics courses that Gordon had taught before or ones that were newly developed. The first two categories of actors that I will consider are resources that helped him structure both the overall course and individual lessons. From here, I will move on to look at two categories of material resources. These are textbooks and lab equipment. The goal of the exploration in this chapter is to look at the relation between the actors he mobilized and the network he was trying to construct.

Course Organization

The POT materials, as potential resources to be used in the new course, embodied many of the changes that Gordon was considering as he was planning the new applied physics course. The planning and enactment of the sequence of lessons, the macrostructure, for the new course was the first point at which the POT materials were considered. As a first step in planning the course, Gordon wrote out the general sequence of the lessons within each unit before concentrating on individual lessons. As he did this, Gordon typically began by considering the sequence described in the POT materials. He normally modified this sequence as he contemplated the appropriateness of that approach for providing the Physics 11 content the students would need. Several conflicts arose between the structure that Gordon had used when he taught physics in the past and the structure provided in the POT materials. An example of a conflict that came up between the lesson sequence found in the POT materials and that Gordon had previously used in teaching physics occurred in the first unit of the applied physics course. This conflict illustrates the role the POT materials played in the planning of the course and also begins to show the basis upon which Gordon made decisions about his approach to the course.

Gordon began the applied physics course by spending several days on standard Physics 11 introductory topics such as scientific notation and units of measurement. These familiar lessons gave Gordon the opportunity to find out about the ability levels and work habits of the students who were taking the course [F-94-09-09; I-94-11-10] while providing them with what he considered to be some of the important ideas that they needed to understand before beginning any physics course [F-94-09-09]. Gordon said that he was using the Physics 11 lessons to “get his feet under him” and after he did that he would try the POT materials to see if they would "work" [F-94-09-15]. After several classes, Gordon began the first unit of the POT materials called forces. The force unit, like all the POT units, was divided into the four subunits: mechanical systems, fluid systems, electrical systems, and thermal systems. Gordon followed the general macrostructure set out in the POT materials for the first part of the unit. He started with an overview of the concept of force and the types of technological systems in which the concept of force would be used. He then taught about forces in mechanical, fluid, and electrical systems, but at this point he made a major deviation from the way the unit was sequenced in the POT materials.

In the electricity part of the force unit, Gordon was dissatisfied with the POT materials treatment of the topic of electricity. The materials only referred to voltage and left out other electrical concepts such as resistance and circuits. The reason for this was that voltage, being considered as a force-like quantity in the POT materials, was the only electrical concept that fit into the unit on forces. This was the first point where there was a significant overlap between POT content and Physics 11 course content, and it was also the first major conflict between the two approaches. This excerpt gives a sense of Gordon's initial reaction to the material in the early planning stages:

> This whole [POT] approach here is so different from everything else. See, the [Physics 11] approach is usually, the first thing you look at is charge, and now you look at separation charge and then you get this pressure like

> idea of voltage and then you define it. Then you have current, it starts to move. And then you have Kirchhoff's Laws, then you have Ohm's Law, then you have circuits. Now that seems to me a very logical way. I mean there's more detail, obviously, but it just seems to make all the sense in the world to do it that way. [C-94-10-27]

In the period leading up to the electricity subunit, Gordon was undecided about whether he would use the POT sequence which only dealt with voltage or whether he would take the opportunity to cover all the electrical concepts that are normally taught in the Physics 11 course.

> Well on Monday we start the new unit, voltage, and the question is whether to go on and just do the Grade 11 [physics] material. . . . See, I'm so tempted to do the lecture that I give with Physics 11. I'm trying to put Physics 11 in but not in the fullness that I do it. And I'm tempted to just take Monday and try it anyway. [I-94-10-27]

When he did cover the section in class, Gordon supplemented most of his usual Physics 11 electricity content into the electricity part of the force unit [F-94-10-31]. This required at least one extra class and involved covering several electricity topics that come up further along in the POT materials.

Gordon's resistance to the approach taken to electricity in the POT materials stems from his concern that it may not have been an effective mobilization in the network he was constructing. The way that the POT materials were mobilized had to be compatible with the translations he was making of the interests of other groups in order to enroll and mobilize them. The mobilization of the POT macrostructure was constrained by the condition of having to develop an applied physics network into which members of the physics teaching community had to be enrolled. The problem with the macrostructure of the POT materials is discussed in the following excerpt in which he is describing his reservations about that way that the POT materials approach science concepts, and, at the same time, his preference for the ways that they are approached in physics. More specifically, he is referring to the way the POT materials break up science topics and mix them with technological content rather than leaving the physics content intact as is done in physics courses.

> Now, another thing that I'm observing now with the whole course, I don't know if you want to say a problem or difficulty, is I really don't like the idea that certain things are put off months away and then you come back to them. It seems to me that more and more I am gearing towards the thought that if you have the physics background and you do the best to establish the background, then you say now let's look at technology, and then you start applying everything in different areas. [D-94-10-31]

This excerpt goes beyond showing a simple preference that Gordon had about sequencing science concepts by demonstrating an epistemological position that he was arguing for. This is that by first gaining a solid and thorough background in physics, students will be able to understand the technology and other areas to which the physics can be applied. In other words, students can obtain a privileged understanding of the world around them if they first have an understanding of physics. This position was important because it was consistent with the way physics was normally taught. Not attending to it had the potential to jeopardize the support of physics teachers for the network. The position was also supported by Gordon's concern with giving the students the background they were promised when they signed up for the course. This is illustrated in the following excerpt which came from a conversation we had after class on the day he introduced electricity the way he does in physics at the beginning of the electrical systems section of the force unit.

> Well the thing is, to just jump in and do voltage without the background that we've laid today, even in a small way, it's just not fair. I mean and it's not like, "Oh, it's so tough. They can't understand it." I think they understood it. I think the ideas are there. I have no problem with this way of doing that kind of a thing and I would feel more honest that I'm giving them something they're going to be able to understand, not just, "Here's how you measure a volt. Okay? Great." [D-94-10-31]

Gordon's choices with respect to the macrostructure of the course are made in an effort to hold the network together. In addition to wanting to keep the physics teachers enrolled and mobilized, Gordon is keeping the students enrolled in the network as well. The difference with the students is that they have already committed to taking the course and backing out would be difficult. Since they had an understanding of what the course would provide them with when they signed up for it, Gordon felt ethically responsible for ensuring that they get the background in physics that they understood they would. He already had the students enrolled but felt obligated to make sure they were given a physics background that was comparable to what they would have received in Physics 11. The nonhuman actors that he draws upon as he organizes the macrostructure of the course are closely related to the sort of network he is constructing.

Gordon was, of course, obligated to use the macrostructure suggested in the POT materials to some extent; it was a necessary enrollment, but the way that it was to be mobilized in the course was somewhat flexible. Gordon used it to the extent that it did not seem to conflict with the network that he was constructing, but when the conflicts occurred he quickly turned to other sources for the macrostructure. The main additional source that he used was the macrostructure that he had commonly used in Physics 11. He enrolled this actor whenever he required a macrostructure to be used in place of the one suggested in the POT materials. In this sense both were mobilized but their centrality in the network varied inversely—that is, when one became more centrally mobilized, the other became more peripheral. The decision of which to use at which time was based on Gordon's judgment concerning the strongest mobilization for the whole network.

Lesson Organization

As Gordon planned and enacted his approach to individual lessons, the microstructure, he made choices about what would be emphasized in the classes. The POT materials suggested an approach to the classes that made a very explicit connection between the specific examples of technological systems and the science concepts that could be used to understand how the technologies worked. The way the POT materials organized lessons also highlighted careers that were related to the technological systems being described. Technological systems and careers were not, however, emphasized in the typical applied physics lessons that Gordon taught. Gordon's approach to the microstructure differed from his approach to the macrostructure in that he started his planning with a physics approach that almost exclusively emphasized the development of physics concepts. Rather than serving as a beginning point, the approach suggested in the POT materials was considered on the basis of its value in supporting the physics approach. The technological or vocational content usually was not part of the day to day lessons in the course, but occasionally it did make it in.

An example of a lesson that included elements of a POT microstructure, is found in a lesson that Gordon taught on torque. The general outline for the lesson was entered in Gordon's teaching diary which he used to record what he did on a given day as well as a few notes about changes he should consider in the following year. The torque lesson that he is commenting on was part of the mechanical systems section of the force unit.

<u>September 27</u>

Discussed the idea of Torque

- did the demo with the door

Did the torque wrench question from the text, then showed the torque wrench.

- used the torque wrench to both measure and calculate the torque

Showed the conversion from

- ft to meter and lb to N

- (used memory trick - think of eating a fig newton at 4:45)

Thought: - the conversions should have been done last class.

- taking the time out seemed to effect the flow

Handed out the conversion worksheet.

Homework assigned:

- do the student exercise

- study for small test on inertia and W=mg

- Activity 3 page 29

- plus complete the conversion sheet

This class was mainly devoted to explaining the concept of torque, showing the students the units of torque and how to convert between different units, as well as solving problems on torque. An important feature of this class was that it involved a POT demonstration which made use of a torque wrench. The torque wrench demonstration was used to take an actual measure of torque applied in a particular situation so that it could be compared with the answer that the students had calculated in a problem. Gordon briefly explained this wrench enabled the user to know how much torque was being applied when something is being tightened and that this helped to avoid destroying equipment [F-94-09-27; C-94-09-27]. Because of the torque wrench demonstration, this particular class had more connection to technology then most of the others—with the exception of the classes in which labs were done—but still the science concepts were emphasized along with mathematical problems involving torque. Gordon told the students that the concept of torque was important because it was applied in Physics 12 problems [C-94-09-27].

As Gordon covered science concepts in class, he frequently went beyond the science in the POT materials by covering it in more detail and in a different way. When he was planning the lessons on fluid systems in the force unit, Gordon became concerned about the POT materials covering several science topics including density and buoyant force in a few pages without developing these notoriously difficult concepts slowly and carefully so that the students would understand them [F-94-09-26]. In response to this concern, Gordon used a density demonstration from Physics 11 [F-94-10-6] and developed two others on his own to supplement the POT approach [F-94-10-11; F-94-10-13]. He ended up spending an extra class on these science topics in addition to what the POT course recommended and he also went far beyond the relatively simple treatment these concepts received in POT. Because density was a topic that he had taught in Physics 11, he was able to draw on the approach to it he used there, but buoyancy was a topic that he had not previously taught. After checking on the approach a science textbook took to the topic, he developed new demos. The approach that Gordon developed emphasized the presentation of the science concepts to the students while the POT materials presented the concepts only to the extent that the students would be able to understand how a hydrometer functioned. Rather than using the technological system that was being introduced in the POT materials as a means of determining what scientific content was of value in individual lessons, Gordon was attending more so to the traditional organizational schemes used in Physics 11.

Gordon's discomfort with the approach taken in the POT materials to the science concepts is demonstrated in the following excerpt where he is discussing his concern about technology education teachers using the POT materials.

> I'm especially interested myself in technology teachers, just how they're going to take it. Because you know the principles can easily be lost from this, like what we've seen in a couple of places. It's very, very easy to sort of go through the applications and lose the principles underneath, and have them not be done well or even forgotten about, or not connected up clearly or it becomes a little bit of knowledge about a hydrometer or something, without really understanding the physics. [I-94-11-10]

Gordon was concerned about whether the technology teachers who were relying heavily on the POT materials at other pilot sites were able to do an adequate job of teaching the science concepts. He was convinced that anyone without a strong science background who taught the course would have difficulty preparing their students to continue on in physics. He thought that the POT materials were inadequate in their treatment of science concepts and unless the teacher was able to go beyond them, the students would only receive a limited science background.

Gordon's general approach to teaching the classes emphasized the science concepts that would be required for the course to count as a legitimate physics course much more than the POT materials did. At the same time, he gave less attention to the technological and vocational content that was central to the POT materials. When it comes to the microstructure of the course, the individual lessons, Gordon enrolled a Physics 11 approach to the science concepts and even though he did enroll the POT approach to some extent, it was mobilized in a peripheral position. Again, these choices are compatible with the network that Gordon was constructing. While he thought it would be good if the students could benefit from being exposed to elements of the POT approach during the classes, this was not critical in maintaining the enrollment of actors such as the physics teaching community and the students.

Textbooks

Gordon's use of textbooks as he taught the POT course was closely related to the ways that he structured individual lessons. Because the lessons themselves normally made little use of the POT materials, the POT textbooks were not a very effective means of supporting them. Gordon did, however, develop a way of ensuring that the textbooks were used by the students. Gordon did not give the students the POT textbooks for the first few days of the course, but when he started the first unit of the applied physics course he handed them out. At that time, he also handed out a study booklet that he had created to accompany the textbook. The study booklet was made up mainly of fill-in-the-blank questions but also a few problems that were to be completed by the students as they read the POT textbook for a homework assignment. Some examples of the questions that were in the first study booklet are:

> What is a simple definition of a force?
>
> ____
>
> What is the prime mover in each of the energy systems?

Mechanical............... ______________________

Fluid........................ ______________________

Electrical.................. ______________________

Thermal................... ______________________

What is meant by a body being in "equilibrium"?

____

Newton's First Law:
Every body continues in its state of rest or of motion in a straight line at a constant speed unless it is compelled to change that state by forces exerted upon it.
If a rock is thrown in space, far from the influence of any gravitational field, what will the motion of the rock be like?

____

____

Some of the questions referred to content that was from the POT text and would not be found in a Physics 11 text, but this was rare. An example of this sort of question is the one that refers to prime movers in energy systems. The study booklet questions rarely referred to specific technologies or types of technology-related careers that were discussed in the POT text. The focus of most of the questions was the science concepts, particularly those that were part of the Physics 11 course. Sometimes there was information added to the study sheet that was important in the Physics 11 course but was not included in the POT materials. An example of this is the statement of Newton's First Law and the question that follows it. The students were told that the purpose of the study booklet was to help them to identify the important ideas and review the content of the POT texts [F-94-09-15]. The technological and vocational content of the books provided some nice applications for the physics concepts but were not themselves emphasized in the study sheets.

The POT textbooks were mainly used as a reading assignment that was done in conjunction with the study booklet. In class, problems from the POT texts were sometimes used, but otherwise there was little direct use made of them. The problem with the POT textbooks, according to Gordon, was that they did not go into enough depth on the physics topics and did not have appropriate student questions and exercises to reinforce the science concepts that Gordon covered in class [P-95-03-15]. Gordon did, however, feel that he needed a textbook that could support his classroom approach at times and, to get this support he turned to the textbook used in Physics 11. The use of physics textbooks first occurred when he was covering the electronic systems part of the force unit early in the year, and he decided to supplement the content found in the POT materials with Physics 11 content. At that time, Gordon also decided that he should hand out the textbook that is used in Physics 11. When I asked him about why he decided to hand the text out he responded:

> I'm thinking that if I'm giving them a legitimate Physics 11 mark, I think they need a legitimate Physics 11 text, plus I think they should be doing more work and I could be giving reading assignments because there are reading assignments out of the text, you know, on modern physics. What I'm going to do with this electricity part here is they will do the labs as in the POT course and get the whole concept of voltages adding, etc. And then what's going to happen is next Monday we'll do the Kirchhoff's Law Lab, which is now a totally different ball game. Now it's the physics thing.

> Then I'm going to develop the idea of solving simple circuits, but without Ohms Law and I'm going to give them a whole bunch of circuits and they're going to solve them and they're going to have the idea of resistors adding in parallel, in series, etc. [D-94-10-31]

Even though the Physics 11 textbooks were not used extensively in the course, Gordon thought that it was important that the students be exposed to a "legitimate Physics 11 text" if they were to receive a "legitimate Physics 11 mark". This association points strongly to the network that Gordon was building around the course. Many of the important human actors that he was enrolling were very concerned about whether the applied physics course could be a legitimate physics course. As was shown in the last chapter, the POT textbooks had been one of the major points upon which the applied physics course was being criticized by members of the physics teaching community. Although Gordon enrolled both the textbooks into the network, the peripheral role that he assigned to the POT textbooks and the more central presence of the Physics 11 textbook was a move that allowed him to continue to successfully translate the interests of all the important actors into the course. The use of the textbooks is best understood as a means of working the whole network.

Lab Materials

Gordon enrolled laboratory procedures and equipment into the network in a way that is somewhat different than the way he enrolled the other nonhuman classroom actors that have been discussed so far. Most of the nonhuman actors that are associated with the POT materials and the ones associated with a Physics 11 approach are usually treated as if they are in opposition, in that either one or the other was centrally enrolled at a given time. In the case of the POT lab materials, though, there were some special circumstances. Gordon did not see them as being in conflict with a Physics 11 approach at all and thought that they may offer a way of overcoming a problem he saw with the Physics 11 approach. In the following excerpt, he describes that problem.

> It was becoming too theoretical. The labs just were not great. I mean, you talk to some teachers and the fact is the labs are just not that great and also they didn't seem to be that practical. So I found myself doing less and less of the lab work, more and more of the theoretical and I thought, "No this isn't right, something has to change here." [I-95-06-23]

He saw the POT lab materials as an opportunity to improve this situation but also recognized that these were new and that incorporating them into a new course would require a great deal of work.

> I knew that a change was due. I was a little bit unhappy with the Physics 11 course, it was missing something, so there was this great anticipation but there was also a fair bit of apprehension because I thought, "Well the labs are different, the equipment is different." [I-95-06-23]

As the above excerpts show, Gordon saw the POT lab materials as a resource that could improve the teaching of physics to students. After having some time to look at the equipment, Gordon's enthusiasm for using it in the applied physics course only increased as he thought that more students would take and enjoy the physics course because of it [I-94-11-10]. He also thought that they would be exposed to "state of the art" equipment that they were likely to encounter in work or post-secondary settings [D-94-11-03]. This provided a different point from which to consider the use of the lab materials in the applied physics course. In general, Gordon treated the POT lab program as an important actor that could be enrolled into the network and mobilized in a central way that would be useful in translating the interests of the other actors. This is quite different from the relatively peripheral position in which the other POT resources were mobilized into the network.

From the very beginning of the course, Gordon was excited about the POT lab materials. He began to test out some of the labs during the summer before the course started, and he decided that several of them were suitable for use in the applied physics course. I became involved in helping Gordon to test out the labs on my second day at the school, and we continued to do this through the school year. In these lab sessions, we usually began by following the POT lab directions and worked through the labs just as students would. Sometimes the labs worked out well and Gordon decided when they should be used in the course. At other times, the labs required some small adjustments for the sake of clarity, safety, or time efficiency. If this was the case, we usually discussed the lab and decided what changes were required. There were other times, however, when Gordon decided that the labs were unsuitable for use in the class. There were several reasons why he made this decision. At times, the equipment or the lab procedure simply did not work, or the lab did not appear to have enough educational value to justify the time it would take to complete it in class. In such cases the lab was either not used, made into a short demonstration, radically altered, or replaced with another lab from Physics 11 or another course.

The judgments that Gordon made about the labs with respect to such issues as safety or effectiveness are reasonably straight forward. The reasons for including or excluding other labs, however, were less obvious. In one such case, Gordon and I worked on a lab involving the measurement of pressure with a manometer. The apparatus that was assembled according to the lab directions was very complex and took a great deal of time. An airtight system had to be constructed from plastic tubing and other components so that a manometer, pressure gauges, and a pump were all part of the same system. It took us more than one hour to set up the lab. The directions for completing the lab once the apparatus was assembled were unclear and we found them difficult to follow. As it turned out, the point of the lab was simply to notice that the manometer and the pressure gauges—two different technological systems—both indicated similar pressures but used different units as the pressure in the system was changed with a pump. Gordon decided that this lab was not worth doing because it required a lot of time and effort and had little to contribute to the concept of pressure that the students were working on in class. Because the equipment was interesting and the students would benefit from seeing a manometer, he decided to use it as an in-class demo that was set up in advance [F-95-09-15; F-95-09-19].

On another occasion, Gordon decided against doing a lab he had tried out in class and considered the possibility of using it as a demonstration instead is seen in the following:

> Now I think that we'll leave out the winch lab, although it does deal with applied torque causing a rotation. Okay, now I did the lab and I found it to be, there was so much in there. I mean you're counting the teeth and you're measuring off this to this and this to this. Maybe that is the way to do the torque. I'll look at the lab again but I'm not keen on it. [D-94-12-01]

In this case, Gordon thought that the winch lab had some value but was too complicated to justify using class time. Although he considered using it as a demo, in the end it was not used at all. This excerpt also suggests that Gordon was more interested in the lab for its value in teaching the concept of torque than he was in using it to have the students become familiar with a winch.

Labs that did not appear to contribute to the conceptual content of the course were not usually used. An important factor in deciding whether to use particular labs was the extent to which they could help students understand the physics concepts they were covering in class. An example of a lab that was judged by Gordon to have little value was one that involved using a conveyer belt to move metal objects. After measuring the rate of the belt in rotations per minute (rpm) and objects moved per second, the POT lab book simply asked the students how the situation could be changed so that more objects would come off the belt. The suggested answers—speeding up the belt and moving the objects on the belt closer together—seemed rather trivial to Gordon and he decided that this lab was not worth doing because it did not contribute to the concept of rate that was being developed in class [F-94-11-04]. Gordon's decisions emphasized the fit of the lab into the development of concepts that were important in Physics 11 and, therefore, the value of the lab for teaching about technology may have been underplayed. The lab book did not do a great deal to point out the technological value of the conveyer belt lab other than to state that such systems are often used in industry to "transport materials, such as sand or gravel" or to "move objects, such as parts or assembled units, from one point to another on a production line within a plant" (ECI, 1995). It is possible that the technological importance of this system could have been further developed, making reasons for doing the lab more apparent. The problem is that technological systems are not normally emphasized in physics teaching, so Gordon may have seen less value in enrolling this lab as an actor in the network. Even though he was clearly concentrating on the science concepts as he planned the lab program, Gordon was not opposed to the technological content. On several occasions, he indicated that he was willing to include more technology-based content and also did, from time to time, make an effort to do so. Although labs that were clearly connected to science concepts had a greater chance of being enrolled in the network, this category of actors was somewhat negotiable and it could be that new places may be found in the network for labs emphasizing technology.

Some POT labs that did not emphasize the physics concepts enough were replaced by labs that were used in Physics 11. One such POT lab involved measuring voltage drops when resisters were placed in a series circuit. The lab worked very well and there was clearly great value in working with the equipment, but Gordon was disappointed that the lab did not go further and discuss how the potential differences across the resistors in the loop added up to the total voltage put into the circuit. He thought that such an approach would have been a nice lead in to Kirchhoff's Law—an important aspect of the Physics 11 course that was not mentioned in the POT course [F-94-11-04]. Despite the value of becoming familiar with the technology used in this lab, it was replaced by a similar one that Gordon used in Physics 11. Like the conveyer belt lab, this one was not judged as an adequate resource to teach the physics concepts. In this case, though, a new actor was enrolled into the network in its place because Gordon thought it was an important to have a lab that supported the development of the concept yet was dissatisfied with the POT lab.

When it came to the lab program for the applied physics course, the POT materials were mobilized in a very central way. Other lab resources, whether they were from the Physics 11 course or newly created, only became central at times when the POT materials did not provide a lab that could be used in a central way in the network. At these times, the requirements for a lab being a resource in the network became evident. There were, of course, practical considerations, like safety or whether the lab worked, but there was also the matter of the support that the lab was able to give to the science concepts that were being developed in the class. Again, the role the lab could play in the whole network was the basis for the decisions.

The Whole Network

The difference between the way the POT lab program was mobilized and the ways that other aspects of the POT program were mobilized raises an important point. Of all the POT materials, the lab procedures and equipment were given a very central position in the network because the interests of the physics teaching community were easily translated into the new course. Translating the interests of the physics teaching community into a course that used other POT materials, however, was far more difficult. Some of the POT materials that other physics teachers had reservations about were only used in a peripheral way so that the interests of the physics teaching community could be translated, while POT materials that had a clear conflict with these interests were often not used. The translation process is crucial in determining which classroom resources get utilized and, if they are, how they are utilized.

The process of enrolling and mobilizing actors at the classroom level is best understood by considering the whole network. In other words, the parts of the network that are being constructed inside *and* outside the classroom are tied closely together. An appreciation of these close ties is gained by considering actors such as textbooks. The POT textbooks had to be mobilized in Gordon's applied physics course but they were put in a peripheral position because they were seen as having limited value when it came to teaching science concepts. The emphasis of science topics became a necessary part stabilizing the network around the new course which had to include other physics teachers, students and their parents, and other groups like universities. The POT textbooks had been the basis of a critique of the course by a member of the physics teaching community that centered on the opinion that they were not effective resources for teaching physics concepts. Gordon's peripheral mobilization of the POT textbooks became of value in convincing other groups that, although he was including an applied emphasis in the course, he was also going to be able to provide students with a strong physics background. If he had mobilized the POT textbooks in a central way he would have had considerable difficulty enrolling other actors. Looked at in this way, decisions about enrolling and mobilizing textbooks and other actors associated with the classroom are complex issues that require an understanding of the larger network that is being worked.

Chapter 7

Piloting Applied Physics: Translations and Networks

The account of planning and teaching the applied physics course that I have developed in the previous two chapters locates Gordon and many other human and nonhuman actors as participants in a network. The analysis to this point has concentrated on Gordon and I have presented him as the central actor in the network who is actively enrolling and mobilizing other actors. This is a limitation of choosing one actor in a network as the main focus of study: the other human actors appear to be less actively engaged in *working the network*. In this chapter, I will step back and provide a brief overview account of the network that was constructed around the provincial initiative that led to the piloting of the applied physics course at LMSS. Rather than place a human actor at the center of the network and follow him as he works the network, I will follow the applied physics course as it went from a vague concept at the initial meetings where it was first suggested to an actual course that was enacted in a classroom at LMSS. As it does this, it will pass through the hands of many actors and undergo transformations as their interests are translated into it. This analysis will provide an assessment of the degree to which the interests of all the actors in this larger network were successfully translated into the course.

The Birth of Applied Physics in British Columbia

Nationally and internationally, schools have been asked to reconsider the ways that they prepare students, through science and technology education, to fill jobs in business and industry (e.g. Canadian Chamber of Commerce, 1994). In Canada, it is claimed that if there is an undersupply of students who can enter into these jobs without massive training initiatives being undertaken at industry's expense, industries will not be able to compete in the global market. This has resulted in pressure being applied on the educational system in an effort to make it more responsive to the needs of industry and, it is argued, the eventual needs of students—the ones who will need to be prepared to fill these jobs if they wish to maintain a high standard of living. The British Columbia Provincial Government, and the Ministry of Education in particular, were concerned about the perceived unresponsiveness of the education system to the needs of industry (Ministry of Education, 1993). In 1993, the Ministry of Education and the newly formed Ministry of Skills, Training and Labor organized, and were involved in, a number of forums held throughout the province with representatives of school districts, business, labor, students, trustees, parents, governments, and agencies (Business Labour Education Advisory Committee, 1995). Many of the recommendations that came out of this forum contributed to the formulation of the Government's *Skills Now!* initiative in 1994, aimed at restructuring British Columbia's educational system to meet the new demands of the workplace (Ministry of Skills Training and Labour, 1994; 1995b). *Skills Now!* was primarily the responsibility of the Ministry of Skills, Training, and Labour but an agreement, referred to as the Memorandum of Understanding to Enhance

Provincial Career Education Opportunities, resulted in a collaborative project with the Ministry of Education (Ministry of Skills Training and Labour, 1995a).

As a result of this agreement, the Ministry of Education began to develop ways of improving the pathways from secondary education to post-secondary education and careers. Part of this effort involved consideration of how senior secondary physics could be made more accessible to a larger number of students and also more relevant to the growing number of careers that require a physics background. Applied physics courses that were already being taught in one school district and at a technical institute in the province were making use of course materials called POT. These materials were highly recommended by those working in the existing programs, and they were endorsed by representatives of business/industry, labour groups, community colleges, and schools at a conference that was held in 1994 (Ministry of Education & Ministry of Skills Training and Labour, 1994). As a result, the decision was made to fund several pilot sites to develop and offer applied physics courses at the Grade 11 level in British Columbia schools using the *Principles of Technology* materials.

Applied physics was underway. The concerns of large business lobby groups and those of British Columbia business/industry, labour, schools, community colleges, and other groups were translated into a provincial initiative. With the support of many of these same groups, the provincial initiative that involved secondary education had part of its mandate translated into the concept of an applied physics course, and then into a set of curriculum materials. The Ministry of Education had mobilized a powerful network of diverse groups and in one massive act of translation, at a conference, all of these groups made it known that their interests would be best represented by having secondary teachers in the province teach an applied physics course using a particular set of materials. The calls for proposals to be a pilot site were sent out to schools shortly thereafter.

From the perspectives of any of the groups involved so far, the agreement to pilot an applied physics course can be perceived as that group enrolling the others in what it wanted to do in the first place. Trying to look at it from the perspective of the course itself, though, all of the other groups had been enrolled: business/industry was going to get an initiative in the education system that was designed to fulfill the needs they had identified; community colleges were going to get more students by becoming better integrated with both the school system and industry; the students were going to feel that they were being taught something in school that would lead to real jobs when they finished; and schools were given a way of responding to calls to better prepare students for jobs. The course went from the expressed needs of various groups, to a general concept of an applied physics course, and then to a concept that was embodied in a set of course materials that were about to be given to schools.

Becoming a Pilot Site

In the spring of 1994, school districts were invited to apply to have one of their schools become a pilot site for applied physics. Eight school districts in British Columbia were funded by the Ministry of Education to develop and teach applied physics courses. One of the schools that ended up piloting the course was LMSS and their experience has been the primary focus of this research. In the piloting agreement that was signed between the school district and the province, the Ministry of Education was responsible for providing specified financial support, arranging meetings for the pilot teachers, and organizing meetings of two overseeing committees. The school districts were responsible for: (1) purchasing and piloting the use of applied learning resources produced by the Center for Occupational Research and Development (i.e. the *Principles of Technology* course); (2) identifying an employee to represent the district on an applied academics working committee; (3) organizing an advisory committee of representatives from post-secondary education, business, and labour to advise the pilot school district and the Ministry on the process and suitability of the applied courses; (4) working with post-secondary institutions to arrange acceptance of the credentials resulting from the applied course for entry into appropriate post-secondary programs; and (5) various reporting duties with respect to the process and results at the pilot sites as well as project administration. These arrangements were unique in the attention that was given to involving post-secondary, business, and labour groups in an advisement role. This arrangement had the potential to bring these groups into contact with school administration and teachers, a type of contact which has been quite rare in the past.

To administrate the pilot projects two committees were established. The entire project was overseen by a steering committee that was made up of representatives from the Ministry of Education; the Ministry of Skills, Training and Labour; business/industry; labour; public school districts; the British Columbia Teacher's Federation; and post-secondary education. In addition to the secondary school pilot project, the steering committee oversaw another related project at the post-secondary level. Reporting to the steering committee was a pilot working committee which involved representatives from the two Ministries, business, post-secondary, and also representatives from each of the school districts or schools acting as pilot sites. This committee was concerned with the secondary school pilot project only. The members of the working committee that were associated with one of the pilot sites reported to that committee on their pilot site's progress and contributed to the discussion of the value of applied courses and the type of approach that would be most suitable in British Columbia. Except in rare circumstances, none of the teachers who taught the applied courses at the pilot sites attended the meetings of the working committee.

A translation was in the works. The schools wanted to pilot the applied physics course for some reason or other. The reasons why LMSS wanted to pilot the course will be explored in the following section but, for now, we can see that the form of the course has been altered again. In addition to the course materials that the schools purchased, there were some additional requirements that were laid out in the piloting agreement. The Ministry took additional steps to support the introduction of these materials to the pilot schools by requiring that advisory groups be established at each school and by arranging for some interaction between the pilot teachers. A structure of reporting and accountability was also put into place to monitor the progress at the pilot sites and to ensure that they were meeting the commitments they made when they agreed to become a pilot site. The form of the course changed so that it included new elements, in addition to the curriculum materials, that made the course more able to represent the interests of all the groups that had been enrolled in the network. The Ministry needed to have the pilot sites be accountable for what they did with the money they were given but, in addition, measures were taken to put the schools in direct contact with some of the other groups who were already enrolled so that these groups could ensure that their interests continued to be represented.

At the Pilot Site

The administration at LMSS had become interested in developing an applied physics course using the *Principles of Technology* materials before the Ministry decided to offer the opportunity for schools to apply to become funded pilot sites. At the time that the call for proposals to be a pilot site was circulated, LMSS was already in the process of finding financial resources within the school and school district to purchase the materials, so the chance to be a pilot site was a fortunate turn of events for them. They subsequently applied to be a pilot site and were granted that status and financial support from the Ministry of Education. Much of LMSS's initial interest in applied physics had to do with the role such a course could play in an initiative that was being undertaken in the school to make changes in the technology studies department—the department had formerly been referred to as industrial education. In the following excerpt, the principal describes the difficulties they were having with the industrial education department and the efforts that were made to solve the problem:

> I asked the department head to work with the department and see if they could come to grips with this obviously serious situation and in the first year we were not able to do that. Nothing much changed so, based on student enrollment, we drastically chopped programs. . . . And so we were left with a much smaller program and about this same time the

> department head started his pursuit of ways of bringing a whole new look at what was not to be industrial education but tech studies. How could we do this? Where were we going? Not just here, but right across North America the old industrial ed had died, everywhere it had died. And so what do you do to replace that and changes need to be made. The department head went off to conferences to learn about this special [applied physics] program that [Gordon] is doing and I gave him just top marks for seeing the need and starting to have some sort of viable solution to a problem that no one seemed to be advancing. [I-94-12-12]

The school administration was anxious to start an applied science course to support the general movement towards establishing a technology studies program. This effort within the school was being made to respond to the wishes of students and their parents but was also made necessary by the financial reality the school was operating in as well as the general educational trends of the time. The decision to develop new technology studies courses to respond to demands to provide students with the science and technology background they would need to enter the workplace was one that they hoped would bring greater vitality and popularity to the program.

The technology studies department head was a central figure in re-aligning the department and he saw the applied physics course as an opportunity to shape the department's goals to respond to calls from employers. This would result in students receiving a stronger background in science and technology. He describes the task he was faced with as follows:

> I was involved in curriculum development for the transition from industrial education to technology education and all these things identified a need for a different type of student to be exiting the Grade 12 year than was currently happening. And the major area, and one that applies most to this project, is that the students that had been doing well in technical courses and often succeeding in post secondary and getting jobs, they did not have the math and science background that was becoming increasingly asked for by employers. And we heard this over and over again. Various advisory committees would sit down and map what a typical student should have on the completion of Grade 12 and the math and science seemed to come to the front constantly. So I began looking at this. . . . Well, in reality in our schools most of the technical students, most of them are boys, and most of them go through with minimal math courses and virtually no physics courses. [I-94-12-15]

The department head eventually encountered the POT materials and saw them as a way of responding to this problem.

> And that's what really kicked it off; it was the presentation by the people from CORD and some of the curriculum developers that got me thinking that this just may be what we need in this province to address the situation of students not pursuing academic science while they're still in technical programs . . . . And I felt that one school in one district should at least take a look at the curriculum, including being the place for the pilot. We started

> making plans at [LMSS]. Fortunately the Ministry also decided that schools should become pilot sites and funding was arrived at and we were ready to go in September of 1994. [I-94-12-15]

To the department head, who was trying to restructure the old industrial education program at his school, the POT materials offered support for the project he was engaged in and he was, therefore, very interested in using them in the school.

The applied physics course had made some new translations and was on its way to entering a technology education classroom. It was an easy translation. What the school wanted was a bit different than what the other actors who had been enrolled wanted but it was compatible. The applied physics course was able to take into account the additional interests of the technology education department head in his attempt to work towards establishing a technology education program in the school. This was a relatively smooth translation but there were still other groups that needed to be enrolled before the course could get to the classroom.

<u>When good translations go bad</u>

As I described in an earlier chapter, very few students initially signed up for the applied physics course that was offered within the technology education department. The course was not popular with the students and their parents, and this was attributed to the fact that it did not lead to credit that was equivalent to that given for Grade 11 physics, a credit that is important for university entrance. In other words, as the technology department head first offered the course in the school, he was unable to get enough students to sign up. The students who were intending to go directly to work or to other career preparation programs such as trades or community college programs were not interested, and students who wanted to go to university were not interested unless they received credit for Physics 11. In consultation with the principal and the science education department head, it was decided that Gordon would need to construct the course in a new way in order to recruit enough students. This new construction involved having the course prepare students to write an exam for Physics 11 credit and having an experienced physics teacher teach the course. This new construction primarily attracted students who wanted to go to university and enough of them so that the course could be offered in the following year.

Compared with the relative ease with which the technology department head had been able to translate the MOE's interests into his own when the school became a pilot site, translating the interests of students and their parents was quite difficult. Substantial adjustment to the type of course that was to be offered had to be made in order to enroll students and their parents. Gordon had to alter the course he had been planning to offer and may have ended up not being able to contribute much to the development of the technology education program because most of the students in this course were there to get Physics 11 credit. As for the course itself, it survived the change but it had been unable to translate the interests of students in the form in which it had first been proposed at the school. By changing the course in an effort to increase the number of students who signed up, new interests were translated into the course. Now it was going to have to prepare students for an academic credit. It was becoming less clear that the course was still a good translation of some of the interests of the actors who had originally been enrolled into the network. While they had talked a lot about jobs, trades programs, and technical programs at community colleges, they had not said much about preparation for university.

Applied Physics in the Classroom

I have already described how Gordon enrolled several groups such as the physics teaching community, in his version of the applied physics course as he taught it, but I did not say much about the relation that Gordon had with the many of the key groups who were involved in the provincial piloting initiative. An aspect of the piloting that was emphasized in the Ministry of Education's conditions for being a pilot site was the formation of advisory committees that brought together the school, local business/industry, and local post-secondary educational institutions. The direct involvement of these groups from outside the school in educational programs would have been rather novel. These groups were expected to advise the school on the piloting process and the suitability of the course that was developing. They were also expected to make decisions regarding credentialing matters. The process is not necessarily collaborative as the wording of the piloting agreement does not recognize any expertise the school personnel may have but, rather, positions the outside groups as experts, even in educational matters. Nonetheless, the advisory committees had to be formed as a condition of being a pilot site, so the school was expected to work at translating the interests of these groups into the courses they were planning and teaching.

At LMSS, the support of local business/industry and post-secondary institutions was secured for the purposes of applying to become a pilot site, but there was little involvement of these groups during the time the course was being developed and taught. The principal said that she was unaware of who the school's post-secondary and business/industry partners were in the project.

> I have no idea what specific articulation we have set up from this, I have no idea. [The technology education department head] could tell you that. I have to say I have not asked that question and I don't know the answer. [I-94-12-12]

The technology studies department head was the one involved in gaining the support of these external groups, but these groups had not been involved beyond that point. As the department head explains, there is a problem with having the external groups being more involved:

> [There is a] problem that exists because the Province, Ministry of Education, has asked for these partnerships to be established before pilot sites begin. And so that was done on paper but in fact very little is happening in these partnerships because both partners need to know how the course will be credentialed and how it will be presented in the school before some decision can be made. So the partnerships exist virtually on paper today. [I-94-12-15]

At the school, the involvement of the external partners was limited to one of indirect support for the initiative. The reference to credentialing illustrates the sort of involvement that was anticipated by the department head as well as the other partners. The involvement of the partners in the course itself in roles of, for example, advisors to the teacher or guest speakers was not considered. The extent of the partnership seemed to hinge on accepting the course as credit towards entry in post-secondary programs or jobs.

A representative of a large corporation that was providing "paper" support for LMSS's applied physics course explained that their involvement came about as a result of their concerns about finding skilled employees in the future, particularly in the trades areas. When asked about the corporation's position on accepting applied physics and other applied courses when hiring, she said that they were not yet ready to do that.

> I know that [our corporation and another large one] were favorably impressed with the Tech Prep [i.e. CORD or POT] stuff that came up and I don't see any reason why that should change. But, in terms of getting that official endorsement and change, then there would have to be something more concrete for [this corporation] to run with it. [I-95-07-14]

This excerpt demonstrates that, as the technology studies department head suggested above, there is some hesitation on the part of business and industry to move beyond general support and deal with accreditation issues. It is apparent that there is some role confusion as the Ministry of Education expected that the outside partners would be able to make credentialing decisions based on their involvement with the course but it appears that the school and, presumably, the outside groups, were expecting the Ministry to make this decision. In effect, the usual minimal involvement of outside groups in school programs was maintained.

Like the principal, Gordon did not initially know about the outside partners or the role the Ministry of Education expected them to play. On one day early in the school year, several representatives from a local community college—an outside partner—visited the school to get some basic information about the course and to talk with the technology education department head. They seemed to be exploring the issue of giving credit for the course in addition to the regular academic physics courses that they already accepted [F-94-09-20]. Gordon had no other interaction with the partners and, early in the year, did not even know that the course was being offered as part of a Ministry of Education sponsored pilot. As he put it:

> I wasn't aware that it was being done all over BC with different pilots at all. I thought that, basically, I was the only one doing it and that there was somebody in [another town] that was doing a course similar to this. That's all I knew. In fact that very first meeting that we went to at [a community college], I was surprised. I didn't know that there were all those people. I mean I didn't know that we were part of this thing called applied academics and *Skills Now!* and everything else. [I-95-06-23]

From his perspective, he was just the teacher at the school who was selected for the course and was just responsible for developing and teaching a course using the materials and lab equipment he was given.

> [The technology education department head] just handed me this set of books and I then took them and then he was going to discussions about the equipment and the next thing you know the equipment is here at the school. Things were moving and so basically I just had these books and this material. So I've been working on my own. [I-94-11-10]

Although Gordon initially found the technology element of the course interesting, he was told that it was most important that he cover the physics content as a first priority [I-94-11-10]. Gordon took the purposes of the applied physics course to be the same as those of Physics 11 and had no indication that there were other goals that the pilot sites were expected to attend to for the first six weeks of the course. Gordon was not initially made aware of the Ministry of Education's or even his school's reasons for piloting the new course. To teach the new applied physics course, Gordon received a set of course materials for the POT course and, as was described in the preceding chapters, enrolled into the role of an enroller of particular sorts of groups, including members of the physics teaching community, universities, and students who wanted to go to university.

Representatives of the groups whose interests had been enrolled in the initial stages leading to the piloting of the course, such as business/industry and community colleges, had little or no contact with Gordon through the year. It was not that Gordon refused to be involved with these new groups but, rather, that there were no arrangements for such contact made. Part of the reason for this was that the technology education department head handled the contact with these groups. He got their support "on paper" in order for LMSS to qualify as a pilot site but apparently had little contact with them after that. This was not so much a case of any one person being neglectful as it was a case of groups who normally had little contact with each other being unsure what the Ministry expected or what they could be doing. The community college and business/industry partners did not seem to want to be directly involved, indicating that they needed to see the "concrete" results of the pilot course. Even the committee that was set up to oversee the pilots of the applied courses in the province only had contact with the technology education department head. Although this committee did receive reports on the progress of the applied physics course, the teacher did not meet the committee and did not have to translate their interests in any way that went beyond using the POT course materials.

As the course went from a general concept to something that was being initiated in schools, its form was changing. From the beginning the course had been translating interests of the groups who were behind the provincial piloting initiative and had become a complex mix of materials and advisory committees that ensured it would be able to continue to translate all the interests of these initial actors. Everything seemed to be going smoothly at LMSS until the problem of translating student interests arose. When the course became one that would lead to credit for Physics 11, everything except for the materials changed. The interests that were then to be translated were those of the physics teaching community and students who wanted to go to university. New materials, like Physics 11 textbooks, were introduced into the course. All of those translations that seemed so important at the beginning of the piloting initiative were less so now, and trying to make these translations at LMSS may have led to problems such as having members of the physics teaching community openly criticize the

LMSS version of the course. The network around the course had taken a radical shift as it was being enacted in the classroom. This was not necessarily bad though. Despite loosing many of the original actors, or having to mobilize them in the periphery, there was a reasonably stable course that was taking shape at LMSS.

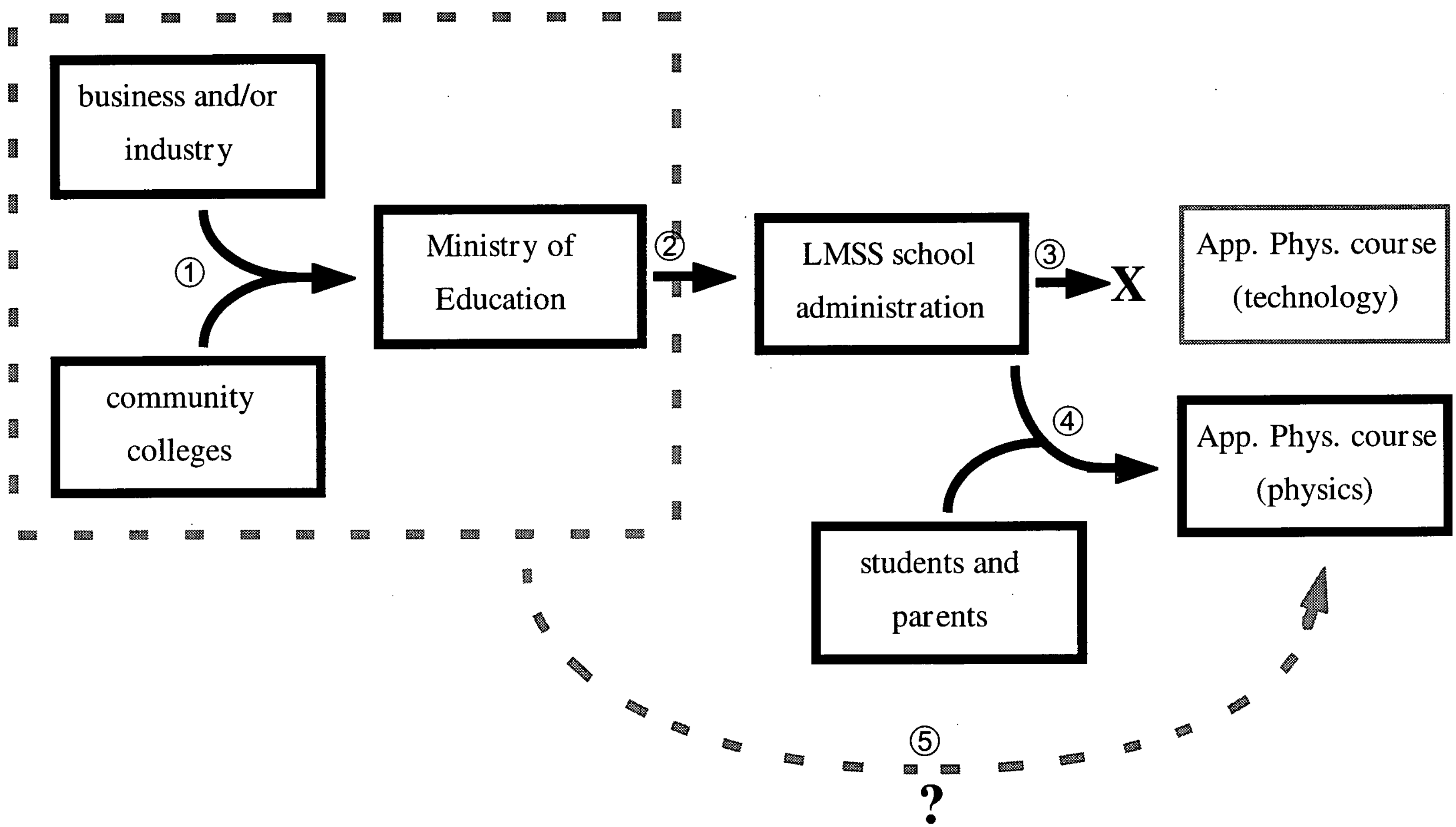
Translations Continue

The networks that various actors were trying to construct through the translations that were described in this chapter are not complete. No stable form has come about that would place the applied physics course along side other courses like Physics 11 as stable and accepted components of the educational terrain. The successful stabilization or eventual failure of the applied physics networks will come about in the future.

Chains of Translations

The movement from the business/industry lobby towards Gordon teaching the applied physics course can be interpreted as a series of translations. These translations occurred in a rather sequential fashion with new actors being enrolled along the way. Figure 1 provides a sense of how this occurred. The arrow on the diagram labeled with the number 1 represents the initial translation in which business/industry and the community colleges (along with some other groups) argued that a particular set of problems they were encountering could be solved by making changes in the education system. The MOE translated these concerns into a course of action (number 2 on diagram) that involved creating a

Figure 1. Translations of the applied physics course



new applied physics course. The strategy for initiating this course was to support several pilot sites which were expected to used course materials that had been recommended and having them report back to the MOE on the status and progress at the site. An additional requirement that pilot schools had to meet was the establishment of an advisory committee so that the concerns of business and industry could be addressed in the course. The interests of the MOE (and business/industry) were translated into the proposal made by the administration at LMSS. Using this course to move from an industrial education model towards a technology education model at the school by offering a course that integrated an academic and applied subject was a way that appeared to link the interests of the school with the interests of the MOE. Despite the successful translation of the MOE's interests, the school administration's plan for bringing the applied physics course into the school was initially unsuccessful (number 3 on diagram). Any course that is to be offered in a high school, where students make choices about the courses they take, must translate the interests of the students and their parents into what will be done in the classroom, and the applied physics course was initially unable to do this. As a technology education course it was not viable: It was not able to attract students who were enrolled in other technology education courses nor was it able to attract students who expected to enter university. As a science course that led to Physics 11 credit, however, it was able to translate the interests of enough students and their parents to make the course viable (number 4 on diagram).

The translations that were involved in the piloting of the applied physics course are better described as a chain than as a web. The linear nature of the translations that were made does not have any features that result in the groups on the diagram being linked to the ones that come immediately before or after them. The linear nature is illustrated by noting the extent to which Gordon was able to translate the interests of business/industry, community colleges, and the MOE in the course he taught is questionable (number 5 on diagram). With reference to the diagram, it becomes less likely that the interests of the groups to the left side are satisfactorily taken into account with each successive move to the right. Mechanisms—that is, the advisory groups—set up by the MOE in the agreements they made with the pilot sites were intended to prevent this but did not materialize, so Gordon was not in a position to consider the interests of these groups. Gordon was given the POT course materials but any contact with outside groups associated with the pilot was usually taken care of by the technology studies department head. This is not to say that Gordon was not trying to translate the interests of other groups into his course. The previous chapters clearly show that he was very concerned with doing this but those groups, of course, were the ones who were associated with academic physics education rather than those involved in the organization of the piloting of the course.

An early step in the chain of translations involved identifying a set of course materials that appeared to be able to embody the interests of business/industry, the community colleges, and the MOE. These are the only actors that were enrolled into the early stages of the piloting process that Gordon had to enroll into the version of the applied physics course. Even the technology studies department head, who originally wanted a version of the course that appeared to easily translate the interests of the MOE, was forced to adjust his plans and support a physics version of the course. Once Gordon was in the classroom using the materials, the other groups involved with the piloting process seemed content to leave him alone. This may have been a way of respecting his autonomy or it may be that the outside groups were so unaccustomed to interaction with teachers and school personnel that they decided not to get too involved. They may also have assumed that the Ministry of Education was able to represent their interests and speak on their behalf. The catch here, and I will say more about this in the next chapter, is that Gordon is already involved with many other groups. The nature of this involvement was described in earlier chapters. Rather than looking at teachers as isolated from other groups, it may be necessary to explore how they are already involved and look at changing this as part and parcel of changing science and technology courses.

Chapter 8

Conclusions, Implications, and Further Research

In this chapter, I outline the conclusions of this research and suggest implications that the work has for several areas of educational research and practice, as well as for further research. In the first section, I state the claims that I am making in response to each of the research questions. In the second section, I discuss several themes that are central to this research and the implications that the research has for each of them. Finally, in the third section, I suggest several areas of further research that should be pursued on the basis of these findings.

Conclusions

In this section, conclusions are given in response to the research questions. Following the underlined re-statement of each of the research questions, individual claims pertaining to that question are given in italics. Each claim is followed by an elaboration of the claim in regular type.

<u>How does the teacher of the applied physics course *work the network* as he plans and teaches the course?</u>

The type of network the teacher was enrolled into pre-configured the general sort of network he had to build. As a starting point for appreciating how Gordon worked networks, it is crucial to be aware that he was enrolled and mobilized into a particular type of network himself. The nature of this network set the stage for the sort of network he would to be constructing. A great deal of translating had gone on before the course came to Gordon's school. These initial translations, however, were not very influential because Gordon became more concerned with translating the interests of groups that were needed to support the LMSS version of the course. The disjuncture between the provincial network and the local network at the school was inherited by Gordon, not created by him. It is reasonable to assume that, in educational initiatives, teachers are often enrolled into local networks that have little to do with networks that have been responsible for bringing the particular initiative to the school. This finding explains how educational change initiatives in classrooms sometimes do not correspond well with the intentions of the outside groups that developed the initiatives. The finding also suggests that when writers like Fullan (1991) and Sarason (1982) say that reform initiatives almost always fail, they may not be appreciating the complexity of educational change. While educational reforms may appear to have failed from the perspective of networks involving policy-makers and other outside groups, they may be quite successful from the perspective of local school-based networks. The problem seems to be that these two networks sometimes remain relatively independent.

The teacher actively engaged in processes of enrollment, translation, and mobilization as he built a network around the course. In exploring the network that developed at LMSS, it is clear that Gordon took on the role of working the network—that is, enrolling other actors by translating their interests into those of the project and mobilizing them in such a way as to increase the strength of the network. This moves the role of the teacher far beyond that of someone who simply implements the curriculum to that of a key player in a large network of diverse actors. The role of the teacher in educational change is often taken as being separate from groups outside the school (e.g. Fullan, 1991) and images of the isolated teacher working behind the classroom door often prevail (Lortie, 1975). This research presents a very different image of a teacher as an active network builder.

The parts of the network that are outside the classroom and inside the classroom are two parts of a whole network. In the analysis chapters, I made reference to the *whole* network. The whole network is a mix of human and nonhuman actors that are located inside and outside the classroom. The distinction that some writers have upheld between outside influences and what occurs in the classroom (e.g. Kliebard, 1988) is challenged by the analysis presented in this research. Although, I upheld the distinction for organizational convenience in the first two analysis chapters, there was a degree of linkage where, for example, teaching communities and textbooks used in class became intertwined. The network that the teacher was working was not interrupted by a dividing boundary at the classroom door. This finding is a necessary preface for the two sub-questions of this first question. The division that is implied by the sub-questions applies to where it was that the teacher was working the network rather than a disjuncture in the network.

How does the teacher *work the network* outside the classroom?

Existing networks preconfigured the actors that the teacher had to enroll in the network he was constructing. Networks that were already established before the applied physics course was undertaken, such as that of Physics 11, played a very important role in the way that Gordon worked the applied physics network. At LMSS, students and their parents wanted a course that would work as if it was a Physics 11 course, mainly so that the students would have an opportunity to enter university. The network that the physics teaching community had historically participated in involved university programs as well as parents and students. Making his course like a physics course meant that Gordon needed to build a network around the applied physics course that was like the one that already existed around current physics courses. This requirement meant he had to enroll the physics teaching community into the applied physics network. In a sense, his network had to become part of the same one of which they were the gatekeepers. If that physics network had not previously existed, the initial requirements in his network building task would have been different.

Successful translations of another group's interests required an awareness of the network that the group participates in. Translating the interests of a group like the physics teaching community in order to enroll them in his applied physics network, meant that Gordon had to be aware of who the other actors were in the physics network and also what the relationship between each of the other actors and the physics teaching community was. This was best demonstrated in Gordon's presentations to physics teaching community members. He knew that their relationship to university physics and engineering programs was important and emphasized how the applied physics course would not weaken, and may even strengthen, that relationship. For this reason, enrolling actors meant knowing about the networks of which they were already part.

Enrolling one group often resulted in the indirect enrollment of several groups. When a group like the physics teaching community was being enrolled into the applied physics network, other groups like university physics and engineering programs came with it. As pointed out above, the physics teaching community already had a strong relationship with these university programs and, because of that, the physics teaching community was able to represent their interests in high schools. The courses taught and endorsed by the physics teaching community were accepted for credit in university. Small changes and variations in these courses were not so much an issue for the university to become involved with as they were for the physics teaching community which kept watch over such changes to ensure that the rigor of the courses was maintained. As Gordon argued for the merits of the applied physics course, he did not have to convince actors from the university or groups of professional engineers; he convinced physics teachers who represented the interests of these groups. In order to maintain their own network, the interests of the physics teaching community were very similar to the interests of the other groups. In his work, Latour (1996) talks about the ability of one individual or group to speak on behalf of others and how enrolling one group sometimes results in enrolling several. As a note of caution with respect to this claim, Latour also points out that the ability of one group to represent another is often very fragile. Taking the situation in this research as an example, even though the Gordon appeared to be successful in enrolling the physics teaching community, their ability to represent university programs could be quickly lost if universities became directly involved with assessing Gordon's applied physics course and rejected it.

The credibility that the teacher had in the community of physics teachers aided his efforts to enroll other community members in the network. Because Gordon was already a credible member of the physics teaching community, he was well positioned within the community to propose changes and suggest what a good translation of the community's interests was. Differential power among members in communities is not a new idea. Siskin (1994) has recognized that some members of subject departments are more powerful than others in everyday departmental functions and Lave and Wenger (1991) have described the differential power of newcomers and oldtimers in sociocultural communities of practice. Gordon's influence in the community and his recognition that some members were more important to convince than others, points to a relation between power within a community and the role of making judgments regarding translations of community interests. This seems to have important implications for which members of a community should be asked to teach courses that may be controversial within communities.

Enrolling some actors in the network meant not enrolling others. As Gordon was constructing the network, he recognized that not all groups would strengthen the network if they were enrolled. The most obvious group that Gordon did not enroll was that of the other applied physics pilot teachers. The trouble with the other applied physics teachers was that the networks that they were constructing around their courses was very different than the one Gordon was constructing. The translation that Gordon would have had to make to enroll the other pilot teachers was unlikely to be compatible with the translation he was making to enroll actors that he had to have in his network—namely, the physics teaching community. The differences between the network he was trying to construct and the one that the other pilot teachers were constructing were so pronounced that he could employ a strategy of disassociating himself with them to help enroll groups he was courting. This difference in Gordon's interaction with the academic and non-academic actors provides some support for the notion of there being a gap between academic and vocational subject areas, or *two worlds*, as is discussed in the subject community literature (Siskin, 1994). The idea of the two worlds, however, is a topic to which I will return further on.

How does the teacher *work the network* inside the classroom?

The enrollment of classroom resources in the network was largely a function of the network the teacher was building. Gordon's decisions about the use of the various classroom resources that he had available were made in relation to other groups and resources that he was enrolling into the network. As a condition of being a pilot site, the Ministry of Education had to remain enrolled which meant the POT materials had to be enrolled as well. At the same time, using resources associated with Physics 11 was helpful in enrolling members of the physics teaching community. Rather than looking at resource use as being determined by previous experience or individual preference, the strategic deployment of the resources as strategically mobilized actors in a larger network provides a richer appreciation for how Gordon was planning and teaching the course.

Classroom resources were centrally or peripherally mobilized to strengthen the overall network. Once enrolled, classroom resources were mobilized in such a way as to maximize the strength of the network that Gordon was constructing. For example, Gordon had to enroll the POT materials but, except for the lab materials, the presence of the materials in the course was not going to be useful as he tried to translate the interests of the physics teaching community. The way Gordon handled this situation was to mobilize the POT materials into the network in a peripheral way and to mobilize other materials that the physics teachers would be more comfortable with in a central way. It was not only the materials and organizational schemes that were used that could be explained by examining their role in the network; the way these actors were used depended on the larger network as well.

How are the interests of various actors who are enrolled in the networks that were constructed around the applied physics course at the provincial and school levels translated into the course?

The interests of various groups who were involved in the process at the provincial level were translated into a particular course of educational action. The political movement that involved such groups as business/industry, community colleges, and the Ministry of Education that was looking for ways to make the education system more responsive to the needs of industry had their interests translated into a largely conventional set of measures designed to lead to the introduction of a new course into schools. On the whole, the measures were similar to many of those that have been used in educational change initiatives in the past which are aimed at top-down control of what occurs in schools (Sarason, 1990). Elements of these measures that have been associated with the control paradigm of educational change include a hierarchical structure designed to implement and oversee change (Hollingsworth & Sockett, 1994) and the use of particular textbooks (Apple, 1986). The translation of interests of the various groups that were involved at the provincial level was also accomplished through a contractual agreement with the schools that were going to be piloting the course. These initial translations were made on behalf of the provincial network that was working towards particular sorts of changes in schools and were based upon a particular view of how those changes could best be accomplished.

Before the POT course materials were mobilized in an actual course at LMSS, the interests of several additional groups also had to be translated into the course. Once the school received the curriculum materials, a local network had to be constructed which meant, first of all, enrolling students and their parents. Enrolling the students and parents into the network also meant enrolling a physics teacher as well as members of the physics teaching community so that the course could be recognized as equivalent to Physics 11. Translating these additional interests into the course began to contribute to the formation of a local network that was characterized by different actors and different translations than the ones that characterized the provincial network.

As the course materials were mobilized in a course at LMSS, it was unclear whether they were still effective in translating the interests of the groups involved in the provincial process. Many of the measures that were taken in the provincial network were aimed at ensuring that they could achieve a degree of control over the way that the applied physics course would develop in the schools. At LMSS, elements of the measures, such as the establishment of advisory committees, did not materialize and some of the mechanisms of control were lost. The POT text materials that were supposed to be at the center of the course were mobilized in the local network in a peripheral way and, to these, additional materials that emphasized the goals and structure of the Physics 11 course were added. The provincial network ended up having little control over the way that the course was approached at LMSS or the way that the local network was formed there. In the educational change literature this lack of correspondence between the intended and taught curricula is generally construed as the problem (Cuban, 1992). The lack of correspondence may be a problem here as well, but a new view of the problem becomes possible once it is seem as a lack or correspondence between networks.

The network that formed at the provincial level and the network that formed at the school did not take each other into account. The formation of two related, yet different, networks appeared as the pilot process is examined from the provincial level and the school level. The problem was that these networks were unresponsive to each other. Gordon did not know much about the provincial network and, therefore, was not too concerned about enrolling the actors who participated in it into the local network. The way that the provincial network attempted to implement the applied physics course did not account for the fact that a local network would be built around the course at LMSS. The apparent incompatibility between the actors and translations of the two networks suggests where a problem may be located. The lack of contact between those inside and outside schools is not a new issue (e.g. Lewington & Orpwood, 1993) but casting these differences as network conflicts recasts the problem. Increased awareness of each others networks may lead to new possibilities for bridging them and exploring the possibility of translating each others interests into their respective networks. While bridging these networks would certainly necessitate working through complex relationships and differences, taking a network approach has the potential to demonstrate that Sarason (1990) is overstating the case when he refers to the differences between the intentions of policy-makers and schools as *intractable*.

Issues and Implications

The findings of this research have implications for several areas of the educational literature. With particular attention to the educational change literature, the divide between the academic and vocational subject areas, and the introduction of STS courses, I explore these implications in this section.

Educational change

The results of this research contribute to a new view of educational change, one that has the potential to overcome many of the limitations of past perspectives. The network model emphasizes the relationships between the various actors, both human and nonhuman, in change initiatives. When educational change initiatives are being explored using a network perspective the focus is placed upon *courses in the making*. Here actors are *working the network*, as they engage in the processes of enrollment, translation, and mobilization to construct a strong network that is required if the course is to be successful. There are several important implications and insights resulting from the use of a network perspective to explore educational change and I will review some of these below.

The realm of teacher action does not stop at the classroom door. Teachers who teach new courses are involved in constructing networks that include actors who are *both* outside *and* inside the classroom. This provides a very different position from which to initiate or study educational change. Participating in educational change is not so much a matter of looking for effective ways to control what happens in classrooms as it is a matter of working as part of a network in which everyone must change. Teachers are only one part of complex and changing networks and the degree to which the way they teach changes is a manifestation of the changes that take place in the larger network. Teachers have points of contact with many different actors in network(s) and they participate in changing others as they are changed themselves. As new courses are introduced existing translations are altered and/or new ones are enacted. Importantly, though, this is not a claim that everything is connected to everything else and that every conceivable actor must be considered in change initiatives. The relationships that make up networks tend to include some actors and not others. Indeed, part of constructing an effective network means that teachers must know what the implications of enrolling one group has for the possibility of enrolling others. The view of teaching that is taken in a network model of educational change takes the focus off the individual as the unit of study and locates individuals as acting within sociocultural communities and the larger networks within which both the individual and the community are located.

Earlier I mentioned a line that Bruno Latour (1987) uses to describe how technoscientific facts come into existence. It was, "The machine will work when all of the relevant people are convinced" (p. 10). Applied to new initiatives in education, rather than to machines, this line focuses us upon who the relevant people are and what it takes to convince them. In this research, the way that the applied physics course at LMSS came about was explained by identifying the relevant people and what it took to convince them. By following Gordon, I was able to see enough of the network he was constructing to allow me to account for how the applied physics course developed at LMSS. The translations he made in his efforts to construct a strong network that held together the relevant actors are what provided the basis for the account. Understanding the nature of these networks is crucial in developing accounts of how new courses develop and should be a focus of research into educational change.

Another important aspect of a network view of education change is an appreciation for sociocultural communities and the relationships these communities have with other groups. The subject community literature and the sociocultural theory literature make a valuable contribution to this aspect of networks. The communities that were already in place and the nature of the relationships they had with other groups effectively structure the landscape that network builders begin with. In this research, for example, the fact that students and their parents knew that Physics 11 is valuable in getting into university programs set the stage for the way that course had to be offered at the school and also preconfigured who Gordon had to enroll in the network. Network builders never really start from scratch in their task because there are already existing groups and relations that must be taken into account. In the case of educational change, this points to the necessity of appreciating how schools and departments are structured in advance of change, as many researchers have already suggested (e.g. Little, 1995a, 1995b).

A network perspective on education change also suggests to those policy-makers and others concerned with educational change that they should look very differently at what it is they are trying to change and how they try to do it. A technical view of educational change, based on employing methods designed to bring about change and then measuring the extent to which these have been successful (Snyder, Bolin, & Zumwalt, 1992), is of very limited value and actually distracts those who employ it from what matters in educational change.

Constructing a chain of translation that takes new ideas about education towards the classroom where the new initiative is to be implemented, locates schools and teachers on the end of that chain. It assumes a direction of flow and also assumes that the teachers are delivering the curriculum as directed (Snyder et al., 1992). Although, according to the technical view, translations are made, it is assumed that they are linear ones and that schools and teachers are only translating the interests of policy-makes into the courses they teach. This research and that of many others (e.g. Sarason, 1982) has shown that such assumptions are simply wrong. When the applied physics course came to LMSS, the interests of the provincial network behind the new course turned out to be relatively unimportant as compared to the host of translations that were made to allow the course to become a reality in the school. I am not claiming that policy-makers and other educational stakeholders do not have a role in the process but, instead, that they have to reconceptualize their role so that they are participants in networks that include the actors that make up local school networks. All the actors in these networks have to realize that new courses ultimately have to be translations of the interests of many groups, including theirs.

The network perspective encourages those involved in educational change to think of it in terms of webs rather than chains. Although their intentions may not have been exactly as a network perspective would have it, in this study the Ministry of Education did try to set up committees of business/industry and community college representatives to oversee the pilot sites. If this committee had materialized at LMSS, it may have served to strengthen the connection between the provincial network and the local network at the school. Gordon may have felt the need to translate the interests of the committee into his course and this may have led to a different course in the classroom. *New interests are best inserted into courses through engagement with the same network that the schools and teachers are working.* Because networks are more like webs than chains, many interests must be translated into new courses and it is unlikely that any one group will end up with a completely satisfactory translation of their interests. The result of this process of engagement in networks, however, is likely to be more satisfactory for policy-makers and other groups who have at times been content to allow a textbook or some other set of curriculum materials stand in for their interests. The idea of the there being many different groups who must be involved in educational change is not new (Fullan, 1991; 1993), nor is the idea of teachers being involved with them (Fullan, 1993). What is new is the idea of *working* the network and some suggestions about what the nature of networks aimed at educational change should look like.

Two worlds?

Little (1995b) and Siskin's (1994) notion of *two worlds,* which refers to the gap between academic and vocational subjects, gets to the heart of the challenge many new courses face. The approach and findings to this research suggest the two worlds may be re-interpreted as two networks. The two network account extends the subject community perspective that Little and Siskin rely upon by locating the subject areas in a network that includes elements of the larger social world. In Siskin's research, when the change is attempted—especially that which threatens to redefine the subject area—subject specialists defend the integrity of the subject because the subject also defines who they are as teachers. The network perspective does not look at teachers who are faced with new initiatives that move beyond the subject areas as resisting in order to defend their subject and their own identity but, rather, as individuals who undertake a construction problem. Bridging academic and vocational subject areas is difficult because the respective networks have different actors in them—for example, different students, parents, employers, post-secondary institutions, and teachers—who have different interests. As this research demonstrates, translating the interests of actors from these two networks is a problem because the translations that would have to be made are very different and often in conflict.

The fact that academic and vocational subjects already have their historically established networks in place makes it difficult to work out new configurations that may support new subjects. Students, parents, post-secondary institutions, and employers have historically participated in one or both of these networks and are well aware of the differences between them as they interpret new educational initiatives against the backdrop that existing subject areas provide. An example of such an interpretation in this research was when students would only sign up for the new applied physics course at LMSS if it led to credit for Physics 11. This situation set the tone for the network building that followed which was focused on enrolling actors that are important in the Physics 11 course moreso than actors that have historically been associated with other communities. The historical establishment of the two types of networks also preconfigures who can speak for whom. Physics 11 teachers, in this research, were able to speak on behalf of universities when it came to making judgments about the applied physics course. Gordon was able to enroll the academic physics network as a whole by convincing the group that represented it in high schools—

members of the physics teaching community—that the applied physics course effectively translated the interests of the community and network. The existing networks that have been established around academic and vocational courses are so ubiquitous that it is difficult for teachers who are constructing new networks to avoid reproducing similar structures in the networks they build.

This research does not provide a way of overcoming the separation of the two worlds/networks but it does provide a basis and a language with which to speculate. First of all, one way that will not get far is to continue to provide teachers who are teaching new courses with textbooks, curriculum guidelines, and perhaps a bit of inservice. These measures fail to recognize that the measures, themselves, are actors among many others that will be part of a network that teachers will be constructing. The teachers and most of the other human actors are left to find a place for these new actors within the new networks that are similar to those that already exist in schools. Measures that are likely to be more successful are ones that recognize that schools and teachers are parts of networks and that when significant change is attempted, new networks must be constructed. Beginning from this recognition, one approach is to accept that networks that have been built up in both of the two worlds cannot be ignored and to set sights on making small changes in the existing networks. Although I don't think that this is what the actors in the provincial networks had in mind in this research, it is effectively what occurred. Gordon did open up some new possibilities for teaching physics but did not do much to overcome the divide between science education and technology/vocational education. Another approach to introducing new courses is to undertake a strategy of significantly changing the networks of which the courses will be part. For example, if new actors such as business/industry had found a way to make the physics teaching community and, therefore, Gordon concerned about translating business/industry interests into the courses they teach, it is likely that the applied physics course would have been different. Likewise, when new courses are undertaken in vocational subject areas, academic groups could become part of the networks that these courses build resulting in a different sort of course. A third option is to not worry about existing networks and to develop a new types of networks from scratch. The danger with this approach is that if a significant network is not developed in advance of the course, the course is likely to have only limited success (Gaskell, 1989). If it were to be done, both the human and nonhuman side of the network would have to be put into place before the course itself is taught so that the teacher had a new network to work. Although these suggestions are just ideas at this point, they begin to provide a theoretical basis for proceeding with new educational initiatives and research.

STS education

Not many STS advocates would underestimate the importance of gaining the support of various educational stakeholders when it comes to the introduction of new STS courses. Support for variations of STS has come from various large organizations and agencies in many countries (e.g. Economic Council of Canada, 1992). These organizations and agencies are influential actors in Canadian provincial policy-making networks. Most provincial science and technology education curriculum guidelines refer explicitly to goals related to STS (e.g. British Columbia Ministry of Education, 1992; Ontario Ministry of Education and Training, 1993) and courses have even been developed that are devoted to STS curriculum—an example being the course that was explored in this research. In addition, curriculum materials and textbooks have been developed to support the teaching of STS (e.g. Aikenhead, 1991). The problem is that these STS goals and courses have not gained anything more then a toe-hold in schools (Bybee, 1991). The results of this research suggests a reason why this might be the case and network theory provides a means of both researching and rethinking how these courses are introduced.

All of the calls for and material support of STS goals and courses that I have outlined above are measures that have been taken in policy areas. There is not a great deal that appears to have been done about the construction of local networks that require STS courses be taught. In this research, the extension of the network at the school level beyond the classroom did not appear to have been taken into account by policy-makers, but it should have been because it turned out to be as much a part of the new course as were the textbooks. While there has been support for individual teachers through the provision of materials and inservice opportunities when new STS initiatives are introduced, there appears to be an underlying assumption that the teachers take the materials and know-how behind the classroom door and implement the course. This research is a clear statement to the contrary. While material and inservice support are important actors in the networks of new STS courses, there are many other actors that need to be given equal, if not more, attention. It is unfair to teachers to look upon what appears to be limited or failed implementation as resistance to the new ideas on their part. Teachers inherit network structures that are already in place in schools and these networks are not ones that facilitate the teaching of STS. The possible approaches to bridging the two worlds/networks of academic and vocational subjects that I listed above apply to STS education. Making inroads with STS courses in schools requires more attention to whole networks that are required to foster the courses, but especially to the human actors who should be part of the networks. Teachers have to translate the interests of relevant actors into courses and it is important to get those whose interests are related to STS into these networks. Policy-makers need to mesh the networks they participate in with those at schools because those interested in change seem to be in the policy networks and not in the school networks where they are needed. This means taking a greater interest in local networks of which teachers and schools are part.

Further Research

This exploration of the introduction of an STS course and of the use of network theory begins to articulate some important aspects of both of these areas but leaves far more unsaid and undone. Networks are vast terrains that, when studied, require researchers to focus on some aspects and either take a superficial approach to others or leave them untouched. In this case I have been able, for example, to give a great deal of attention to the relationship between the teacher of the applied physics course and the physics teaching community but, at the same time, I have not explored the relationship between the teacher and his students or their parents in sufficient detail. Further research in this area will emphasize parts of networks that I have underplayed or ignored as well as provide new versions of the ones to which I have given attention.

One thing that I have only touched upon in this research is the performance of power in these networks. Power pervades all the relationships between the human actors in the network and this dynamic needs to be analyzed far more carefully than I have done here. Looking at power relations in educational networks also brings important questions about who gets enrolled into networks, whose interests are translated into educational projects, and how peripheral mobilization is tied to other social relations. The network perspective provides a strong basis upon which to explore issues of power and, hopefully, this will be undertaken in further research.

A final area that requires further study is one that I have become quite interested in. Actor-network theory imposes a particular sort of interpretation on the actions of groups and individuals. Catalytic validity draws attention to the usefulness of the perspective provided through research to the participants in the study as it is fed back to them (Lather, 1991). Although I have informally relied on this form of validity in this research, I have not incorporated it into the research results. Further research which concentrates on the way that the network perspective re-orientates the participants in useful ways would make an important contribution.

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