IS IT DESIGN OR IS IT INQUIRY?: EXPLORING TECHNOLOGY RESEARCH IN A FILIPINO SCHOOL SETTING

by

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ABSTRACT

My case study explored Filipino secondary students' and teachers' experiences with technology research, project-based pedagogy. The study was conducted to examine the nature of a Technology Research (TR) Curriculum, and how it mediates non-Western students' learning, and interest in technology-based careers.

The context for my study is Philippine Science High School's (PSHS) TR program wherein students outline a proposal, design an experiment or a device, and implement their design to address a real world problem. My data sources included semi-structured interviews of 27 students and 2 teachers; participant observations of classroom and group activities, teacher-student consultations, and Science-Technology Fair presentations; TR curriculum documents; and researcher journal logs.

My examination of curriculum documents revealed that since the 1960s, the Philippine government has implemented specialized educational programs, such as the PSHS Science/Technology Streaming and TR programs, to support Filipino youth interested in science and technology courses and careers. Data analyses showed that the TR program provided a rich, practical learning environment where 'doing technology design' blended with 'doing science inquiry'. The TR activities enhanced student understanding of science and technology; helped them integrate and apply knowledge and skills learned from other school subjects; encouraged them to be creative, problem-solvers; and helped develop their lifelong learning skills. Students recognized that TR teachers adopted alternative instructional strategies that prompted students to adopt more active roles in their learning. Research findings revealed that student interest in pursuing technology-related careers was supported by their participation in the streaming and the TR programs. Data also showed that Filipino cultural practices
mediated student learning, and career decision-making.

My research findings suggest that present notions of scientific inquiry, and technological design need to be re-examined; that integrated science-technology school programs must be implemented to enhance students' academic and vocational knowledge and skills; and that career direction interventions should address personal and socio-cultural factors other than student interest and aptitude.

My study provides strong evidence that technology research pedagogy can change teaching-learning approaches in a Filipino classroom. This study showed that academic-vocational, technology-enriched science curriculum could be effectively designed to help equip students to become critical thinkers and leaders in the 21st century.
# TABLE OF CONTENTS

Abstract .......................................................................................................................... ii

Table of Contents .......................................................................................................... iv

List of Tables ................................................................................................................ vii

List of Figures ............................................................................................................... viii

List of Abbreviations, Institutions and Programs ...................................................... ix

Acknowledgements ...................................................................................................... xi

**CHAPTER 1: BACKGROUND OF THE STUDY** .......................................................... 1

- Purpose of the Study .................................................................................................. 4
- Research Questions .................................................................................................. 4
- Research Methods .................................................................................................... 5
- Significance of the Study ......................................................................................... 6
- Organization of the Thesis ....................................................................................... 7

**CHAPTER 2: REVIEW OF RELATED LITERATURE** .............................................. 9

- Science and Technology Educational Reforms: An Overview .................................. 9
- Historical Context of Science Inquiry Learning ....................................................... 12
  - Science Education in the 1950s to 1960s: Educating Future Scientists .................. 13
  - Science Education in the 1980s to 1990s: Science Literacy for All .................... 15
- Defining Scientific Inquiry ....................................................................................... 18
- Inquiry Learning in Practice ..................................................................................... 21
- Historical and Sociopolitical Contexts for Technology Education ......................... 31
- Defining Technology Design ................................................................................... 38
- Technology Design in Practice ................................................................................. 39

**CHAPTER 3: METHODOLOGY** .............................................................................. 47

- Context of the Study ................................................................................................ 47
  - The School Setting ................................................................................................ 48
  - The PSHS Curriculum ......................................................................................... 49
  - Science/Technology Research Program .............................................................. 51
- The Research Study Participants ............................................................................ 53
  - The Students ....................................................................................................... 53
  - The Teachers ....................................................................................................... 54
    - Juana ................................................................................................................. 54
    - Maria ............................................................................................................... 56
- Methods of the Study ............................................................................................... 56
  - Naturalistic Case Study ....................................................................................... 56
LIST OF TABLES

Table 1. List of Student Participants and Their Profiles ............................................................. 55
Table 2. PSHS Technology-Enriched Science Curriculum .............................................................. 105
Table 3. Sample group activities and consultations in Juana’s class ........................................... 125
Table 4. Reasons Why Students Chose the Technology Rather than the Science Stream ....... 153
Table 5. Undergraduate Degree Programs in the University of the Philippines Taken by PSHS 2002 Graduates .................................................................................................................................................. 161
Table 6. Top 5 Undergraduate Degree Programs Students Chose to Enrol in the University of the Philippines .................................................................................................................................................. 167
LIST OF FIGURES

Figure 1. Research activities and case study timeline .......................................................... 65

Figure 2. Science/ Technology Research 2 course requirements ........................................... 112

Figure 3. Group 10 working on gas-detecting pellets............................................................ 116

Figure 4. Students in group 6 molding the chitosan beads.................................................... 119

Figure 5. Science and Technology Fair activities................................................................. 133
LIST OF ABBREVIATIONS, INSTITUTIONS AND PROGRAMS

ADB-WB  -  Asian Development Bank and World Bank

CHED  -  Commission on Higher Education
- manages public and private post-secondary institutions in the Philippines

DECS  -  Department of Education, Culture and Sports
- plans, directs and manages the basic education programs and projects in the Philippines

DOST  -  Department of Science and Technology
- plans, directs and manages the science and technology programs and projects in the Philippines to help support national development

DOST-SEI  -  Science Education Institute of the Department of Science and Technology
- established to assess and upgrade Philippine science and technology education, and to implement education programs and projects that would help meet the science and technology workforce needs of the country

Engineering and Science Education Project
- a 1994 SEI-funded project that converted 110 existing schools across the Philippines into science & technology-oriented high schools (also called node or network schools).

PSHS  -  Philippine Science High School
- system of schools under the DOST that selects Filipino youth gifted in mathematics, science and technology through a competitive national examination. In 2003, the government had set up seven campuses, and envisioned the establishment of additional campuses across the 16 administrative regions of the country.

RSHSs  -  Regional Science High Schools
- with one school established in each of the 16 regions of the country, these schools implement a specialized science-oriented curriculum for all their students who are selected through a competitive regional examination

RSTCs  -  Regional Science Teaching Centers
- instituted in major universities across the 16 regions of the Philippines as “centers of excellence” that provide science teacher training programs
STR Program - Science/Technology Research Program
- a two-year program within the PSHS curriculum wherein students work in groups as they undertake a scientific or a technological research project that addresses a problem in the community or the workplace.

S/T Streaming Program – Science or Technology Streaming Program
- distinguishes between a science or a technology specialization for PSHS students.

STAND - Science and Technology Agenda for National Development
- a series of strategies initiated by the DOST in 1993 to help strengthen Philippine science and technology and attain newly industrialized country-status by 2000

STCC - Science and Technology Coordinating Council
- as a multi-sector council with representatives from the government departments, business, industry and education, it is said to be the highest governing body for science and technology policies in the Philippines

STEP - Science and Technology Education Plan
- a 1993 education master plan managed and funded by the SEI that aimed to address the problems in Philippine science and technology education through projects and programs that target the teacher, the learner and the delivery mode

Science & Technology-Oriented High Schools (also called Node or Network Schools)
- refers to 110 existing secondary schools where the government implemented a science and technology-oriented curriculum in one or two classes per grade level in 1994. A competitive examination selects students with a science aptitude from within the school division.

TESDA - Technical Education and Skills Development Authority
- manages vocational and technical education and training in the Philippines.

TR - Technology Research
- a course or program within the PSHS curriculum that is taught with a project-based, technological design approach.

UP-NISMED - National Institute for Science and Mathematics Education Development of the University of the Philippines
- formerly called the Science Teaching Center when the University of the Philippines established it in 1964 to train teachers in science curriculum and textbook development. The Institute’s functions have expanded to include the upgrade of Philippine basic science and mathematics education.
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CHAPTER ONE
BACKGROUND OF THE STUDY

This research study inspects the nature of a Technology Research Curriculum that aims to enhance Filipino students’ interest in technology-related careers. This study also investigates secondary students’ experiences with and perspectives on technology-oriented research pedagogy as defined in a Filipino setting. In exploring a Technology Research Curriculum, I examine assumptions that inform curriculum initiatives, and the dynamics of curriculum reform implementation. I also seek to promote a deeper understanding of the notion of technology-oriented research and its impact on enhancing or impeding student learning.

My interest in studying Technology Research teaching and learning in a non-Western context stems from my teaching experience in the Philippine Science High School (PSHS), a system of government schools for students with mathematics, technology and science aptitude. As schools for the intellectually gifted Filipino youth, the PSHS System aims to select, develop and prepare its scholars for science and technology-based careers, to contribute to the country’s economic growth and stability. The curriculum in the PSHS is expected to provide varied learning experiences, and to foster a spirit of inquiry and innovation. In line with these educational goals, school leaders and teachers developed and implemented a reform program in the mid-1990s that introduced an applied, technology-focus to the existing science curriculum. Technology-enrichment of the curriculum was a response to calls from Filipino educators, government leaders and alumni to make the curriculum more relevant to everyday life by introducing authentic, practical learning experiences for the students (PSHS, 1993; Reyes, 1994). Specifically, the curriculum reform involved the introduction of science and technology ability streams and the infusion of technology-oriented courses. Patterned after Western
educational models, school administrators implemented their reform agenda based on the assumptions that a technology-enriched science curriculum would enhance student learning and interest in science and technology. Although these assumptions about technology-based learning have not been studied, the entire "Western-based" program was used as a template for other PSHS campuses and science high schools in the Philippines. Despite the investment of time and money in the reform, the anticipated effect on enhancing the Philippine science and technology workforce remains unexamined. These issues prompted me to explore the rationale and the goals of the PSHS curriculum reform program vis-à-vis the participants' classroom experiences and the students' career goals. Specifically, I set out to investigate the influence of curriculum changes on students' and teachers' experiences in one aspect of the educational reform, namely, the Technology Research Program. I was interested in studying how the technology design approach taught within a project-based, research course mediates student learning in science and technology. This educational approach has not been previously examined in a Filipino context. Through my examination of the PSHS Technology Program, I also hoped to provide insights into broader educational issues related to the process of curriculum change and learning about research through a technology design approach.

Case studies of project-based and technology-and-design learning (see e.g., Schneider, Krajcik, Marx, & Soloway, 2002; Seiler, Tobin, & Sokolic, 2001; Vickers, 1998) suggest that these strategies can be creatively and effectively used to promote interest and learning in science and technology. Some studies also claim that student involvement in research projects that seek to answer a real world problem make learning more relevant to students and help them find connections between theoretical classroom knowledge and their world outside of school (see Krajcik, Czerniak & Berger, 2003; Steinberg, 1998; Vickers, 1998). Classroom activities
and lessons connected to students' experiences in the home, community or future work environments provide authentic contexts where learning can occur. Supporters of this contextual approach argue that students learn better and more when provided with practical applications for the concepts and theories they study (Berryman, 1993; Steinberg, 1998). Educators further maintain that these authentic, open-ended learning contexts increase student autonomy, motivation and interest in learning (Krajcik, et al., 2003).

In the area of science education, the practical contexts for learning science concepts and skills have often been closely linked with technology education (Fensham & Gardner, 1994; Layton, 1984, 1993b; McGinn & Roth, 1999; Roth, 2001; Seiler, et al., 2001). The hands-on nature of technology design activities and their practical connections to science concepts have led to their integration into science curricula in the hope of promoting science and technology literacy and learning by doing (Layton, 1993b). Science and technology educators and researchers claim that pedagogical practices associated with technology research benefit students, as these practices enhance the development of students' higher order thinking and social skills. As significant amounts of time and resources are directed into science and technology educational reforms across the globe, there is a need to determine whether these instructional strategies lead to effective learning. Since most claims regarding project-based and technology design learning have been premised on case studies conducted in Western contexts, I was curious whether findings from these settings applied to student learning in other classrooms. Thus, I decided to investigate how application of these largely Western, learning approaches mediates science and technology pedagogy in a Filipino context.
Purpose of the Study

My purpose in conducting this research study is to explore the characteristics of a technology-enriched science curriculum as defined in theory and experienced in practice in a Filipino setting. This study investigates an implemented curriculum initiative by examining the assumptions that have informed its development and by analyzing the practices of teachers and students in one component of the curriculum, the Technology Research Program.

A second purpose of this study is to describe and analyze students' experiences with and views on teaching and learning in a Technology Research program to better understand how the Western notion of technology-based research facilitates or constrains non-Western students' science and technology learning. The study also aims to examine how participation in a technology-based science curriculum influences students' interest and motivation to enter university programs and careers in science and technology.

Research Questions

This study examines the characteristics of a Technology Research Curriculum as defined and enacted in a Filipino setting. My research questions are:

1. What is the nature of a Technology Research Curriculum as defined in a Filipino context?

This question explores the theoretical bases for the development and the implementation of the Technology Research Curriculum as defined by school officials, curriculum developers and technology research teachers.
2. *What are Filipino students' experiences with and views on Technology Research pedagogy?*

This question examines the pedagogical practices of Technology Research students and teachers as I observed them in the classroom and as students reported in their interviews.

3. *How does participation in a technology-enriched science curriculum influence Filipino students' interest in science and technology-oriented careers?*

This question investigates the students' academic and career choices and decision-making practices in relation to their experiences in the technology-oriented science program.

**Research Methods**

To investigate these questions, I conducted a naturalistic case study of a Technology Research Curriculum in the Philippines from December 2001 to August 2002. I examined curriculum documents and interviewed school administrators and teachers to explore the historical, social and political issues underpinning the development and implementation of the Technology Research Program in a PSHS campus.

I conducted semi-structured interviews to investigate the pedagogical practices and experiences of the Filipino students and teachers in the Technology Research classroom. Twenty-seven students and two teachers agreed to participate in the research study. I also attended class sessions to gain a situated understanding of how learning was facilitated and experienced in the course. I documented classroom observations and conversations with teachers and students through journal logs after class or interview sessions. I audiotaped and transcribed all interviews conducted with the study participants, and analyzed the interview data.
using methods suggested by Lincoln and Guba (1985) and by Miles and Huberman (1994) to search for common patterns. I combined interview data, classroom observations, researcher journal and curriculum documents to triangulate my findings. I present my study findings as emergent themes and insights using vignettes and interview excerpts to characterize the classroom interactions and practices in the Technology Research Program.

**Significance of the Study**

My study of a Technology Research Curriculum in a Filipino setting is timely and relevant. First, the study contributes to the growing body of knowledge regarding the impact of technology-oriented, project-based learning strategies on science and technology teaching and learning. Findings from this study provide practitioners and education researchers with a picture of how technology design-based research is practiced in an Asian context. The findings also contribute to an enhanced understanding of the role of a technology research curriculum in promoting student learning and interest in science and technology. Education researchers of technological design and of project-based learning have advocated these learning strategies as effective means to increase students’ technological literacy and participation in science and technology careers (e.g., McGinn & Roth, 1999; Ritchie & Hampson, 1996; Seiler, et al., 2001). This study contributes to our understanding of these researchers’ claims.

This study also provides educators with a deeper understanding of non-Western students’ experiences with Western educational practices. For example, findings from this study can enhance teacher awareness of non-Western cultural norms and beliefs that may restrict or enhance student participation and learning in technology research classrooms. In light of the growing number of students from diverse cultural backgrounds in classrooms across North America, this increased awareness can help inform teaching practices in these
Lastly, a study that examines effective science and technology curricula is critical for developing countries where science and technology education are deemed to play pivotal roles in the nation’s economy (see e.g., Brown-Acquaye, 2001; Sapnu, 1997), yet funds for all educational programs are severely limited. With time and money invested in the development and implementation of the technology-enriched science curriculum, it is prudent to assess the program’s effectiveness in achieving its goals. Findings from this study can inform Filipino education leaders and curriculum developers on prospective directions for technology-based science programs, that is, whether such programs should be implemented in schools nationwide, redesigned for further improvement or dropped from the curriculum. In a broader educational context, data from this study can provide future curriculum developers and reformers with possible models for (re)designing Technology Research curricula and addressing issues on curriculum reform implementation.

**Organization of the Thesis**

I present this research study in six chapters. Chapter One of this dissertation provides an overview of the general background for the research study. In this chapter, I introduce the purposes of the study, research questions, significance of the study and organization of the thesis.

In Chapter Two, I review the related literature on scientific inquiry and on technological design learning approaches. I discuss the historical bases for these learning strategies within the context of science and technology education reforms. I define both science inquiry and technology design, and present examples of these learning approaches in the classroom. I also review empirical research studies that describe how these pedagogical approaches are
implemented in Western settings.

Chapter Three of this thesis is a description of the research methodology I employed in this naturalistic case study. I characterize the setting and context of the Philippine Science High School, the Filipino school where the study was conducted, and present the teachers and students who participated in the research. I outline the methods I used in the case study. Lastly, I address the issues around the conduct of a qualitative research study in a school where I am both an insider and an outsider.

In Chapter Four of this thesis, I provide the reader with a historical and a social perspective of science and technology education in the Philippines. I first describe the Philippine historical and social contexts. Then, I present an overview of the general, and the science and technology educational system in the Philippines. Finally, I trace the development of the PSHS Technology-Enriched Science Curriculum, which is the focus of my study.

Chapter Five of the dissertation is a report on my research study findings and analyses. First, I characterize the classroom setting, the students’ activities, and the teaching styles in the Technology Research 2 course, which is a representative program within the Technology-Enriched Science Curriculum. Second, I describe the students’ experiences with and views on Technology Research curriculum as enacted in the Technology Research program. Last, I present findings on how the technology-enriched science curriculum mediated Filipino students’ academic and career decision-making.

Chapter Six presents a summary of the research study findings and their implications for science and technology teaching and learning. I also draw conclusions and discuss areas for further research from the study findings.
CHAPTER TWO
REVIEW OF RELATED LITERATURE

In this chapter, I review the literature on vocational education that informs my study of a Technology Research Curriculum designed to encourage Filipino students to enter technology-related careers. I also examine the literature on scientific inquiry and on technology design learning practices to better understand Filipino teachers' and students' practices in and experiences with Technology Research. I consider these two learning approaches separately. First, I discuss the historical contexts and assumptions underpinning their use in the classroom as advocated by school science and technology reforms of the past 45 years. Second, I define and characterize scientific inquiry and technology design based on national school standards and literacy documents. Last, I explore empirical studies of both learning strategies as practiced in the classroom.

Science and Technology Educational Reforms: An Overview

In this age of automation, space travel, and medical innovation on the one hand, and poverty, food shortage and overpopulation on the other, the goal of having a scientifically and technologically informed citizenry is imperative. The increasing influence of science and technology in our homes, schools, workplace and global economic community has led to calls from various stakeholders for education to provide the skills that equip citizens to understand and to function in our technological world. Parents, politicians and industry leaders claim that students and adults with skills in communication, collaboration, technology-use, critical thinking and problem solving have an advantage in the workplace. Governments and economies that can provide for these skills in their labor force are deemed to have an edge in the technological global market.
In answer to perceived scientific and technological needs of the nation, government, corporate and industry leaders have recommended a number of educational programs and reforms at various times in the history of schooling. For example, the Sputnik era moved the American government to call for more rigorous science, technology and mathematics education to counter the Soviet Union's perceived scientific and technological edge (Fensham, 1992; Hurd, 1995). Educators note that concerns about the cold war triggered the government's undue emphasis on "learning to become scientists" at that period in North American educational history (Hurd, 1969; Spring, 1976). In the more recent past, legislation through the 1990 Perkins Vocational Education and Applied Technology Act and the 1994 School-to-Work Opportunities Act promoted support for vocational education to address industry's technical workforce needs. These government legislations have spawned various school programs exploring the integration of vocational with academic education (see e.g., National School-to-Work Opportunities Office, 1998).

Other countries outside of the U.S. introduced similar reforms in science and technology education (Fensham, 1992). In the United Kingdom, initiatives from major science professional organizations led to the establishment of the General National Vocational Qualifications (GNVQ) and the National Vocational Qualifications programs (NVQ) (Coles, 1998; Lynch, 1993). The GNVQ courses are designed to teach general skills useful in a variety of jobs (e.g., from performing arts to engineering), whereas the NVQ provides work-related skills (e.g., technical, craft) to prepare students entering technical jobs or university degree programs (Department for Education and Skills, 2001). The British government also introduced the Technical and Vocational Education Initiative in the 1980s, which called for more practical and technological learning in primary and secondary schools to address
perceived needs in the labor market (Layton, 1995). Canadian government and education leaders implemented similar curricular changes in response to calls for reform from industry and business sectors (see Gaskell & Hepburn, 1997; Wideen, 1996). Beginning in the late 1950s, Philippine educators and government officials have also established science and technology curricula and schools to parallel the educational changes occurring in the Western world. I provide more details about the historical context of Philippine science education in Chapter 4.

Curricular reforms in science and in technology came in two major periods of curriculum restructuring, between the 1950s to 1960s era, and the 1980s to 1990s \(^1\) to the present period. These waves of reforms were premised on varying assumptions and fueled by different advocacies. Scientists and government leaders rallied behind the early reforms of the 1950s to 1960s and advocated for a science program for would-be scientists and engineers (Duschl, 1990; Hurd, 1969). Students were to learn scientific inquiry as practiced by scientists. Science programs also incorporated some technology-based activities to enhance students’ interest as they learned the practical applications of science concepts in the real world (Layton, 1993b). Beginning in the 1980s and continuing to the present time, educators and curriculum designers restructured school science to have a more inclusive “science for all” focus to address the needs of students who were not interested in pursuing engineering and science professions (Duschl, 1990; Fensham, 1992). The curriculum designers and implementers also incorporated technological concepts and skills into the science curriculum through applied science or applied academics (see e.g., Gaskell & Hepburn, 1997; Gaskell & Tsai, 2000), and the science-technology-society programs (Solomon & Aikenhead, 1994; Yager, 1996a). These programs

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\(^1\) Identification of these two periods is based on Fensham’s (1992) classification of the major periods in science curriculum reform. Fensham includes the curriculum improvements of the 1970s under the 1950s to 1960s period of reform.
sought to integrate vocational and academic goals, and to enhance scientific and technological literacy for all students.

In the next section, I explore some of the assumptions underpinning reform initiatives in science and technology education in the past 45 years as educational goals progressed from “learning to become scientists and engineers” to “science and technology learning for all”. I analyze how the focus on scientific inquiry learning and on technology design evolved within these educational reform initiatives. I also examine the rationale for introducing these practices into the science curriculum.

**Historical Context of Science Inquiry Learning**

Much of school science teaching in the pre-Sputnik years focused on science knowledge as a collection of concepts and theories to be memorized and regurgitated in class discussions and exams. Science laboratory courses likewise supported this more conventional method of science instruction as laboratory activities focused on reproducing the “right” results. By the 1960s, U.S. scientists and government officials considered it important to improve education because of the increasing influence that science and technology played in establishing political, economic and social strength and stability in post-war America (Duschl, 1990). The perceived political and military threat posed by the Soviet Union’s edge in the space race may have been the impetus for the United States to seek extensive educational reforms, but the concern for addressing workforce needs of an industrialized society was seen as more urgent (Spring, 1976). In particular, scientists, politicians and industry leaders of that time considered science education too “soft” and lacking the rigor that would prepare students for university science education and careers as scientists and engineers. Thus, these influential leaders called for a more academic and discipline-oriented approach to teaching science (Hurd, 1969).
Science Education in the 1950s to 1960s: Educating Future Scientists

In answer to the calls for educational reform, the National Science Foundation in the U.S.A. funded the design and implementation of curriculum programs to initiate students to the science enterprise and train them in the work of scientists (Duschl, 1990; Hurd, 1969; Marshall & Burkman, 1966). With the help of scientists and science professional groups, the Foundation conceived science curriculum projects such as the Physical Science Study Committee (PSSC), School Mathematics Study Group (SMSG), Chemical Bond Approach (CBA), Chemical Education Materials Study (CHEMS) and Biological Sciences Curriculum Study (BSCS) (Lee, 1967; Spring, 1976). The government provided teacher training, textbooks and educational resources to ensure wide use of the redesigned science curriculum within schools. These curricula advocated for a more student-centred approach to science learning through the “discovery” or “inquiry” approach (Duschl, 1990; Hurd, 1969; Marshall & Burkman, 1966).

If most pre-Sputnik science curricula presented science as historical facts and concepts to be memorized, the NSF-funded science curriculum projects were different in that they promoted a more tentative or speculative presentation of science concepts. These curriculum projects sought a shift from an emphasis on science concepts as verifiable doctrine to science as open-ended knowledge in a discipline that was constantly changing. The new curricula adopted this shift in focus to encourage the students to think on their own (Hurd, 1969). Curriculum projects of the 1960s also called for a more hands-on, interactive approach to science education. Students were encouraged to be active, self-directed learners and to develop skills for lifelong problem-solving and inquiry learning. Scientists who redesigned the curriculum intended the inquiry approach to provide students with opportunities to understand the science enterprise using the methods scientists practiced and the historical context (i.e., what is known) of the
scientific knowledge (Hurd, 1969). Educators note that that Dewey’s views on “learning by doing” (Fensham, 1992, p.792) and psychologists’ beliefs that students can “learn how to learn” (Marshall & Burkman, 1966, p. 6) influenced the focus on the inquiry approach during this era in school science reform.

Bruner (1973, c1961) referred to inquiry as the “discovery” approach and defined it as “all forms of obtaining knowledge for oneself by the use of one’s own mind” (p. 402). Marshall and Burkman (1966) further characterized the inquiry approach as one wherein

... the student is placed on his own in a carefully contrived problematic
situation and given just enough clues to enable him to have a reasonable chance
of solving the problem. He is thus forced to “discover” major science
generalisations for himself as opposed to having such information revealed to
him by the teacher. (p.6)

Some assumptions in the use of the approach are that students understand concepts better when they actively engage in the discovery of this knowledge and that they learn to think on their own in the process of inquiring (Bruner, 1973, c1961). Another assumption was that students are intrinsically motivated to explore and to investigate how science concepts develop rather than to simply assimilate formulas and theories (Duschl, 1990).

The curricula initiated by NSF in the 1960s presented science learning as an active process. As Hurd (1969) succinctly puts it, science is “more a verb than a noun” (p. 39). To support this new thrust of the curricula, science laboratory investigations emphasized an open-ended approach, as opposed to just verifying textbook information. Curriculum designers introduced laboratory activities that allowed students to go through the steps of hypothesis making, experimentation and observation (i.e., the “scientific method”) in search of an answer
to a problem. These activities and tasks were consistent with the idea of using inquiry to highlight the goals and practices of the scientist (Hurd, 1969, 1995; Marshall & Burkman, 1966).

Hurd (1969) maintains that the move towards making science “interesting” through inquiry learning was a shift from the traditional teaching practice of focusing on the technological applications and usefulness of science. From the scientists’ and industry leaders’ point of view, a de-emphasis on practical applications was necessary, as they believed that students entering universities and the workforce lacked the “pure” science academic background needed for future careers as scientists (Layton, 1984). These scientists perceived a need to add rigor to school science by focusing on the inquiry processes, science concepts and their evolution within the disciplines (Fensham, 1992; Hurd, 1995).

In summary, the curriculum reform projects of the 1950s to 1960s aimed to redefine science education by advocating: 1) a discipline-oriented or pure science approach; 2) inquiry-based learning practices; and 3) an investigative approach in laboratory courses in line with the way scientists practice their discipline (Fensham, 1992; Hurd, 1969). Whether science teachers achieved these goals in the classroom will be discussed in a later section of this chapter.

Science Education in the 1980s to 1990s: Science Literacy for All

The NSF-supported reforms and related curricular changes in the 1960s proposed to teach all students the “new” science curricula, the same way. Educators now argue that the 1950s/1960s curriculum authors and implementers failed to address the increasing diversity in students’ aptitude, science interest, study and career plan, and sociocultural background. Another shortcoming of the curricula was that they failed to integrate science with other
disciplines, to define science applications in real world contexts, and to identify technology’s role in science education (Hurd, 1997; Yee & Kirst, 1994). Some educators also argued that “performing science” through science inquiry may not necessarily translate to a better understanding of science (see Duschl, 1990; Hurd, 1995). Moreover, the process of inquiring into science in the 1950s/1960s focused on investigating teacher-constructed, abstract problems that students were unlikely to solve or to discover on their own without some guidance from the teacher.

Recognising that the majority of students do not opt to enter science- or technology-related occupations, curriculum developers designed science curricula in the 1980s to the 1990s to cater to the needs of a diverse student population (Aldridge, 1992). This emphasis on “science for all” implied a redirection from learning science as a pure discipline to a more generic understanding of science needed for day-to-day, decision-making (Rutherford & Ahlgren, 1990). Educators also agreed that with science and technology’s increasing influence on the global community, any new science curricula must address the social, economic and environmental impact of the two disciplines (e.g., Aikenhead, 1994c; Bybee, 1993; Hickman, Patrick & Bybee, 1987; Hurd, 1995; Rutherford & Ahlgren, 1990; Yager, 1996a).

While science programs of the 1950s/1960s had advocated “learning like a scientist,” curricula of the 1980s/1990s advocated “learning for scientific and technological literacy.” Curriculum reform documents like the American National Science Education Standards (National Research Council, 1996) and the Canadian Common Framework of Science Learning Outcomes K-12 (Council of Ministers of Education Canada, 1997) proposed science learning outcomes or goals that included the acquisition of technological skills and knowledge to underscore the close link between science and technology. There was also a growing
educational movement initiated in the late 1970s that focused science pedagogy around science-technology-society (STS) contexts. This movement called for integrating knowledge from both disciplines to help students resolve personal and societal issues (Bybee, 1993; Hickman, et al., 1987; Yager, 1996b; Zuga, 1996). These reform initiatives envisioned the development of a scientifically and technologically literate society of individuals from diverse backgrounds who can discern and decide about the socially responsible applications of science and technology (Eisenhart, Finkel & Marion, 1996).

The shift in science education goals during this period was also accompanied by a move away from the view of scientific knowledge as discipline-driven, objective, and value-free, at least among science educators. In the 1980s/1990s, educators and education researchers started to recognize that science knowledge was subjective and value-laden and that the science enterprise was socially constructed (see e.g., Aikenhead, 1994b; Latour & Woolgar, 1986; Latour, 1987). Science educators began to acknowledge that the “scientific method” was a myth (see McComas, 1996). In addition, new understandings on what constitutes “effective” science pedagogy in the present technological age, and on the nature of science learning were emerging. For example, computers and other related educational technologies were redefining science teaching and learning. In addition, the work of Driver, Champagne, Gunstone, White and other educators (see Fensham, Gunstone & White, 1994) on students’ construction of conceptual knowledge advanced a constructivist learning model, which challenged traditional notions of science learning.

During the 1980s to 1990s period of curriculum reforms, the national science standards and the literacy documents in North America (see e.g., American Association for the Advancement of Science (AAAS), 1993; Council of Ministers of Education Canada, 1997;
National Research Council, 1996, 2000) continued to advocate the use of inquiry-based learning practices. However, there was a shift away from teaching inquiry as a methodical approach used to “discover” scientific truths. Instead, the science curriculum documents encouraged students’ “construction of knowledge” based on their interpretation of events and human experiences through nonlinear inquiry strategies (Duschl, 1990; Yager, 1996a). Further, curriculum designers proposed that science inquiry practices be used in ways that motivate students to apply scientific-technological concepts, attitudes and critical thinking strategies to solve problems in real-world contexts, instead of abstract ones (Hurd, 1997; Yager, 1996a). Curriculum reformers also called for a shift in the “locus of control” for science inquiry from the teacher, who normally directs the inquiry activity, to the students who choose and implement the project or experiment to investigate (Lochhead & Yager, 1996). Reformers envisioned that in learning to do inquiry, students could acquire science skills and knowledge; and in learning about inquiry, students could gain an understanding of how scientists work and produce knowledge, and thus, make informed decisions about scientific issues (Lederman & Flick, 2002). In the next section, I discuss the notion of science inquiry and examine its implementation in science classrooms.

**Defining Scientific Inquiry**

In the United States, the National Research Council (1996) and the American Association for the Advancement of Science Project 2061 (AAAS, 1993) set standards or benchmarks for the concepts, knowledge and skills that science students need to achieve in American schools. As in the other U.S.-initiated reform efforts of the 1950s to 1960s, scientists (not science teachers) were the main curriculum developers of these recent projects on science education reform. In Canada, the Council of Ministers of Education commissioned the
development of a parallel reform project through the preparation of the *Common Framework of Science Learning Outcomes* (Council of Ministers of Education Canada, 1997) for K-12 science students. These project reports emphasize the central role that inquiry must play in learning science and in achieving scientific and technological literacy for all students (AAAS, 1993; Council of Ministers of Education Canada, 1997; National Research Council, 1996, 2000). However, a perusal of the U.S. reports reveals the absence of a precise definition of the process of "scientific inquiry". Instead, the documents list and describe the activities associated with the inquiry process. For example, the *National Science Education Standards* document states that:

Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world.

Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (National Research Council, 1996, p.23)
The AAAS Project 2061 and its subsequent *Benchmarks for Science Literacy* document (AAAS, 1993), also promotes the goal of achieving literacy in science, mathematics and technology for all students through the application of inquiry learning practices. The AAAS characterizes scientific inquiry by stating that it is more sophisticated than a laboratory experiment or the steps in the "scientific method" as students develop imagination and become inventive in their search for answers to their own questions.

Similar to the earlier 1950s to 1960s curriculum restructuring, these projects advocate the application of inquiry learning in the science classroom based on the assumption that students' active engagement with inquiry as practiced by scientists, provides effective means for learners to gain understanding and knowledge about the natural world. However, educators note that the absence of an exact definition of or a goal for "inquiry learning" in the reform or the standards documents makes it difficult for science teachers to apply the intended curriculum in their classrooms (see Anderson, 2002; Fensham, 1992; Lederman & Flick, 2002; Welch, Klopfer, Aikenhead, & Robinson, 1981). 2 For example, Anderson (2002) notes that the *National Science Education Standards* (National Research Council, 1996) document uses the term *inquiry* in reference to "scientific inquiry", "inquiry learning" and "inquiry teaching". Although distinctions among the three processes may be clear to the curriculum developers, the documents are not explicit about what science teachers can do to bring about inquiry in the classroom. That is, there was confusion whether the science teacher was supposed to adopt an inquiry teaching approach, to teach students about inquiry, or to teach them how to do inquiry (Bybee, 2000; Lederman & Flick, 2002). Anderson (2002) further adds that this vagueness, particularly concerning inquiry teaching/learning, may be one of the reasons why initially there

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2 Interestingly, this observation that there was confusion among teachers over the meaning of inquiry in the science classroom was evident in the implementation phases of both the NSF reform documents of the 1950s/1960s (Welch, et al., 1981) and the 1980s/1990s standards documents (Anderson, 2002; Lederman & Flick, 2002).
were few reports on exemplars of good inquiry practices in science classrooms as teachers interpret the intended curriculum in different ways.\(^3\)

What exactly is "scientific inquiry" or "inquiry learning"? The *Oxford English Dictionary* (1989) defines inquiry as "a question, a query; a course of inquiry; the action of seeking, especially (not always) for truth, knowledge, or information concerning something; search, research, investigation". Compared to the American science standards and literacy reports, the Canadian *Common Framework of Science Learning Outcomes K-12* (Council of Ministers of Education Canada, 1997) provides a more straightforward definition of scientific inquiry as the process of "seeking answers to questions through experimentation and research" (p. 14). With these definitions and the inquiry practices listed in the standards and literacy documents as a guide, I now examine what empirical research reveals about students’ and teachers’ involvement with inquiry learning as practiced in the science classroom.

**Inquiry Learning in Practice**

My initial literature searches for inquiry practices in science classrooms revealed a limited number of empirical studies using the word inquiry in their project titles. However, upon closer inspection of the research studies, it became apparent that educators and researchers have applied the inquiry label to refer to various classroom practices that parallel the aforementioned definitions of inquiry. My experience supports the observations of Anderson (2002) when he conducted his own search on inquiry teaching in science classrooms and found that researchers and educators apply inquiry in a variety of ways. Having identified the learning approach in their classrooms as discovery (e.g., Ajewole, 1991), project-based (Krajcik, et al., 2003; Marx, et al., 1994), apprenticeship (Bell, Blair, Crawford & Lederman, 3 To help teachers in their classroom practices and assessment, the National Research Council produced the *Inquiry and the National Science Education Standards* (National Research Council, 2000) as an addendum to their first standards document.
2003; Roth & Bowen, 1995), community-based (Donahue, Lewis, Price, & Schmidt, 1998) or technology-mediated (Linn, Slotta, & Bauingartner, 2000; White & Frederiksen, 2000), teacher-researchers have also described these approaches as exhibiting aspects of inquiry learning. For some of these research practitioners, inquiry refers to the simple task of exploring answers to questions on a worksheet. For others, it indicates the more complex and lengthy process of investigating and solving a problem in the community. Other researchers further complicate the multiple meanings for the inquiry label by distinguishing between an open inquiry approach, wherein the teacher allows students to explore science activities on their own, and a guided inquiry approach, wherein the teacher provides some information to help direct the inquiry process (see e.g., Fisher, 2000; Roth & Bowen, 1995). Some educators refer to these two approaches, respectively, as discovery and guided discovery (e.g., Ajewole, 1991; Heywood & Heywood, 1992), or as free inquiry and mediated inquiry (e.g., Flick, Keys, Westbrook, Crawford, & Carnes, 1997). Teachers have applied these different types of inquiry-based approaches in a variety of settings: the science classroom, the field, or the workshop.

An inspection of the research literature also indicates that empirical studies on inquiry in science education have focused on aspects of, and issues around, both inquiry teaching (e.g., Bencze & Hodson, 1999; Fisher, 2000; Flick, 1995, 2000; Heywood, & Heywood, 1992; Welch, et al., 1981), and inquiry learning (e.g., Minstrell & van Zee, 2000; Schneider, et al., 2002; Scruggs, Mastropieri, Bakken, & Brigham, 1993). Research findings on inquiry teaching practices suggest that teachers who assume nontraditional roles in the classroom provide the best support for inquiry-based pedagogy. For example, Flick (2000) suggests that teacher interventions that give students time and opportunity to reflect on their learning foster scientific
Polman and Pea (2001) claim that teachers can facilitate open-inquiry through "transformative communication" (p. 223) strategies, i.e., teacher-student interactions where the teacher provides guidance and coaching that help students transform raw information for possible inquiry explorations. Inquiry-based classrooms are also characterized by extensive teacher support and intervention through scaffolding practices (Flick, 2000), and by less teacher-centered activities such as small group sessions that encourage student autonomy, peer interactions and collaborative learning (Flick, et al., 1997; Marx, et al., 1994). Studies suggest that in inquiry-oriented classrooms, the teacher acts more as a guide or a coach who facilitates student learning, than an expert who directs student tasks (see e.g., Flick, et al., 1997, 2000; Marx, et al., 1994; Polman & Pea, 2001).

Some research studies seek to compare the effects of inquiry-based pedagogy against more traditional instruction. For example, Scruggs and co-researchers (Scruggs, et al., 1993) found that Grade 7 and 8 students (N=26) with learning disabilities performed better on tests on magnetism, electricity, rocks and minerals after a weeklong experience with hands-on, inquiry activities compared to when they were exposed to a week of textbook-based instruction on these topics. Students in this study expressed a preference for the activity-oriented, inquiry approach, which they found more interesting and enjoyable than textbook-based learning. They also stated that the inquiry approach encouraged them to try harder at accomplishing the learning tasks.

In a multi-case study in Ireland, pre-service teachers compared the impact of expository (i.e., didactic), discovery and guided discovery instruction on different groups of students in their classrooms (Heywood & Heywood, 1992). Research findings indicate that student test performances were not any different after exposure to the three types of instruction. These
studies also revealed that students in the discovery-oriented groups exhibited higher degrees of
motivation and enjoyment than those in the expository approach groups. Another study pre-
and post-tested 240 secondary students to compare student attitude towards biology after one
class period of discovery (i.e., experimentation) and expository (i.e., teacher-centered
instruction) learning activities (Ajewole, 1991). The research study showed that students in the
‘discovery group’ had a better attitude towards biology than those in the ‘expository group’.

Results from the above mentioned comparative studies are important as they may encourage teachers to move away from traditional instruction and to explore alternative
teaching strategies that increase student motivation and interest in science learning. However,
assessment of the (in)effectiveness of the inquiry approach based solely on a single lesson or a
week of participation in the instructional strategy is questionable. In addition, evaluating the
impact of inquiry-based teaching strategies by focusing on one-time test results is inadequate to
comprehend the complexities of the strategy. There are insufficient studies that explore the
long-term use and influence of inquiry practices in classrooms. There is also a need for
research that examines whether and how inquiry approaches help develop student cognition and
literacy, which are stated goals of science standards and curriculum reform documents
advocating inquiry pedagogy. Some of the research studies I cite in the next paragraphs begin
to address this need.

Empirical data suggest that science instruction through an inquiry approach provides
varied benefits for students (see e.g., Minstrell & van Zee, 2000). For example, research
studies claim that inquiry learning helps to develop learners’ conceptual understanding as
indicated by test performance (Roth & Bowen, 1995; Schneider, et al., 2002; Scruggs, et al.,
1993); foster autonomous learning (Marx, et al., 1994); and promote student interest and
motivation in science (Gibson & Chase, 2002; Knox, Moynihan, & Markowitz, 2003). Researchers further maintain that inquiry pedagogy encourages students to pursue science careers (Gibson & Chase, 2002; Knox, et al., 2003), and increases participation of girls who are normally underrepresented in science (Eisenhart, et al., 1996). In the remainder of this section, I examine three forms of science learning strategies that espouse an inquiry-based approach: information mining and analysis; apprenticeships or science camps; and project-based learning. I inspect research data on these three types of inquiry approaches to better understand what inquiry looks like in science classrooms.

One form of scientific inquiry is information mining and analysis. Especially successful with younger learners, this approach to inquiry involves the posing of questions that guide students to explore a science topic without engaging in firsthand laboratory experimentation or data collection. Working in small groups, students can use library resources, the Internet, or pre-generated data to address inquiry-oriented questions that are difficult to test in school science laboratories. For example, teachers used this inquiry strategy with students interested in exploring questions around the nature of black holes, plate tectonics, earthquakes, and UFOs (O’Neill & Polman, 2004); hurricanes and moons (Polman & Pea, 2001); or dinosaur extinction and nuclear power plants (Flick, 2000). Although the teacher plays an important role in any learning activity, research indicates that this role is even more crucial in inquiry-based classrooms such as those using information-mining approaches. For example, research studies reveal that teacher support and guidance help students to better understand science concepts and to progress through the inquiry process, which they would have had difficulty negotiating on their own (Flick, 2000; O’Neill & Polman, 2004; Polman & Pea, 2001). Polman and Pea (2001) claim that an inquiry approach calls for teaching strategies that balance teacher
intervention and student autonomy in the learning process. Flick (2000) found that by providing reflection time before class discussions, teachers can help students develop skills in scientific inquiry, such as the ability to analyze, argue and defend their conclusions based on scientific data and evidence. O’Neill and Polman (2004), who inspected students’ email exchanges with scientists and written reports, found that inquiry helps students develop science literacy skills. That is, students were able to ask their own questions, formulate their own inquiry designs, use data to support their scientific arguments, and link evidence to their conclusions (O’Neill & Polman, 2004). However, it is evident that while information mining and analysis activities provide students with opportunities to engage in scientific reasoning and logical thinking, they do not engage in thinking about solutions to socially relevant problems in authentic contexts, which is one of the goals of science literacy (see e.g., National Research Council, 1996). Moreover, these activities do not involve students in the practical, hands-on experimentation that is an integral part of the work of scientists.

The most common venues for inquiry-based learning in science are hands-on, laboratory activities. These activities include both short, open-ended laboratory experiments and more time-intensive, research investigation projects (see e.g., Bencze & Hodson, 1999; Krajcik, et al., 2003; Minstrell & van Zee, 2000; Roth, 1995). Science teachers have not limited the application of these hands-on, inquiry projects to the classroom. They have also introduced them in field and workshop settings where students are free to explore problems in out-of-school contexts (e.g., Roth, 1995, 2001). This contextual learning approach may take the form of apprenticeship or science camp programs where an adult “expert” (e.g., a scientist or a teacher) provides students tutelage as they seek creative ways to solve real-life problems (e.g., Bell, et al., 2003; Roth, 1995; Roth & Bowen, 1995). Empirical data suggest that inquiry
activities via apprenticeship and science camp programs enhance learning, and foster interest in
science and science careers among students (e.g., Abraham, 2002; Knox, et al., 2003). Some
research studies also claim that the hands-on activities in these programs make science more
enjoyable for the students (e.g., Giscombe, 2004). I explore these claims about inquiry learning
by inspecting some empirical data.

In their study of an 8-week apprenticeship program, Bell and co-researchers (Bell, et al.,
2003) conducted surveys and interviews with high school students (N=10) and their scientist-
mentors to assess what students learned from participation in the program. Students, working
alongside practicing scientists, engaged in experimental design, data collection and data
analyses. Study findings revealed that contrary to the mentors' perceptions, student
understanding of the nature of science and the inquiry process did not change because of the
apprenticeship experience. For example, students still believed that a single scientific method
existed, and that the process is linear. The research study concludes that students do not
necessarily understand the nature of science just by doing science unless mentors who guide
students through the scientific inquiry process deliver more explicit messages about what they
want students to learn.

Abraham (2002) investigated 75 high school students' experiences and views about
science and scientists before and after participation in field-based research as part of an
apprenticeship program. Student responses in the open-ended and Likert-based surveys
indicated that the program supported or confirmed student interest in pursuing science courses
and careers. Students gained a more positive and realistic view of science and the work of
scientists after participating in the program. For example, students observed that field-based,
science research may be complicated by unexpected incidents and that science inquiry can lead
to more questions than conclusions. Students also recognized and valued the social aspect of learning with peers and scientists as they engaged in their research work.

In another study, Knox and co-researchers (Knox, et al., 2003) surveyed and interviewed 112 secondary students on their attitudes towards science, and their perceived skills and knowledge after participating in a two- to four-week summer science program. This science program engaged students in laboratory experiments, discussions, computer sessions, and fieldtrips. The pre- and post-surveys showed that students felt more confident in their science laboratory and instrumentation skills after taking part in the inquiry-based program. Interview responses suggest that working with real scientists and authentic science projects enhances student interest in science and in science careers. Due to attrition, only 16 of the original 112 students participated in a longitudinal aspect of the study that investigated the program's impact on student academic performance after 16 months. Self-reported data reveal that students felt that the science program did contribute to their academic performance in advanced science courses, but did not influence their interest in pursuing a science career since this interest was existent prior to their involvement in the program. These mostly positive comments from students about learning through inquiry-based science camps substantiate claims to support these pedagogical approaches. Research studies on apprenticeship and summer camp programs such as the ones cited above are relevant for their comprehensive scope that enable the studies to provide reliable data. Usually, these studies investigate years of program implementation and survey large student populations. These researches also present valuable information on how the experience of working alongside scientists who are investigating authentic research problems impacts student learning, attitude, motivation and interest in science. However, most studies of apprenticeship and science camp programs rely
heavily on students’ self-reported data, with no corroborative data on what the students actually learned and experienced through the inquiry-based science programs.

Other examples of contextual learning with an inquiry approach are science or research investigations where students explore a problem in a specific locality or the bigger global community. This type of inquiry approach has been termed community-based or project-based learning. In project-based learning, students typically select their own research problem and research design. Working collaboratively with their peers, teacher and other adults, students choose a local or real-world problem, propose a project or design an experiment, and implement the proposal to address the problem (Krajcik, et al., 2003). Blumenfeld and others (1991) note that an essential feature of the project is that it “result(s) in a series of artifacts, or products, that culminate in a final product that addresses the driving question” (p. 371).

Particularly useful science projects are those dealing with social controversies on health-related or environmental issues (e.g., Eisenhart, et al., 1996; Helms, 1998). Some educators claim that providing inquiry-oriented learning opportunities within this socio-scientific context is an effective instructional strategy as it makes science and technology more interesting and highlights their usefulness in students’ lives and the community (see Donahue, et al., 1998; Krajcik, et al., 2003; Vickers, 1998). In fact, Eisenhart and co-authors (Eisenhart, et al., 1996) argue that science benchmarking and reform agenda (i.e., AAAS, 1993; National Research Council, 1996) will not succeed unless students are given opportunities to be actively involved in projects that focus on “socially responsible science” (p. 266), i.e., the responsible uses of science for oneself and one’s community. These educators further claim that the projects can provide rich environments not only for learning science content outlined in standards

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5 See e.g., Krajcik, et al., 2003; Moss, Abrams, & Kull, 1998; Schneider, et al., 2002.
documents, but more importantly, for promoting an interest in socioscientific and technological issues (see also Donahue, et al., 1998).

Empirical studies support these claims about the benefits of learning through project or community-based inquiry. A study by Giscombe (2004) used classroom observations, focus-groups, and individual interviews to investigate Grade 7 students’ experiences with and views on project-based instruction. Giscombe (2004) also collected student portfolios and science fair display boards to better assess what students learned in the process of conducting their projects. Students’ interview responses indicated that they found science learning fun, interesting and motivating when taught through the hands-on, project-based approach. Students stated that work on the science projects, which dealt with the different environmental issues around arsenic, was challenging and thus, prompted them to investigate their project topics more extensively. Giscombe’s (2004) analyses of the information from the portfolios and project boards showed that student involvement in project-based inquiry enhanced their science knowledge and skills in areas that match intended learning outcomes in the National Science Education Standards (National Research Council, 1996).

Other educators provide evidence for the benefits of project-based, inquiry learning. Schneider and co-researchers (Schneider et al., 2002) found that students from project-based science (PBS) classrooms scored higher in a U.S. national science achievement test compared to the national sample. The researchers used the 35-item science test of the 1996 National Assessment of Educational Progress (NAEP) to evaluate 142 students in Grades 10 and 11. These tenth and eleventh graders had two and three years of experience, respectively, with PBS. Using statistical tests to compare student scores with national averages, the research study

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6 The NAEP examination consists of three types of questions: *multiple-choice* that test conceptual and factual knowledge; *constructed-response* that assess ability to synthesize, connect, construct, assess and convey information; and *performance tasks* that evaluate ability to conduct scientific inquiry tasks (e.g., observe, problem-solve) (Schneider, et al., 2002, pp. 412-413).
showed that PBS students outscored the national sample on 44% of the NAEP test items. The data also revealed that students performed better in test questions that either required a lengthy response or made reference to scientific investigations. The researchers claim that students’ long-term engagement (from 8 to 15 weeks) in PBS pedagogy provides an advantage for these students to do well on tests items that entail critical thinking, reasoning or scientific inquiry skills. The researchers suggest that with its positive impact on student learning, science inquiry through a project-based approach should be more extensively used as vehicles for curricular reforms in science classrooms. In conjunction with all the other benefits associated with the use of project-based learning, I concur with their suggestion.

To summarize, all forms of inquiry learning described and explored in the above mentioned studies appear to be variations on the same theme, namely, providing students with a context to learn scientific concepts and to apply inquiry skills. Most science educators and teachers acknowledge that the end goal of these learning strategies is to develop independent learners who are equipped to investigate, problem-solve and make informed decisions about socioscientific issues in their daily lives.

In contrast to inquiry, whose applications science teachers have explored since the 1960s, technological design as a vehicle for science learning is a relatively new development (e.g., Benenson, 2001; Roth, 2001; Roth, Tobin & Ritchie, 2001; Seiler, et al., 2001). In the next section, I explore some of the main historical and sociopolitical influences that define the role of technology education in the general and the science curricula. I also review the literature on technology design to examine how it is characterized in theory and in practice.

**Historical and Sociopolitical Contexts for Technology Education**

In the history of schooling, calls to integrate technology education in the general
curriculum came from groups with varying interests and motivations. For example, in England and Wales in the early 1980s, engineers lobbying for the status of their profession and government leaders concerned for the economy initiated moves for introducing technology education in the national curriculum (Layton, 1995). The move to integrate was an attempt to increase the number of trained industrial workers in the country. Politicians and other advocates hoped that early exposure to technical courses would provide students with practical skills to equip them for everyday, real world experiences. The seriousness in the government’s pursuit of this goal can be seen from the amount of money invested in technology education. In 1983, the British government funded the Technical and Vocational Education Initiative project with a budget of £46 million for an initial 5-year period and £2 million for the succeeding 5 years. Layton (1995) reports that money went towards equipping schools and funding additional teaching staff.

Similar initiatives to develop strong technical-vocational education programs were evident in the U.S. as government legislated the Perkins Act in 1990 and the School-to-Work Opportunities Act in 1994 (National School-to-Work Opportunities Office, 1998). Parallel to the England reform projects, the U.S. legislations called for a focus on a more practical, work-oriented education of school children and youth, and thus, technology education during that period had an industrial arts focus. The American curriculum models for technology education exhibit a strong emphasis on industrial systems, i.e., “production, transportation and communication” (Layton, 1993b, p. 13), and recently biotechnology. The U.K. curriculum models focus more on the processes involved with technology studies, particularly technological design (Layton, 1993b).

In trying to understand the historical evolution of technology education, my discussion
includes descriptions and analyses of the sociopolitical influences exerted by various stakeholders on technology education. Most educators argue that these influences helped to shape how technical education is defined and taught in schools (e.g., Cajas, 2001; Layton, 1993a, 1993b; McCormick, 1994). McCormick (1994) presents different traditions, while Cajas (2001) cites contrasting definitions of technology and goals for technology education as some of the important sociopolitical influences on technology education.

McCormick (1994) traces the evolution of technology education in England and Wales, which were among the first countries to effectively implement technology-based school programs, as it progressed through the five traditions of tradecraft, art and design, science and technology, home economics, and science-technology-society. Technology learning through tradecraft focused on the development of tool skills as students worked with wood, metal, hand tools and machinery. McCormick (1994) points out that within this tradition of technology learning, the model of a single worker controlling the entire manufacturing process is flawed and runs counter to the industrial culture of teamwork. Supporters of an art-and-design approach to technology education (later called crafts, design and technology) argued for a focus on the child’s abilities to create, invent, and imagine. McCormick (1994) claims that the art and design approach to technology education is the precursor of the technology design practice. Integration of technology into science and into home economics was another approach to linking school curriculum to the practical. The partnership forged between technology education and home economics was evident in the food technology and textile technology subjects. Although scientists and science educators advocated a “back to pure sciences” focus in response to the education reforms of the Sputnik era, they eventually heeded calls to include technology as the practical component to learning science. By the mid-1980s, recognizing that
both science and technology had expanding influence on society, the STS movement sought to integrate the two disciplines through learning contexts that dealt with their social influences (McCormick, 1994). These five different traditions in teaching about technology imply a valuing for different notions of technology: as artifact, as process or skill, or social enterprise. This is what Cajas (2001) argues.

Cajas (2001) claims that changes in the pedagogical focus for technical education through the years coincide with the different ways society perceives or defines “technology”. He states that in the early 20th century, the curriculum offered technology courses in tradecrafts or manual arts in line with the notion of technology as tool or artifact. Then, when school curricula introduced technical arts in the 1920s, there was a shift in focus towards technology teaching and learning that leads to the acquisition of technical and tool skills. This focus parallels a view of technology as vocation-related knowledge and practical skills. Beginning in the 1980s to the present, society tends to perceive technology more as a “social practice” (Cajas, 2001, p. 717). Parallel to this notion of technology as social practice, technology education is expected to help students understand and use technology within the context of its role and influence in society (Pannabecker, 1995). Thus, there were calls for technology education to focus on the development of students’ technological and scientific literacy skills (International Technology Education Association (ITEA), 2000; Pearson & Young, 2002). Cajas (2001) argues that the development of literacy skills is facilitated by learning technology using the design-and-build approach. He also claims that this approach helps students see the interconnections between science and technology.

Highlighting the interconnections of technology with science, and with other academic disciplines is the goal of education policy makers and educators who have been exploring ways

Educators cite at least three main objectives for this integration, namely, to achieve vocational goals, to make education practical and relevant, and to increase scientific and technological literacy (Cajas, 2001; Fensham, 1992; Layton, 1993b). I discuss each of these three goals for technology education in the next sections.

As previously discussed, the initial goal for introducing technology studies into the curriculum was vocational in nature. Fensham (1992) claims that the thrust of technology education in the United States and in Canada in the late 19th century was to link the goals of technical learning to the needs of industry and the economy. Thus, the mandated technology curricula in these two countries continue to emphasize traditional trade skills in working with wood, metals, and other materials used in industry. Other education stakeholders such as parents and students seek a clearer link between school and work to increase student’s future employability. Employers hire workers who possess good social, communication and teamwork skills, and also the appropriate technical skills to work in jobs and careers that have become technology dependent (Carnavale, 1992). Clients of the educational enterprise welcome the emergence of technology education in the school curriculum.

A second goal for the integration of technology with science or with general education is to address the need to make curricula more relevant and practical to students. Calls for a more utilitarian curriculum came from government leaders, parents and other education stakeholders after reports such as A Nation at Risk (National Commission on Excellence in Education, 1983) revealed the dismal state of American education based on students’ low achievement in schools and in international assessment examinations (Fensham, 1992).
Science educators in the 1980s infused technology topics into science classes to enable students to explore and appreciate the practical applications of science principles in everyday technological artifacts (Layton, 1993b). It is also claimed that technology infusion has helped make science learning interesting as the technological device provides context to what were previously de-contextualized science principles (Layton, 1993a). In addition, the hands-on nature of computers and other technical gadgets provides students with motivational and fun ways of learning science, arts or humanities (Foster, 1997). The call to link practical skills with academic learning continues to face resistance among specialist teachers who are reluctant to relinquish their subject areas expertise. There is also resistance to explore the integration of vocational with academic educational goals because of the perceived lower status of technical courses (Foster, 1997; Gaskell & Hepburn, 1997).

In the past 10 years, educators have promoted technology education for the goal of developing technological literacy for all students (ITEA, 2000; Pearson & Young, 2002). With technology's growing influence on the environment, and on social practices and norms, educators seek the integration of technology into education to enable students to critically examine social, environmental and health issues around the applications of science and technology (see e.g., Yager, 1996b). With the fast changing developments in technology such as computers, information technology and biotechnology, society expects schools to graduate students with both technical skills and critical thinking skills to make informed decisions about the benefits and dangers of technology. Cajas (2001) contends that knowledge of scientific and technological principles, within the context of design tasks, is important in enhancing students' scientific and technological literacy.

Layton (1993b) states that regardless of stakeholders' objectives for inclusion of
technology in general education, these influences have placed value on technology as a separate
discipline from the arts and sciences. Foster (1997) argues that the continuing struggle to
change the status of technology in the curriculum depends on the openness of both academic
and vocational teachers to embrace the pedagogical practices that accompany this curriculum
change. Young (1998) and Kincheloe (1995) note that the higher value placed on academic
over practical learning in schools perpetuates the socioeconomic inequalities and distinctions
between intellectual and skilled labour in the workplace and the larger society. For example,
the lower status placed on learning technical skills, as opposed to learning classical knowledge,
has strongly influenced the exclusion of technology education from the general curriculum in
the past (Foster, 1997). These authors call for the integration of the academic and the practical
goals of learning (Kincheloe, 1995; Layton, 1993b; Young, 1998). Layton (1993b) argues that
teaching about technology as technological design may be the way to bridge this head-vs-hand
dichotomy. Layton (1993b) maintains that technology taught within the technology design
approach provides students with opportunities to engage in both mental and manual learning
activities.

Standards documents for developing both scientific (AAAS, 1993; National Research
Council, 1996) and technological literacy (ITEA, 2000) strongly support the use of
technological design in classrooms (see also Cajas, 2001). Among the many manual activities
associated with technology learning, some educators claim that it is technology design that
plays an important role in engaging students in creative thinking and problem-solving (see e.g.,
ITEA, 2000; Layton, 1993b). I explore these educators’ claims as I investigate the nature of
technology design learning.
Defining Technology Design

Researchers and authors apply the phrases design-and-construct\(^7\), design, engineering, technology (see e.g., Krause, et al., 2004), or engineering design (Eggleston, 2001; ITEA, 2000; 2003; Roth, et al., 2001) to the process of technology design. I use these terms interchangeably when I want to refer to the technology design approach I discuss in this dissertation. Eggleston (1976), defines design as:

> the process of problem solving which begins with a detailed preliminary identification of a problem and a diagnosis of the needs that have to be met by a solution, and goes through a series of stages in which various solutions are conceived, explored and evaluated until an optimum answer is found that appears to satisfy the necessary criteria as fully as possible within the limits and opportunities available. (p.17)

At least four attributes of design are evident in the above-mentioned definition. The design process involves establishing a goal (e.g., address a social need), identifying the product requirements (e.g., attributes and limits), exploring solutions, and evaluating and improving product efficiency until the requirements are met (ITEA, 2000). Some technology curriculum documents and textbooks refer to the process as design and technology to emphasize that designers address the identified problem by constructing a technological product (Eggleston, 2001). In designing and constructing technology, the design criteria define what the technological artifact is expected to do, while the constraints establish the limits (e.g., cost, materials) on the design. Designers or engineers weigh product constraints against each other and make compromises or trade-offs in the process of achieving product efficiency (Cajas, 2001; ITEA, 2000). Layton (1993b) describes the process as an interactive cycle and argues

\(^7\) Also called design-and-build or design-and-make.
that as designers engage in the iterative stages of “designing-making-using” (p. 37), they should also be aware of the political influences on and the social impact of the technological artifact they create. The ITEA (2000) characterizes design as one strategy of problem solving within technology activities. Layton (1993b) claims that creating and problem-solving within the design-and-construct approach makes this approach an effective tool in teaching not only technology, but also other disciplines in the curriculum. Advocates of technological design contend that students’ engagement with design tasks enhances their creativity, technical, and analytical thinking skills. I now examine this and other assumptions about technology design.

**Technology Design in Practice**

Technology educators and researchers claim that teaching technology education through the design process is important in nurturing students’ technological and scientific skills and knowledge. For example, Kimbell (1982) argues that design education not only teaches students tool skills and technical knowledge, but also advances the learners’ potential to explore, design and create a technological product in answer to a particular need. Benenson (2001) argues that “the processes of design [italics in original] are central to the practice of technology, just as inquiry is the central activity in science” (p. 737), and that carefully crafted design problems can be effective media for learning scientific concepts and processes. Roth (2001) points to research findings indicating that technology-oriented activities are rich venues for science learning when these activities involve “(a) designing and testing artifacts and (b) critical analysis and explaining performance failures of artifacts” (p.768). Other educators believe that applied within the context of STS, design and technology education can foster inquiry skills (e.g., Fensham, 1992); increase understanding of science-technology relationships (e.g., Layton, 1993b); and develop literacy among students (e.g., Frank & Barzilai, 2004).
Fensham (1992) further states that designing, as a novel alternative to technology education, provides a practical context for learning since the invention and creation of a product addresses a societal need.

Education researchers maintain that in addition to developing students' science-related knowledge, skills and literacy, technology design enhances problem-solving, communication and social skills as students collaborate with teachers and peers (Hennessy & Murphy, 1999; Murphy & Hennessy, 2001, Roth, 1998). Education and industry leaders consider these skills important in preparing students for the world of work. I present empirical research on technology design to help substantiate these educators' claims, and to better understand the nature of technology education as it is practiced in the classroom.

Roth, who has extensively researched classrooms that engage students in design and technology (see e.g., Roth, 1998, 2001), as well as in scientific inquiry practices (e.g., Roth, 1995, Roth & Bowen, 1995), argues that technological design is an effective approach to learning science. He further maintains that in the process of completing projects, students learn to collaborate, argue, analyze and problem-solve with their peers and teachers (Roth, 1998, 2001). He substantiates these claims through empirical data from his classroom visits and teaching. In one research study he conducted in a Canadian elementary school where students from two classrooms designed earthquake proof-towers, gondolas and bridges, Roth (1998) found that design provides a rich learning context for students to test ideas and to work collaboratively towards a goal. Roth (1998) used semi-structured pre-interviews to ask students about their knowledge of engineering and design, and to get a better perspective of student practices he later observed in the classrooms. Roth (1998) presented thick, rich data to show that students gained knowledge on the artificial and the natural world, on designing and testing,
and on teaching and learning. For example, as students manipulated glue guns, adhesive tapes, straws, strings and other materials for their design projects, they learned about the natural laws and the properties of materials. Students also exhibited an increased understanding of engineering concepts and skills. This included knowledge in the designing (e.g., design limits, specifications), and the testing processes (e.g., weakness, stability). Students learned about the sources of knowledge (e.g., peers, teacher) and the learning process (e.g., discussing ideas). Roth (1998) observed that teacher scaffolding and eventual ‘fading’ helped foster students’ independent learning and increased their confidence to initiate interactions. For example, during small group discussions, the teacher did not have to prompt students with her own questions because students discussed project-related issues on their own. In addition, the teacher did not ask about factual information or design terminologies, but was more interested in talking to students about the design process. These instructional strategies encouraged small group and student-student conversations, and supported student-directed discourse.

In another study, Roth (2001) examined the practices of Grade 6 and 7 students in his own classroom as they tackled topics on simple machines within a 4-month period. His research goal was to explore how and why students learn science through technology design. For 60% of the class time, students designed machines and presented their work to their peers for critique and comments. The class also engaged in some teacher-designed investigations, and in whole class discussions. Roth (2001) assessed student learning through formal and practical tests, and interviews (conducted before, during and after the 4-month course unit on machines), in addition to analyzing student work. His study findings reveal that the technology design environment provides opportunities for students to learn both science and design concepts. Roth (2001) claims that students who learn the design process gain a “cognitive
advantage” (p. 786) as they create both a mental, and a physical model of their design ideas. Students’ use of physical or manipulative artifacts enhance their ability to think through their ideas (a process Roth calls “thinkering” [p. 780]), compared to if they simply relied on mental models. These students learn to communicate, develop ideas, describe and explain theories behind their designs, and thus become good problem-solvers. Roth (2001) also observes that students do not talk about the science concepts inherent in their projects during the construction process, but will do so when prompted to present and demonstrate their device through both small group and whole-class discussions. He argues that this kind of discussion must be sustained in technology design classrooms, if science learning is an equally important goal. Roth (2001) claims that similarities between inquiry-based science (Roth, 1995) and technology-oriented classrooms are evident from his analyses of study findings. He anchors his claims on the observation that in both these learning approaches, students extensively use artifacts (e.g., gestures, concept maps, experiments, drawings, technological devices) to think with and to communicate what they have learned. The case studies conducted by Roth (1998, 2001) are valuable as they provide thick descriptions of both teaching and learning practices in the technology design classroom. They also reveal significant findings that suggest the possible integration of technology education and science education goals through teaching of design. In addition, because of his extensive work in both inquiry-based (e.g., Roth, 1995; Roth & Bowen, 1995) and technology design classrooms (e.g., Roth, 1998, 2001), Roth is able to present well-documented evidence that convincingly supports his claims and theories about both learning environments.

Sadler, Coyle and Schwartz (2000) conducted a study on the learning experiences of middle-school children who had participated in design competitions. The study investigated
students’ experiences with engineering challenges as they participated in iterative design activities. From across 22 classrooms, the researchers engaged 457 students from Grades 5 to 9 in various engineering competitions and challenged them to build, test and re-design technology products. An example was the design challenge where students constructed a bridge using a single sheet of notebook paper suspended by two posts at the end. The challenge was to use paper of minimal weight (i.e., by cutting off parts of the paper) without hampering the capacity of the bridge to carry a 1-kilogram mass hanging from its center. The researchers investigated the impact of the design competitions on student learning through pre- and post-tests, interviews, classroom observations and storyboard analyses. The open-ended, 11-item tests assessed student knowledge and skills in hypothesizing, identifying variables, and analyzing experimental data before and after the design competitions. Student interviews focused on soliciting student explanations regarding the results of their design artifacts. The researchers claim that test scores indicated a slight improvement in students’ scientific thinking and analytical skills after participating in the design challenges. They also maintain that effective design challenges should involve a series of iterations where testing and redesigning activities provide students with opportunities to learn from their mistakes. Findings from the study also indicate that effective engineering competitions are those that allow students to measure the efficiency of their design products against an instrument (e.g., stopwatch, ruler, thermometer) instead of subjective tests based on teacher or peer assessments. The study findings suggest that storyboards (i.e., successive sketches that depict design-evaluate-redesign stages in the evolution of the technological artifact) are effective tools in assessing students’ technological abilities as the storyboards highlight the need for students to test one design variable at a time. This study of technology design is relevant because of its comprehensive scope, and use of
multiple data sources. The significance of the large sample size and multiple data sources is that they illustrate that there is strong evidence for the claims that the researchers make in this study.

The study is also significant because it provides practical, alternative strategies for assessing student learning in technology design environments, which a technology teacher may want to apply in his/her classroom. Data from this study help support claims by some science educators that technology design is an effective vehicle to learn science concepts when design activities are not limited to a one-time design challenge (see e.g., Penick, 2002). However, although design challenges are important vehicles for encouraging student participation and interest in technology-related activities, these challenges are limited in the sense that the product is built to satisfy an imagined, instead of a real-world, need. Technology literacy and standards documents highlight the need for teachers to provide students with practical, authentic contexts that enable students to see the value and connections of school-based learning to the world of the home, community or workplace (ITEA, 2000; Pearson & Young, 2002).

Published research studies that provide empirical data on technology education practices in non-Western classrooms are rare. The few that I found in my literature search were interested in looking at students' attitudes towards technology after engaging in technology-based learning tasks (see e.g., Ankiewicz & Van Rensburg, 2001). Other studies focused on the use of technology design strategies in non-Western classrooms. For example, in one qualitative study conducted in Israel, Frank and Barzilai (2004) investigated the experiences of 43 pre-service teachers with project-based technology learning in a Science and Technology methods course. The 14-week course aimed to prepare student-teachers to teach the subject as mandated by the Israeli secondary curriculum. Modeling technology design within a project-based approach, student-teachers worked in teams to design technological products. Through
analyses of interviews, questionnaires and reports, as well as observations of classroom
practices, researchers examined these novice teachers' perspectives on and experiences with the
course. Study findings indicate that pre-service teachers gained knowledge about technology
principles because of their course participation. For example, student-teachers recognized that
to solve their design problems, they had to choose the best among various possible solutions,
and consider the product trade-offs. Research data revealed that pre-service teachers developed
a better understanding of science-technology interconnections. Student-teachers also
encountered some challenges with the project-based learning approach, which included
challenges in dealing with group conflicts, coping with time and effort demands, and adjusting
to the unstructured, non-traditional learning environment. This study provides valuable
research data on how science and technology pre-service teachers, who are encouraged to teach
through a project-based, technology approach, experience firsthand the benefits and the
challenges of this learning strategy. The study is also a source of significant information about
the implementation of project-based technology learning in a non-Western classroom. But,
while this study provides an important look at non-Western contexts where design learning is
applied, it does not explore the possible role that culture may have played in these students'
experiences with a Western learning approach.

In summary, this examination of the research literature has shown that inquiry and
technology design can be effective vehicles for supporting student interest and motivation in
science and technology learning. These pedagogical practices help develop students'
independent thinking, and problem-solving skills. The approaches also encourage student
interest in science and technology careers. Amidst the numerous studies that document the
benefits of inquiry and technology design practices in science classrooms, there is a small but
growing body of research that critically examines the issues around applications of these Western notions of science and technology learning in non-Western classrooms. For example, some multicultural researchers question the assumption that these Western science practices can support learning for all students (see e.g., Aikenhead, 1996; Eisenhart, et al., 1996). Other researchers have investigated the role of culture and language in non-Western science classrooms (see, e.g., Lee, 2002). These critical studies pave the way for my research study that examines technology design in the Philippine classroom.
CHAPTER THREE
METHODOLOGY

This research study investigated Filipino secondary students' and teachers' experiences and practices in a Science/ Technology Research program that aims to enhance the students' interest and participation in science and technology-related courses and careers. This study was conducted with the intent of examining how a science-technology course with a technology research approach is defined in a Filipino setting and how the course mediates science and technology learning among the students. In this chapter, I begin by describing the context of the study, the school and program setting where the research study was conducted and the science-technology curriculum that was being implemented. Then, I describe the students and teachers who volunteered to participate in the study and the research methods I used to conduct the investigation. Lastly, I outline some personal reflections on what it meant to be both an outsider and insider in the research setting.

Context of the Study

In this section, I first describe the setting and the special science curriculum of the school where this research was conducted in the Philippines. Second, I describe the focus of the study, namely, the Science/Technology Research Program that exists within this curriculum.
The School Setting

The Philippine Science High School (PSHS) is a system of government schools that provides a scholarship program\textsuperscript{8} for Filipino youth who are identified as gifted in mathematics and the sciences. Since the inception of the first PSHS campus in 1964, the school’s main objective has been that students who undergo its unique four-year program

\ldots shall someday constitute a pool of science and technology professionals who are endowed with the spirit of inquiry, analytical thinking, creativity and innovation, motivated by love of God, concern for society and the environment, and prepared for responsible leadership and citizenship. (PSHS, 1997, p.16)

This goal is aligned with the Philippine government’s vision of using quality science and technology education to move the country towards industrialization and economic stability. Whereas other public secondary schools in the Philippines are under the jurisdiction of the nation’s Department of Education, the PSHS is the only system of high school financed and managed by the Philippine Department of Science and Technology (DOST). The jurisdiction of the DOST ensures the continued development and improvement of the special science and technology curriculum of PSHS.

The vital role that science and technology are perceived to play in national development and progress led Congress to approve, in 1997, the creation of a PSHS System of 16 campuses located in the different geographical regions of the country\textsuperscript{9}. In 2004, the PSHS System consisted of eight campuses. Provided that funding is available, the Philippine government

\textsuperscript{8} The scholarship grants the PSHS students free tuition and books, and a monthly living allowance for four years.

\textsuperscript{9} The Philippines' 79 provinces are organized into 16 geographical regions for administrative purposes. The provinces grouped under an administrative "region" share common cultural and ethnological backgrounds (Villar, 2003).
plans for the addition of one campus each year until all 16 campuses are established. This research was conducted in one of the seven campuses existing at the time of the study.

Admission to the school system is based upon two competitive written examinations that measure the students’ English, Science, Mathematics and non-verbal (analytical) aptitudes. The entrance tests are administered nationally to recruit students from across the Philippine archipelago. Students who qualify in the examinations and maintain good academic and moral standing are granted a four-year high school scholarship. With the country’s 7,100 islands comprised of 79 provinces and a Metropolitan Manila area of 16 cities, students entering PSHS come from varied socioeconomic, cultural and educational backgrounds. The population of students that attend the PSHS System consists of Filipino youth ranging in age from 11 to 17 years old. These students are equivalent to students enrolled in Grades 7-10 in the Canadian educational system. The PSHS curriculum aims to provide quality secondary education that supports learning in the sciences, mathematics, technology, languages, humanities, arts and physical education, and enhances the student’s personal and social development.

The PSHS Curriculum

In the PSHS System, learners are offered a balanced curricular and co-curricular program. However, the academic program puts an emphasis on the implementation of school subjects and activities that enhance student learning in the fields of Science, Technology, and Mathematics. Whereas the Department of Education regular high school’s mandated curriculum includes the teaching of one science subject (i.e., General Science, Biology, Chemistry, or Physics) per year level (Somerset, 1999), the PSHS curriculum has always

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10 Formal schooling in the Philippines includes 6 years of primary school (Grades 1 to 6), and 4 years of secondary school (first to fourth-year). Students who attend a private elementary school may opt to complete an additional year in Grade 7. Typically, Filipino children enter Grade 1 at 6 or 7 years old, and graduate from high school at 16 or 17 years old.
required that students take three or more Science subjects per year. In 1993, the PSHS curriculum changed. In addition to the core subjects, students were now required to enroll in specialized electives based on one of two ability groups or streams\textsuperscript{11}: the Science or the Technology Stream. Both Science and Technology Stream electives had an applied focus. For example, Science Stream electives included such courses as Microbiology, Food Science, Industrial Chemistry, Environmental Science, and Digital Design, among others, while the Technology Stream electives included Woodcraft and Metalcraft, Drafting, Computer-aided Design, and Electronics. The assumption underlying the introduction of the Technology Stream and an applied focus into what was originally a science-intensive curriculum is that students with high mechanical aptitude might benefit more from a technology-enriched science program than a purely science one. The exposure to Technology courses was believed to enhance these students' interest and encourage them to pursue future degrees and careers in engineering. The claims about the benefits of the Science/Technology Streaming program have gone unexamined since 1993 but continue to serve as the bases for the design of the taught curriculum in eight existing PSHS campuses and two other Philippine high schools. My research study begins to address the need to explore the assumptions behind the Streaming program. In Chapter 4, I provide a more detailed description of the historical context and rationale for the introduction in 1993 of a technology focus and the streaming process into the school curriculum.

One aspect within the PSHS curriculum that is representative of the Streaming and applied focus is the Science/Technology Research Program. The Science/Technology Research Program is a series of courses that uses an investigative research and project-based learning approach to further stimulate and sustain student interest in science and technology.

\textsuperscript{11} I will interchangeably refer to the science and the technology ability groups as \textit{streams}, \textit{tracks} or \textit{strands}. 
The Research Program is the focus of my study as I examine both the assumptions behind the implementation of the Science/Technology Streaming process and the experiences of Filipino students with a project-based, technology research learning strategy.

Science/ Technology Research Program

The Science/ Technology Research (STR) Program at PSHS consists of two core research courses: Science/ Technology Research 1 (STR 1) which is taken by third-year students, and Science/ Technology Research 2 (STR 2) which is offered to fourth-year students. The STR Program engages students in the process of scientific research and/or design-and-technology through a combination of an “investigative research” and a “project-based learning” approaches. The STR Program is intended to help the students acquire higher order thinking skills through research-related learning experiences (J. M. Cruz, personal communication, June 1999).

The STR students work in groups of 3s or 4s as they seek out science- or technology-based solutions to a real problem within the school or community. Students are also encouraged to consider working on projects that address some economically important concerns of the country. Driving questions and problems that learners choose as the basis for their projects are typically related to pollution and recycling, health and medicine, agriculture, aquaculture, chemical industries, food production, telecommunications as well as some basic or pure research problems. Students then propose a possible solution to the problem in the form of an inquiry-based science experiment or the construction of a technological device or innovative practice that utilizes Philippine indigenous materials.

The STR 1 course provides an introduction to the scientific research or technological
design process. The classes meet for two periods per week for one school year. As part of the curriculum, all STR 1 students select a problem they will investigate, plan their experimental design, write a review of related literature and a research proposal, and run a pilot version of their project. Core topics taught in this course include the basic principles of research inquiry, sampling, design and writing. The course also provides lessons on statistical tests that students may need to know in order to process and analyze their research data. The STR 1 teachers discuss additional concepts and skills intended to help students design projects consistent with their chosen science or technology specialization. That is, students in the STR 1 Science Stream learn basic laboratory techniques, instrumentation and safety in preparation for conducting a scientific investigation. While, students in the STR 1 Technology track are exposed to design-and-build learning activities and encouraged to work on the production of a technology device.

The STR 2 course focuses on hands-on activities dealing with the scientific research and/or design-and-technology process. The STR 2 classes meet for three periods per week for one school year. During the STR 2 course students refine and implement the project design they chose and began the previous year in STR 1. Thus, during this second year of STR, students in the Science Stream typically conduct scientific experiments, data collection, and complete data analyses. On the other hand, learners in the Technology track of STR 2 begin by improving their proposed design before proceeding to construct, test, and evaluate a prototype of the technological artifact. For successful completion of the STR 2 course, students must prepare a poster for display in the school’s annual Science & Technology Fair Competition, give an oral defense presentation in front of the class, complete a report on the project, and

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12 A school year in the Philippine educational system runs from June to March of the following year. Within this 10-month school year, students typically work on their projects from 6 to 8 months only because of other school activities and vacation time that interrupt the school year.
write an examination. Because of the specialization attributed to the two streams, PSHS students and teachers also refer to the STR courses dealing with technology as Technology Research 1 and 2, and to the Science Stream counterparts as Science Research 1 and 2.

With the curriculum changes attributed to the introduction of the Science/Technology Streaming in 1993, I was interested in examining the rationales and goals of the curriculum reform program in light of the PSHS students’ classroom experiences. Specifically, I wanted to investigate the supposed benefits of the Streaming program for enhancing students’ interest and learning in science and technology by examining one of the technology-based courses, namely, the Technology Research 2 course. I was also interested in studying how the research approach taught with a technology focus mediated student learning in science and technology. The technology-based, research learning approach has not been previously examined in a Filipino setting.

**The Research Study Participants**

This section describes the students and teachers who agreed to participate in my research study.

**The Students**

The fourth-year PSHS students who participated in the study were enrolled in the Technology Stream STR 2 class. Thirty-three students initially volunteered to participate in the study, but due to attrition, only 27 of these volunteers were finally interviewed. The students who were interviewed included 14 girls and 13 boys with ages ranging from 15-17 years old. These students were representative of the school’s diverse student population in that they varied in socioeconomic, cultural (i.e., whether they were from the rural or urban area) and educational (i.e., coming from a public or private elementary school) backgrounds. The group
of participating students was not, however, representative of the gender distribution in TR2 classes, which enrolls twice as many boys as girls. This may reflect the fact that the female Filipino students were more willing than the male students to volunteer and converse with a female researcher in the classroom. Table 1 provides a list of all students (by pseudonyms) who participated, and a summary of their demographic and educational backgrounds.

The Teachers

I wanted to examine the teaching practices in the Technology Research class in order to gain a richer understanding of the classroom context for the students’ experiences with technology-based, research pedagogy. I invited the two teachers of the Technology Research 2 sections, Juana and Maria (pseudonyms), to participate in the study, and both agreed. Juana and Maria are PSHS alumni who are now teachers in the school’s Computer Science and Technology Unit.

Juana

Juana, who had been teaching for 12 years at the time of the study, had her undergraduate degree in Computer Science. At PSHS, she has taught Computer Science, Computer-Aided Design, Advanced Electronics, Technology Preparation and the STR 1 and STR 2 courses. But at the time of the study, she was teaching only STR 1 and STR 2 classes. Juana had worked as the head of the school’s Computer Science and Technology Unit in the past. Juana stated that she had dreamed of becoming a teacher since she was in high school, and that she likes teaching because it is where one can help in the “shaping of minds” (Interview, December 5, 2001). She was working on her Master’s thesis in Computing when

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13 A class section enrolls a maximum of 30 students.
Table 1. List of Student Participants and Their Profiles

<table>
<thead>
<tr>
<th>NAME OF STUDENT</th>
<th>AGE</th>
<th>TYPE OF ELEMENTARY SCHOOL GRADUATED FROM</th>
<th>SOCIOECONOMIC STATUS&lt;sup&gt;b&lt;/sup&gt;</th>
<th>4&lt;sup&gt;th&lt;/sup&gt; YEAR SECTION&lt;sup&gt;c&lt;/sup&gt;</th>
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<td>A. BOYS</td>
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<tr>
<td>1. Aaron</td>
<td>17</td>
<td>private</td>
<td>high</td>
<td>A</td>
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<tr>
<td>2. Anthony</td>
<td>16</td>
<td>private</td>
<td>high</td>
<td>A</td>
</tr>
<tr>
<td>3. Eric</td>
<td>17</td>
<td>private</td>
<td>upper middle</td>
<td>C</td>
</tr>
<tr>
<td>4. Frank</td>
<td>17</td>
<td>private</td>
<td>high</td>
<td>C</td>
</tr>
<tr>
<td>5. James</td>
<td>16</td>
<td>private</td>
<td>low</td>
<td>C</td>
</tr>
<tr>
<td>6. John</td>
<td>16</td>
<td>private</td>
<td>lower middle</td>
<td>C</td>
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<tr>
<td>7. Jomari</td>
<td>17</td>
<td>private</td>
<td>high</td>
<td>B</td>
</tr>
<tr>
<td>8. Jonathan</td>
<td>17</td>
<td>private</td>
<td>high</td>
<td>B</td>
</tr>
<tr>
<td>9. Noel</td>
<td>16</td>
<td>public</td>
<td>upper middle</td>
<td>C</td>
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<td>10. Raul</td>
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<td>upper middle</td>
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<td>11. Roland</td>
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<tr>
<td>13. Xander</td>
<td>16</td>
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<td>B. GIRLS</td>
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<td>14. Ana</td>
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<td>15. Cherry</td>
<td>17</td>
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<td>16. Christina</td>
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<td>17. Diana</td>
<td>16</td>
<td>private</td>
<td>upper middle</td>
<td>A</td>
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<td>18. Elen</td>
<td>16</td>
<td>private</td>
<td>lower middle</td>
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<td>19. Gail</td>
<td>17</td>
<td>private</td>
<td>low</td>
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</tr>
<tr>
<td>20. Isabel</td>
<td>17</td>
<td>private</td>
<td>high</td>
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<tr>
<td>21. Maggie</td>
<td>16</td>
<td>private</td>
<td>low</td>
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<tr>
<td>22. Nikki</td>
<td>16</td>
<td>private</td>
<td>high</td>
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<td>23. Rhodora</td>
<td>17</td>
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<td>24. Richelle</td>
<td>16</td>
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<td>25. Rosario</td>
<td>17</td>
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<td>A</td>
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<tr>
<td>26. Trixie</td>
<td>16</td>
<td>private</td>
<td>lower middle</td>
<td>B</td>
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<tr>
<td>27. Vanessa</td>
<td>15</td>
<td>public</td>
<td>high</td>
<td>A</td>
</tr>
</tbody>
</table>

Note. <sup>a</sup>Pseudonym. <sup>b</sup>Data for the SES was based on the student's scholarship status that sets the student's monthly stipend. The school determined the scholarship status based on the parents' income and other indicators, such as, the parents' occupations and statement of assets and liabilities, family size, type of schools siblings attend, number of household help and number of cars. <sup>c</sup>Juana was the teacher for class section A, and Maria for sections B and C.
she was recruited to teach at PSHS. At the time of the study, she planned to pursue a Master’s degree in Information Technology.

Maria

Maria has an academic background in Mathematics, Industrial Arts Education and Architecture. She began teaching at PSHS after returning from Australia where she had been working towards a degree in architecture. At the PSHS, she taught Computer Science, Technology Skills, Visual Communication, and STR 2. At the time of this study, she was teaching STR 2 and Technology Skills classes. She says, “I realized that I ended up in a good place [in teaching] because I really enjoy interacting with many people” (Interview, June 19, 2002). While Maria claims that she does not see herself going into teaching as a long-term career, she was enrolled in a Master’s program in Education at the time of the study.

Methods of the Study

To explore the research questions on what technology research pedagogy is like in a Filipino context, I examined students’ and teachers’ experiences and practices in the STR 2 Technology Stream classes.

Naturalistic Case Study

In this study, I was interested in examining Filipino students’ and teachers’ experiences in, and views on, a technology-based, research course. Through my investigation of the participants’ pedagogical practices as they engaged in the technology-based research learning strategy, I sought to understand how this approach mediates Filipino students’ science and technology learning. Because my research dealt with participants’ experiences in a natural
setting, within a particular time and specific learning context, my research questions were best answered through a naturalistic case study methodology. A case study methodology is the appropriate research design to use when a qualitative researcher’s questions are directed towards observing an event or experience happening within a particular context (Miles & Huberman, 1994) or examining “a contemporary phenomenon within its real-life context, especially when the boundaries between the phenomenon and context are not clearly evident” (Yin, 1994, p.13).

This study fits the three attributes of a qualitative case described by Merriam (1998). It is particularistic as I focus on the experiences of a specific group of teachers and students in a particular learning context. It is descriptive as I use a range of data sources to produce a detailed and thick description of the research context and findings. Finally, it is heuristic as the rich data I collect and analyze are used to help others gain a deeper understanding of the pedagogical practices and experiences in the Technology Research classroom.

Data Sources and Collection Techniques

This study was conducted in a Science/ Technology Research classroom in a Philippine secondary school over a nine-month period from December 2001 to August 2002. Twenty-seven students and two teachers were recruited to participate in the study through a short presentation made in class where I explained the purposes and methods of the study. Interviews and conversations were the primary data sources I used to examine pedagogical practices in the classroom. I attended and observed classes in order to gain a situated understanding of how project-based, research learning was experienced by the teachers and students in the class. These observations aided me in the design of interview protocols. I also observed project groups during planning discussions with their teacher and/or with their peers.
as they worked on their Science-Technology projects. Other sources of data for my study included 1) observations of the students' presentations during the school's annual Science & Technology Fair; 2) informal conversations with teachers and students; 3) samples of student work; 4) email exchanges; and 5) curriculum documents pertaining to the STR Program.

Throughout the study, I kept a research journal where I recorded my field notes, descriptions of the activities, direct quotations from conversations, and other observations during the weekly classroom and small group visits. As suggested by Merriam (1998), I also kept a personal record of my "ideas, fears, mistakes, confusions and reactions to the [research] experience and ... include[d] thoughts about the research methodology itself" (p.110) to support my research study notes.

I discuss my data collection strategies under three general categories: interviews, observations and documents, and describe each strategy in more detail in the next sections.

**Interviews**

I conducted interviews with the research study participants through 1) semi-structured, one-on-one interviews; 2) informal conversations; and 3) email exchanges.

**Semi-structured Interviews**

My primary data sources were semi-structured interviews of the students and teachers from the Technology Research 2 classes. I conducted one interview of 45 to 60 minutes with each of the students who volunteered to participate in this research study. In interviews with students I focused mainly on the students' experiences with and views of science and technology teaching and learning through the technology research approach in the STR course. These interviews also provided opportunities for me to ask the students about their personal
history, future education and career plans, and aspirations.

I interviewed the teachers, Juana and Maria, on two occasions. Each interview lasted from 45 to 90 minutes. My first interviews with Juana and Maria took place on December 5, 2001 and June 19, 2002\textsuperscript{14}, respectively. Through this interview, I became (re)-acquainted with the teacher’s personal backgrounds, as well as their educational and professional history, and future plans. During Juana’s first interview, I also asked questions about the history and evolution of the Technology Stream in the PSHS curriculum. In my second set of interviews, I primarily asked the teachers about their experiences with and views of teaching and learning in the Technology Research program. These second interviews took place on April 3, 2002 for Juana, and August 27, 2002 for Maria. I audiotaped all student and teacher interviews.

Although the interview questions were posed in English (see Appendix A for the interview protocols), the participants were given the choice of responding either in English or in Filipino. This option was provided because most of the teachers and students were more comfortable speaking in the native language of Filipino even though English is the medium of instruction for all subjects at PSHS\textsuperscript{15} and most other Philippine schools.

I prepared verbatim transcriptions of the student and teacher interviews after each interview was conducted. The interview transcripts were written in the original language used by the interviewees. I sent print or electronic copies of the transcripts to the student and teacher participants and asked some additional questions for clarification or elaboration of responses that were unclear to me. I also asked students and teachers to read through their responses in order to check the accuracy of the names, dates, and technical terms, and the meanings of some initials or colloquial words used in the interview transcripts. This review of the interview transcripts also allowed the study participants to edit or omit responses that they did not want to

\textsuperscript{14} I requested interviews at the teachers’ convenience and Maria requested that the interview be conducted later in the study when both our schedules allowed for it.
be included in the data set. The participants provided their comments and edits on the paper or electronic versions of the transcript. This strategy of seeking the participants’ verification of the information on the interview transcripts was repeated throughout the study and continued into the dissertation writing stage as the process was arranged around the participants’ availability.

**Informal Conversations**

I had informal conversations with the students and teachers on a regular basis throughout the study period, and kept a record of these conversations in my research journal. Interactions and conversations with the students took place during their small group meetings with their STR teacher, outside the class periods while they were working on their projects, during the Science & Technology Fair, and at the regional or national science fair competitions where some of them participated. During these conversations we discussed the progress of their work, any problems they were encountering in their research projects, and their experiences at the fair competitions. I also asked the students to explain some of the scientific and technological concepts and methods they applied in their projects. My informal interactions with the teachers occurred during small group consultation sessions, lunch hour or break periods and at the science fair competitions. In our conversations, we discussed the students’ progress in their projects, the teachers’ expectations of their students, and how students were or were not meeting these expectations.

**Email Exchanges**

I sent electronic or paper copies of the interview transcripts to the research study participants as I solicited their feedback and edits on the interview data. I also used electronic

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15 An exception is the Filipino course that is taught in the native language.
mail to pose additional questions after the interviews were conducted, and the participants sent their responses by email.

I also had email exchanges with a number of teachers (n = 3) and administrators (n = 4) who helped in the development of the school curriculum into a technology-enhanced version. These individuals provided information about the goals, program rationale and historical context for the introduction of technology-based courses into what was originally a science-intensive school program.

Observations

While the semi-structured interviews served as my main data sources for this case study, I also observed classroom, small group, and science fair activities to help set the interview questions and to contextualise the interview findings. As Merriam (1998) notes, observing behaviour as it happens provides important first-hand information that may be lost when asking someone to describe it instead.

Classroom and Small Group Observations

I observed participating students and teachers in the Technology Research 2 classes for 50 minutes, three times a week. I attended to the participants' activities, conversations, interactions, roles and behaviours in the classroom and small group sessions. I recorded field notes and comments in my research journal as classroom or group activity was ongoing. During class and group sessions, I observed the students' activities as they worked on their projects and interacted with their classmates and teacher. I noted the questions that students raised and conversations they had with their peers and teachers. How the participants talked to each other, to whom they talked, what they said and how they behaved in their conversations
were observed. I also watched for “off-task” student behaviours and activities.

I kept notes on the teacher’s planned activity or lesson for the day, and her deadlines for submitting course requirements. Teachers’ and students’ responses to my informal questions were also recorded in my research journal. Finally, recognising that my presence could affect classroom dynamics, I kept a record of what I did and said, where I positioned myself during lessons, and how students reacted as I observed the classroom and small group activities.

Science Fair-Related Observations

Additional sources of data in my study included observations of the students’ poster and oral defense presentations as the students showcased their projects at local, regional and national Science & Technology Fair competitions.

All STR 2 students were required to present their group’s research findings and products to a panel of practicing scientists and/or engineers for evaluation and to the public for viewing during the school’s annual Science & Technology Fair. Ten winners from a total of 75 team projects were chosen by the judges based on the evaluation criteria suggested by the Science Research or Technology Research teachers. One member from each of the top 10 projects gave a two-minute oral and powerpoint presentation, and answered questions fielded by the judges as the projects’ final rankings were decided upon. Four of these 10 winning projects belonged to eight of the students who participated in the study.

The research teachers encouraged STR 2 students to send in entries and participate in other research competitions such as the Philippine Science & Technology Fairs that took place on January 18, 2002 (regional level) and March 25, 2002 (national level). This Intel-sponsored science and technology competition is conducted annually by the DOST in order to select the Philippines’ student and teacher representatives to the International Intel Science and
Engineering Fair held in the U.S.A. At the time of the study, two of the three STR 2 projects that competed at the regional level were designed by two pairs of students who participated in my study. One of these two projects won second place at the regional science fair, and went on to compete at the national level. I attended the Intel science fairs to observe, and to support these students’ efforts and participation at the regional and national competitions.

At the PSHS science fair, I observed the exchanges between evaluators and students as the judges visited each poster display. I also attended the oral defense presentations given by one member from each research team before a panel of judges. Students’ responses to questions and their explanations regarding their projects were recorded in field notes. I also included sketches of the poster displays in my research journal and took photographs to document the science fair proceedings.

Documents

Documents served as additional sources of information for my case study. Merriam (1998) defines the term document as “a wide range of written, visual and physical material relevant to the study at hand” (p. 112). The documents I examined included samples of the students’ work, photographic data, and curriculum documents pertaining to the STR course.

Student Work

In addition to observing the students’ poster and oral presentations at the science fairs, I examined the science experiments or technological devices that they designed. As students worked on their experiments or devices during and outside class periods, I asked them questions regarding their research methods and findings, background scientific and technological concepts related to their projects or the significance of their work. I also read parts of their research paper to better understand their research project.
Photographic Data

I took photographs of the students at various times throughout the study to contextualise my field notes: as students worked on their projects, consulted with the teacher and presented at science fairs. The pictures provided a visual sense of the students’ interactions with their teachers and peers, and involvement in their research projects.

Curriculum Documents

To understand the goals and historical context of the STR Program and to critically examine how it is implemented in the classroom, I collected and read a number of school-based curriculum documents. The documents I examined included the STR manuals (Cruz, 1999; PSHS, 2002) that students used in class, STR syllabi and timetables (Cruz, 1996), the old and the revised science curriculums, and summary reports that documented the development of the technology-enriched science program (PSHS, 1993, 1994; Reyes, 1994).

A summary of the data sources and collection strategies described above is shown in Figure 1 in reference to the research study timeline.

Data Construction, Interpretation and Analysis

The data sources and collection strategies described in the previous section were combined to provide a holistic understanding of how participation in a research course mediates Filipino students’ science and technology learning, and impacts teachers’ pedagogical practices and views in the research classroom. In this section, I describe the analytical procedures I employed to understand the students’ and teachers’ experiences.
Figure 1. Research activities and case study timeline.

<table>
<thead>
<tr>
<th>RESEARCH ACTIVITIES</th>
<th>2001</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dec</td>
<td>Jan</td>
</tr>
<tr>
<td>Establishing contact with study site and participants(^a)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Classroom and small group sessions</td>
<td></td>
<td></td>
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<tr>
<td>- Science Fair</td>
<td></td>
<td></td>
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<tr>
<td>Interviews and conversations</td>
<td></td>
<td></td>
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<tr>
<td>- Semi-structured</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Informal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Emails(^b)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Document collection and examination</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Student work</td>
<td></td>
<td></td>
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<tr>
<td>- Curriculum records</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Photographic images</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field notes and researcher journaling</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data verification and feedback(^b)</td>
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<td></td>
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</tbody>
</table>

Note. \(^a\)Initial contact with the school director, Board of Trustees and STR teachers occurred in October 2001. \(^b\)Email exchanges, data verification and feedback continued until 2003 during the thesis writing stage.
Data Construction and Analysis

To begin data analysis, I transcribed the interviews in the language used by the interviewee, either Filipino, English or a combination of both. I read and re-read the printed copy of the transcript to get an overall sense of a participant’s experiences. I then prepared a two to three-page summary of each interview in English wherein I worked to capture the participant’s thoughts and experiences about learning and teaching in the technology research course.

Using an initial set of interview transcripts, I applied the constant comparative method (Lincoln & Guba, 1985) to search for patterns, regularities, common themes and issues in the responses. I used these “common” elements to set up four initial conceptual categories that were either constructed by me or emerged from the participants’ own words. All interview transcripts were then individually coded in reference to these initial conceptual categories and new categories added as they were identified through the analyses of additional transcripts.

Following procedures suggested by Miles and Huberman (1994), I indicated the codes on the left margin of each transcript and wrote my ideas, interpretations and insights about the data on the right margin. Whenever appropriate, I colour-coded portions of the interview transcripts that expressed similar ideas among the participants.

Though student and teacher interviews were my main data sources, observations and document data were used to confirm themes that emerged from the interviews. To allow for analyses across the different types of data, a display was prepared using pieces of paper and cards that contained parts of the vignettes, synopses, interview quotes, and the emergent categories or themes. I then constructed tables and concept maps to provide a visual picture of the various data, and to organise them into some general or specific categories during the data
sense-making and interpretation. Using these tables and maps, I looked for connections among the data to support or refute the conceptual themes identified from the interviews.

Data from the curriculum documents and from conversations with school administrators were used to examine the objectives and rationale of the technology-enriched program vis-à-vis the participants’ classroom experiences. Guided by the research questions, I looked for an alignment between the proposed versus the implemented curriculum as enacted by the students and teachers in the Technology Research course.

It is important to mention that some of my conversations with the research study participants and school administrators took place after the course had ended and my data analyses had begun. These additional conversations conducted beyond the formal “data gathering” stage, reflect what Huberman and Miles (1994) refer to as the interactive and iterative nature of qualitative research.

Data Verification

Data in this study were verified through the processes of member checks (Merriam, 1998) and triangulation (Lincoln & Guba, 1985; Miles & Huberman, 1994). Member checks were conducted during the data collection and the data analysis stages of the research study. During the interviews, I asked participants questions about the meaning or significance of what I had observed in class, small group or science fair activities. I also invited participants to read their personal interview transcripts and my summary of their interviews, and asked them to give feedback on the accuracy of my description and initial interpretation of their classroom experiences in the course. Some student participants provided additional comments to clarify their initial responses. A few students chose to delete parts of their interviews when they could not recall details of the classroom incidents they were describing. These deletions did not
affect the overall findings or conclusions of this study. Through this process of member-checking I was able to confirm whether my documentation and interpretations agreed with those of my participants (Merriam, 1998).

Qualitative researchers employ triangulation to help them find a convergence among the different evidences collected, and to increase the research findings’ validity (Huberman & Miles, 1994). Triangulation was applied in my study as multiple voices, methods, and data sources were used to capture the essence of the classroom experience. For example, I used information about the teaching or group dynamics in the class from one participant and compared these with the accounts presented by the other participants so that as complete a picture as possible was revealed (Merriam, 1998). I also compared statements made by my interviewees with my classroom and small group observations to check for congruence or variations among the stories told and what I observed in the classroom. Though triangulation brought together different sources of information to corroborate and support some research findings, triangulation also revealed inconsistencies that I had to examine to provide a holistic picture of the classroom experience (Mathison, 1988; Merriam, 1998).

The Researcher as In/Outsider

I conducted this study in a school system where I had formerly taught and was concerned with my researcher role in the classroom. In the following section, I explore some of the subjectivity-objectivity issues involved in conducting this study at the school where I am both an “insider” and an “outsider”. Relevant research issues that I examine and address include: 1) the epistemological and ethical concerns pertaining to my relationship with the research participants and setting; and 2) how interviewing and participant observation may have influenced the data and findings of the study.
Epistemological Issues Raised in Conducting a Case Study

Debates on the objectivity-subjectivity dichotomy in qualitative research reflect the influence of competing inquiry paradigms of positivism, post-positivism, constructivism and critical theory, among others, on social science research (Guba & Lincoln, 1994; Jansen & Peshkin, 1992). These competing paradigms present contrasting views of a positivist-objectivist researcher on one hand and a relativist-subjectivist researcher on the other. "The qualitative investigator's traditional image as a seeker of knowledge and "truth that is out there to be discovered" has now evolved into one where the researcher, together with the research participants, co-construct or re-construct knowledge (Denzin & Lincoln, 1998). Increasingly more qualitative social science researchers espouse a constructivist or critical theorist perspective as they focus on presenting research findings as socially constructed knowledge accessed through researcher - participant interactions (Guba & Lincoln, 1994). These qualitative researchers acknowledge that the effect of the researcher's presence as insider, interviewer or participant observer cannot be neutral but greatly influences a study's outcomes.

Having been away from the PSHS System for three-and-a-half years to commence my graduate program in Canada, my first few weeks back in the school were spent getting re-acquainted with the school setting and program where classes are still mainly teacher-directed and lecture-based; and various school activities or faculty meetings disrupt regular class sessions. During the first few weeks of attending the STR 2 classes, I paused at various instances to reflect on my role as a researcher in a classroom, school and program context that is both familiar and new to me. As a Biology teacher who taught the Science version of the Research course in the past, I am familiar with the goals, requirements and timetable associated with teaching the STR course as originally envisioned by school administrators. However, the
Technology Research counterpart and its focus on design-and-construct activities were foreign to me.

As a graduate student-researcher-participant-observer during those first weeks back in the PSHS System, I tried to distance myself from my previous role as teacher-colleague. Initially, I attempted to sit back and examine the classroom proceedings and interactions through a researcher's supposed objective eyes. This turned out to be a futile exercise. For one thing, as I eased into the routine of attending and observing the Technology Research classes, I eventually ended up comparing what I observed in the classroom with my own teaching style and the classroom decorum I would expect if these learners were my own students.

The concept of an investigator with an objective eye is a myth in any qualitative research study that involves human beings. Clearly, my presence as the researcher in the classroom influenced (and was influenced by) the manner in which the study was conducted, what questions were asked, what and how data were "collected", as well as how the research findings will be reported. As qualitative researchers note, the educational investigator (whether as an insider or outsider, and consciously or unconsciously) influences the design and progress of the research study as well as the classroom or interview interactions with the participants (Merriam, 1998; Patton, 1990). A number of qualitative researchers (e.g., Denzin & Lincoln, 1998; Merriam, 1998) suggest that rather than distancing oneself from the research participants in an attempt to be objective, the researcher must instead critically reflect on her beliefs, values, prejudices, and historical context, and account for their possible effects on the conduct of the study and presentation of its findings.

Following these qualitative researchers' advice, I questioned and reflected on some of my personal contexts and beliefs before and during the conduct of my study. For example,
some important questions I asked myself included the following: How do I view knowledge or truth that will be gained from the study (i.e., is truth out there to be discovered or is knowledge constructed and negotiated between researcher and research participants?). How do I plan to present and situate the findings from the research project? Do I present it with a positivist, culturally constructed (e.g., class, gender or social status-related) or postmodernist-constructivist perspective? Whose perspective will be represented in my research narrative?

As I reflected upon my research study, even these types of qualitative questions were new to me because of the purely science background of my undergraduate and Master’s programs. I had previously thought that science studies involved only exact information and quantifiable data, and I taught my science courses from this positivist perspective. Coming from a traditional Asian background where the teacher, regarded as the authority figure and source of knowledge in the classroom, is respected and is never questioned, I had always taught in the way that I had been taught. I mulled over how to perceive and evaluate the classroom interactions I observed in my study after three years exposure to Western education and such concepts as constructivism, post-modernism, critical pedagogy and social constructivism.

**Ethical Issues in Conducting Research as an In/Outsider**

Researcher-participant interactions in a qualitative study not only raise epistemological problems but also ethical questions. In my situation, this was heightened by the fact that I was both an insider and outsider with respect to the research study setting.

My relationships with the two teacher-participants in the study were familiar and yet strangely “different”. Having previously worked in the PSHS System, I was well-acquainted with the two female teachers handling the Technology Research course: Maria was my former student who now teaches at PSHS, while Juana who is also a PSHS alumnus, is a close friend.
Both are younger than me and though they are only two years apart in age, the former refers to me as "Ma'am" in deference to my status as her former teacher, whereas the latter calls me by my nickname, "Jess".

When I initially solicited their involvement in my study, Maria and Juana both responded with "How can I say 'no'?" With such a close relationship between the teacher participants, and myself as the researcher I had misgivings about how I could accurately and honestly report their experiences in teaching the course without being influenced by my own biases and personal history with them. I also wondered whether some results that I report in this study that may reveal discrepancies between what these teachers say they are doing and what they are actually doing in the classroom would betray their trust and confidence in me.

My relationship with the students who participated in the study raised additional ethical issues. For example, some of the students were comfortable enough with me to share candid feedback about their teacher, school programs and subjects. A number of the students also raised some sensitive issues or concerns regarding the STR course that school administrators may not want to hear. How should I report these data regarding students' experiences and feedback? How should I include such politically controversial findings in my research report to the school? If I decided not to include these controversial findings, what did this say about my commitment to the students to relay their candid feedback about the science and technology program to school administrators?

Obviously, there are no easy answers to these epistemological questions and ethical issues. Instead, I chose to address these questions and concerns through what Measor (1985) calls a researcher's critical reflexivity. I clarified my personal views, prejudices and thoughts in a research journal during the conduct of my study and the thesis writing stage.
recorded my thoughts on a weekly basis as I tried to continuously question and re-evaluate the research design, data, findings, and analyses. I examined the inquiry assumptions, biases and ideas that I brought into the study and assessed them in light of my personal experiences, social, educational and cultural background. It was also important that I reflected on how my presence during class and interview sessions affected the research participants and the events that I was observing. I outline some of these reflections in the following sections of the chapter.

Addressing the Epistemological and Ethical Issues

When I think about the world of the classroom accessed through qualitative research, I concur with social constructivists who claim that the knowledge gained about that world is a co-construction of both the research investigator and participants. Working within this social constructivist view of knowledge, I present my research findings mostly from a culturally constructed (e.g., class or social status-related) perspective. Because of the ethical limits posed by my relationships with the two teacher participants, the narrative I present in this dissertation primarily emanates from the students’ perspectives and experiences. I have used the data reflecting the teachers’ pedagogical practices and the school community’s socio-cultural norms to provide the context for this narrative.

What follows are my reflections on how participant observation, interviewing and other research strategies were used to address the epistemological and ethical issues of doing research. In the process, I address issues of research validity and reliability.

Reflections on my Role as Researcher-Participant Observer

The researcher, whether as insider, interviewer, participant or distant observer, ultimately affects the research participants’ behaviour and response, and/or the scene being observed. The investigator’s manner of questioning, attitudes, responses and demeanor during
class and interview sessions can send varied and subtle messages that may elicit positive or negative responses from the student and teacher participants. For example, Merriam (1998) points out that students and teachers may tend to act in more formal and socially acceptable ways than they would if the researcher was not around.

An incident that took place in one of the Technology Research 2 classes clearly supports Merriam's claim and shows how my presence in the classroom influenced how the class was normally conducted. Prior to the first day of my regular classroom observations, Maria forewarned me that she normally comes late to her first period class because it begins too early (9:10 a.m.) in the day for her. However, during the first few class sessions when I sat in Maria's class, she came in on time because as she remarked, "It would look bad if you came in the class before I did!" (Field notes, January 7, 2002).

With Maria's comment in mind, I reflected through my journaling on my own role and its influence upon the students who saw me sitting at one corner of the classroom. I had earlier introduced myself to the class as a "PSHS teacher on study leave" when I presented and solicited their participation in my research study. Despite identifying myself as such, I hoped that they would perceive me more as the researcher-classroom guest and not as a teacher-colleague who was out "to spy" on them. This was important for me to keep in mind as I sat in the class and group sessions. The perception that I am more a teacher than a researcher might mean that students would be less willing to speak out if they felt that I would report untoward incidents to their teachers or school authorities. As Merriam (1998) notes:

The interdependency between the observer and the observed may bring about changes in both parties' behaviors. The question, then, is not whether the process of observing affects what is observed but how the researcher can identify those effects and account
for them in interpreting the data. (p. 103)

I was concerned that my presence did have an adverse effect on the students’ and teachers’ behaviour and asked them about this during our interview sessions. Their responses were generally the same: that yes, they initially were self-conscious and wanted to project a positive image of themselves, but that as the classes and group work progressed, they eventually eased into their usual classroom activities. Maria mentioned that she was ill at ease when I first sat in her classes, but later realized that she had gotten into the daily routine and even failed to acknowledge my presence to the class, as she took on her teacher role (Interview, August 27, 2002). It was evident by the third week of my classroom visits that things had gotten back to normal as Maria returned to her habit of arriving a bit late to class (Field notes, January 25 & 28, 2002).

One student explained that she saw me as the teacher’s friend and so did not consider me a stranger in the classroom. Another student mentioned that visitors came into their classroom occasionally, and thus, my observing them at the time of the study did not seem to be any different. Evidence of the students’ increasing ease with my presence was their engaging in off-task activities when I was observing like one student reading her pocketbook (Field notes, February 20, 2002), or a group of students singing and playing the guitar (Field notes, February 12, 2002) in class rather than doing assigned work.

The participants’ responses and my observations substantiate Lillian Weber’s (cited in Patton, 1990) claims about the visitor-researcher in the classroom:

Under the best of circumstances a teacher might get kids to move out of habitual patterns into some model mode of behavior for as much as 10 or 15 minutes, but that, habitual patterns being what they were, kids would rapidly revert to normal behaviors
and whatever artificiality might have been introduced by the presence of the visitor would likely become apparent. (p. 474)

The foregoing statement is encouraging as it suggests that for the most part, the students’ and teachers’ classroom behaviour were probably not unduly affected by my presence in the classroom.

**Reflections on the Interview Strategies**

In some instances, the participants’ interview responses as a form of self-reporting were one way by which the students and teachers highlighted what I perceived to be their positive behaviour and involvement in the classroom. At various times when I noted a discrepancy between self-report information and what I thought I had observed in the classroom, the research study participants were asked to reflect further on their earlier responses. This type of probing was done not only during the one-on-one interviews, but also afterwards either through solicitation of feedback on the printed or electronic copy of the interview transcript, or through follow-up questions sent to the participants via email. The strategies of probing and member-checking helped to reduce ambiguity in the qualitative data and enhanced the reliability of the research findings.

**Increasing Access to Research Participants**

Once the study was underway, it was important to minimize the distance between the participants and me, and to strive to increase participants’ accessibility. Qualitative investigators (e.g., Fontana & Frey, 1998; Measor, 1985; Merriam, 1998) note that it is critical for the researcher to have easy access to interview participants, and to foster relationships built on trust. This increased trust paves the way for the participants to be more open in their
interview responses and to act in more natural ways as the study progresses. Appropriate ways of dressing (Measor, 1985) and showing interest in what were important to the participants (Ball, 1985) were some suggested strategies I adopted that helped to develop the students' and teachers' trust in me. For example, I sometimes engaged students in conversations about their extra-curricular activities like the junior-senior prom or their future plans for university and how their college applications were progressing.

Though I would never have been considered a peer because of our age difference and my teacher status, a number of student participants were able to relate to me as if I was one of their approachable teachers rather than an outsider. I was regularly visible and available, and sought opportunities to interact with them as the research study progressed: outside of class time; in the classroom, hallways, or cafeteria; as well as during small group discussions, lab work sessions and the science fair presentations. I had additional interactions with four students who were finalists at the regional and national science fairs as I sat in and gave feedback on their mock oral defences, or accompanied and cheered for them during the competitions.

To further develop rapport with the two teacher participants, I actively participated in various faculty activities, research teachers' meetings, informal outings and lunch hour discussions. As I gained acceptance by the group under study, I believe that the research participants behaved in more natural and less contrived ways during the conduct of the research study. They also showed interest in my own research work as gleaned from the questions they asked me during our interviews and other interactions. This mutual respect and interest in each other's work was important and useful as it has fostered good relations beyond the confines of the research study. This made the task of re-creating and sharing their classroom stories less
Addressing Issues of Trustworthiness in Qualitative Research

I conclude this chapter by addressing issues of validity and reliability in qualitative research and summarizing the strategies I used to enhance my research study’s trustworthiness.

Lincoln and Guba (1986) identify the standards for evaluating rigor in quantitative research to include: “exploring the truth value of the inquiry or evaluation (internal validity), its applicability (external validity or generalizability), its consistency (reliability or replicability), and its neutrality (objectivity)” (p. 75). Qualitative investigators contend that these same standards of rigor cannot be applied to their work because it is contrary to the inquiry paradigms or assumptions that are inherent in qualitative research studies (Denzin & Lincoln, 1998; Lincoln & Guba, 1986; Merriam, 1998). These researchers argue that most quantitative investigations are based on a positivist perspective, while qualitative studies are informed by the alternative paradigms of constructivism, critical theory, feminism or postmodernism. Traditional, scientific researchers are out to discover the truth as quantifiable and exact data, whereas qualitative researchers do not support this positivist view that only a single version of the truth exists. Because of the differing epistemological assumptions that underpin their work, qualitative researchers have suggested the use of the alternative terms trustworthiness and authenticity to address issues of rigor in their research studies (Denzin & Lincoln, 1998; Lincoln & Guba, 1986). Lincoln and Guba (1986) further qualify the standards of trustworthiness (or rigor) by using the terms credibility, transferability, dependability, and confirmability as standards that should be considered parallel to quantitative notions of internal validity, external validity, reliability and objectivity, respectively.

Internal validity in research studies deals with the way the study is designed (i.e.,
participants, instruments and methods used) to ensure that data gathered to answer the research questions are in fact what the researcher wants to measure or observe. Establishing a study’s internal validity is equivalent to answering the question: ‘How accurately does the research data or findings match the truth?’ (Merriam, 1998; Schumacher & McMillan, 1993).

Most qualitative researchers argue that their work shows strong internal validity or credibility because they are examining “reality” in the context of a naturalistic study. Operating under the assumption that reality or “truth” is a co-construction of the humans involved in the research study process, what could be more valid than observation in situ? (Lincoln & Guba, 1985; Merriam, 1998). They further state that trustworthiness in qualitative research has to be assessed based on the epistemological assumption that multiple realities exist, and that the participants’ and the researcher’s value-laden constructions of reality are all equally valid.

Establishing external validity in a qualitative inquiry means aiming for naturalistic, reader, or user generalizability (Merriam, 1998) or transferability (Lincoln & Guba, 1986). Naturalistic, qualitative investigators provide thick, rich descriptions of the research study context and findings to enable the reader to evaluate the universalities presented by the study, and the (non)application of the findings to the reader’s particular context.

Qualitative investigators believe that in any research work involving humans, the researcher’s personal views, values and biases influence the study results and interpretations. These investigators conduct research under the assumption that there is no objective researcher or instrument. Thus, instead of aiming for objectivity or neutrality, qualitative researchers lay out their gendered and cultural biases, inquiry paradigms, and theoretical assumptions juxtaposed with their reflections on the research design and findings. By constantly clarifying and (re)evaluating the theoretical framework and personal biases that they bring into the study,
the research inquirer attempts to address the issues of reliability and objectivity (Denzin & Lincoln, 1998; Merriam, 1998).

Qualitative methodologists suggest a number of strategies that can be used to strengthen a study’s trustworthiness and authenticity (see e.g., Krefting, 1991; Lincoln & Guba, 1986; Merriam, 1998). The methods that I employed included the multi-method approach, triangulation, member checks, researcher’s reflexivity, increased access to participants, and rich text descriptions. I briefly describe each of these strategies below.

I used a combination of research methods (interview, observation, document analysis) and data sources (participants, documents) in the conduct of my case study and triangulated the information from these multiple sources as a means of confirming emergent themes from the interviews. My use of different research “tools” and data sources to characterize the participants’ classroom experiences, i.e., the case, helped substantiate any claims I made in the research study. By examining the convergence among the different data collected, I am able to report a holistic picture of the participants’ experiences. Denzin and Lincoln (1998) point out that multiple method and triangulation strategies add “rigor, breadth, and depth to any investigation [as it] reflects an attempt to secure an in-depth understanding of the phenomenon in question.” (p. 4)

Member checks were conducted at the data collection and the preliminary interpretation stages of the study. Through the process of member-checking, I solicited feedback from the participants by asking them if the interview transcript and summary I prepared accurately depicted their experiences in the course. I reflected upon the research design, findings and interpretations, and recorded these thoughts in my research journal. By re-evaluating my inquiry assumptions, research perspectives, and biases at various points in the investigation, I
strove to clarify personal views that I brought into the interpretations of the study. I also reflected upon the nature of researcher-participant interactions during the conduct of the study, and analyzed research findings with these relationships in mind. I minimized the distance between the participants and myself as I sought to be an “insider” to the classroom setting. As I re-integrated into the school community, the participants acted in less contrived ways. The improved access to the participants allowed us to develop relationships that lent credibility to what I observed and reported in my study.

In writing this thesis, I outline all the important aspects of the research methods, context and findings through a thick, detailed description that allows readers to follow my sense-making and logic of inquiry. The rich, thick description should enable the reader to judge whether my conclusions and interpretations are plausible based on the data presented. The detailed descriptions also provide the reader with an opportunity to evaluate, compare and apply my research context and findings to his or her own situation.
CHAPTER FOUR
SCIENCE AND TECHNOLOGY EDUCATION IN THE PHILIPPINES

In this chapter, I describe the historical and social contexts for the development of science and technology education in the Philippines. I provide an overview of the Philippine historical and cultural settings to give the reader a context for understanding some Filipino social and cultural practices that I discuss in my analysis of the findings from my study. I characterize the general education, and the science and technology education programs in the Philippines. Finally, to answer my first research question, I outline the government-directed initiatives that led to the development of a technology-enriched science program at the school where my study was conducted.

The Philippine Historical Context

The Philippines is an archipelago in the Asia Pacific region. Before the coming of the Spanish and the American colonizers, the native inhabitants of the islands constituted a mixed race with a predominantly Malay heritage (Agoncillo & Alfonso, 1967). In pre-colonial Philippines, the family was the basic social and economic unit of the community. A group of people consisting of the clan, family friends and slaves, lived together in a barangay, a word still used in 21st century Philippines to refer to the basic political unit that is situated in a barrio or town. A male chieftain or datu was the recognized leader of the pre-Hispanic barangay. The datu ascended to power based on his noble ancestry, wealth and number of slaves. A three-class social system existed with the ruling class, which included the datus and others of noble descent, their supporters, and their slaves (Scott, 1994). Because of the archipelagic nature of the land, distinct languages existed among the peoples from the different regions.

The Spanish arrived in the Philippines in 1521 and ruled the nation for nearly 400 years.
Spanish colonization introduced Roman Catholicism, a religion that is still practiced by some 80% of Filipinos today (Rodell, 2002). The initial influences of Western culture through the Spanish invasion started the Filipinos' struggles in establishing their own cultural and nationalistic identity. By discouraging the learning of Spanish, except among the Spaniards and Filipino-Spanish mestizos, the colonizers reinforced the distinction between the social classes of the rich, intellectual elite and the poor, uneducated natives, which the Spaniards called indios (Agoncillo & Alfonso, 1967; Rodell, 2002). The Spaniards also instituted the first system of formal education in the Philippines as religious congregations established schools, colleges and universities directed towards the wealthy. Idol and nature worship practices of the Filipino natives initially clashed with the religion brought by the Spanish colonizers. In time, as more natives converted to the new religion, the practices of the Roman Catholic Church and the priests melded with existing practices and became accepted as part of the Filipino culture. Elements of Roman Catholicism's influence are still felt in 21st century Filipino society as seen for example in the Filipinos' high regard and respect for elders, close family ties, religious piety, and passivity in questioning or rebelling against authority. Some of these cultural practices are discussed more extensively in the next chapter as I analyze the roles they play in Philippine science education.

The Philippines became a U.S. territory in 1899. The American colonizers purportedly governed and educated the Filipinos based on democratic principles and laws, as they prepared the Filipinos for independence and self-governance. Among the American legacies were the establishment of a democratic government, the development of the Philippine public school system, the installation of military bases, and the extensive use of English in education, media

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16 Real power stayed in the hands of the American governor general even after the election of a Philippine assembly in 1907. In addition, Americans continued to head vital government bureaus, e.g., the Bureau of Prisons, Science, Forestry, the Mint, until 1921, and the Bureau of Education until 1935 (Constantino, 1975).

17 The last U.S. military base in the Philippines was dismantled in 1992.
and commerce (Agoncillo & Alfonso, 1967; Gochenour, 1990). Though the American occupation of the Philippines lasted less than 50 years, it left a great impact on a nation that continues to exhibit North American influences in its culture. For example, most Filipino textbooks, literary work, and serious newspapers are in English; mass communication, fashion and music exhibit a strong American influence; and commercialism and materialism associated with Western affluence have infiltrated even remote Filipino communities (Andres & Ilada-Andres, 1987; Rodell, 2002). Some Filipino historians claim that by introducing the American public school system and adopting English as the medium of instruction, the American colonizers left a lasting legacy of “miseducating” the Filipinos (Constantino, 1966). The emphasis on the English language and Western practices is believed by some to prevent the Filipinos from developing and valuing their own linguistic, cultural and national identity (Agoncillo & Alfonso, 1967; Constantino, 1966, 1975).

The Filipino People

Filipino society reflects both the people’s Asian culture, and their affinity for Western influences and practices. Filipinos’ Asian heritage is evident in their religious spirituality, respect for elders, and the importance that they give to educational achievement and social status (Andres & Ilada-Andres, 1987). At the same time, Filipinos highly value Western culture and tend to buy foreign goods in preference to local products. This tendency to value Western culture has been described as a “colonial mentality” (see Agoncillo & Alfonso, 1967; Mulder, 1997; Shahani, 1988). This colonial mentality has two elements. One element is the

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18 I caution the reader that although I attempt to characterize the Filipino people and culture in this section, I do not imply that one can typify what it means to be “Filipino” based on a set of socio-cultural values and practices. For example, even as I read Filipino and foreign historians’ accounts of our history and culture as a people, I pondered whether these narratives reflected my own Filipino experiences and character, and discovered that it was not always so. With the Philippine archipelago’s varied indigenous and colonizing histories, and its present social, political and economic influences, the Filipino identity and culture should be viewed as one that is constantly evolving.
fondness for foreign (which usually means Western) products. A second element is the absence of a sense of nationalism or appreciation for the Philippines (Shahani, 1988).

There are over 100 languages and dialects spoken in the different regions of the Philippines (Andres & Ilada-Andres, 1987; Mulder, 1997). Tagalog is the predominant language spoken in the Metropolitan Manila cities and the neighbouring provinces. Tagalog is also the main root of the Filipino national language that was established in 1937 and taught in schools starting in 1940 (Agoncillo & Alfonso, 1967). Despite government efforts to establish a common language, a Filipino prefers to converse in his or her own local language. This practice has been interpreted to suggest that the Filipino is regionalistic by nature, and “does not think in terms of national boundaries but in regional oneness” (Agoncillo & Alfonso, 1967, p. 13). Distinct from their Asian neighbours, Filipinos take pride in identifying themselves as the only predominantly Catholic nation in Asia and the third largest English speaking country in the world (Mulder, 1997), characteristics that reflect the great influences of the Western colonizing cultures on Filipino society.

The Filipino Family

The family exerts great influence on a Filipino’s personal development and social role. Filipinos are clannish, and they maintain extended, closely-knit family ties that include the husband’s and wife’s kin. The failures or successes of a family member are perceived to have an important effect on the family’s good name and status in the community. The Filipino acquires his or her sense of worth and identity from the family. As Rodell (2002) notes,

A basic reality of Philippine society is that one’s family is as intimately linked with an individual’s social status as is material wealth, while social, economic, and political success, especially in small towns and villages, is in large part
contingent on the size and strength of one’s family. (p. 119)

In the Philippines, it is not unusual for single adult children to live within the parents’ home because it is considered proper and practical. Other adult children who are married may also choose to live with their parents for economic and practical reasons. This is in contrast to most Western families where individualism and independence are encouraged early in life (Gochenour, 1990; Rodell, 2002). The Filipino also shows high regard for the family as s/he seeks and defers to the opinion of the parents and older family members on important decisions regarding education, career, and marriage.

Respect for Elders and People in Authority

While Filipinos have embraced Western commercial values, they retain specific non-Western cultural and social practices. Filipinos’ respect for elders and for people in authority is a socio-cultural practice that appeared to influence study participants’ classroom experiences in the STR course.

The practice of showing respect for elders and authority manifests itself among Filipino family and community relationships. Filipinos show deference to grandparents, parents, aunts, uncles and older siblings in that they generally obey the elders’ wishes and address them in a respectful manner. It is unheard for Filipino children, even as adults, to address or speak about their parents using their first names. The appropriate titles like nanay\(^\text{19}\) (mother), tatay\(^\text{19}\) (father), lola (grandmother), lolo (grandfather), tito (uncle), and tita (aunt) are used, or “Mr.” and “Mrs.” are affixed to the first names of the elderly in the community. When conversing with someone older or in an authority position (e.g., one’s employer, supervisor, or teacher), a

\^\text{19} Most contemporary Filipino families use “mommy” and “daddy”, or “mama” and “papa”.

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Filipino may interject his or her sentences with the words *po* or *ho*\(^{20}\) to denote respect (Agoncillo & Alfonso, 1967).

Filipinos use the appropriate titles when addressing people deemed to be of higher social or educational status, or in positions of authority. For example, in speaking to or about someone, a Filipino would append the titles “Professor”, “Dr.”, “Attorney”, or “Engineer” to a person’s name, or refer to the individual as “Ma’am” or “Sir” (Gochenour, 1990). The Filipino practice that accords recognition and distinction to people of a particular social standing was inherent in pre-colonial Philippines, and reinforced by the Spanish and the American colonizers (Rodell, 2002).

Because of the status and influence attributed to the elders and authority figures in the community, it is uncommon for Filipinos to question or contradict the elders’ opinions (Mayers, 1980; Tubianosa, 2000). Typically, Filipino children do not talk back to their parents or older siblings, students do not question the teacher’s expertise, and subordinates do not challenge the supervisor’s authority. To do so is perceived as being impudent and disrespectful (Mayers, 1980).

As mentioned previously, Filipinos will seek the opinion of senior family members during decision-making. Enlisting the advice of one’s kin is not just a sign of respect but is also a means of soliciting sound judgment from someone perceived to be wiser and more experienced. As an extension of this practice, Filipinos also seek the counsel of people in positions of authority when making decisions in their personal and professional life (Gochenour, 1990). The Filipino’s deference to the opinion of elders or authority figures in the community is sometimes (mis)interpreted by Westerners as a sign of the Filipino’s immaturity, indecisiveness, or lack of initiative and creativity (Andres & Ilada-Andres, 1987; Dolan, 1993).

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\(^{20}\) The Filipino words *po* and *ho* have no appropriate English translations. These are common words of respect among Tagalog-speaking Filipinos.
The practice of seeking group consensus or an elder’s counsel may appear to impinge on the Filipino’s personal judgment and discourage individual responsibility (Dolan, 1993), but is crucial in maintaining harmonious relations with others in the home, workplace or community (Andres & Ilada-Andres, 1987; Gochenour, 1990).

**General Education in the Philippines**

In 2004, basic education in the Philippines consisted of six years of primary (Grades 1 to 6) and four years of secondary education (first to fourth-year high school or equivalent to Grades 7 to 10 in the Canadian educational system). Students in private elementary schools may opt to enroll in Grade 7 before proceeding to high school. Primary education in public schools is compulsory and free, and secondary public education is free but not compulsory (Asian Development Bank & World Bank [ADB & WB], 1999). Despite the government’s free basic education program, not all students choose to continue with their schooling due to financial constraints that may compel them to stay at home or to find work instead. Post-secondary education is comprised of four years for most Bachelor degree programs, and longer for medicine, engineering, nursing and other specialized degree courses.

All areas of education in the Philippines were under the jurisdiction of the Department of Education, Culture and Sports until 1994 when the Department was split into three agencies, namely, the Department of Education, the Commission on Higher Education (CHED) and the Technical Education and Skills Development Authority (TESDA). The Department of Education is in charge of the administration of basic education in both public and private schools, CHED manages public and private post-secondary institutions, and TESDA has jurisdiction over vocational and technical education and training (Department of Education, n.d).
Teacher preparation in the Philippines involves a four-year Bachelor of Elementary Education or Secondary Education degree program at major universities or teacher training institutions, and participation in an additional year of pre-service teaching. Prospective elementary or secondary school teachers must pass the Licensure Examination for Teachers that is administered by the Philippine Board for Professional Teachers before they can practice their profession (Ibe & Punzalan, 1997).

Most Philippine basic instruction is teacher-centered. In most classrooms there is an emphasis on the teacher covering an extensive list of topics, and using the prescribed textbook as the curriculum. The average teacher-to-student ratio in 2003 was 1:36 for elementary schools and 1:40 for secondary schools (Department of Education, 2003). Ibe and Punzalan (1997) note, however, that the average class size may vary from as few as 25 students in remote rural villages to as many as 65 students per class in some highly populated urban areas.

In most schools, the teacher lectures and writes on the blackboard, as students quietly listen and copy notes (Mayers, 1980; Shahani, 1988). As Carino (1993), a former Philippine Department of Education Secretary points out, “in our curriculum what is emphasized is the ‘know-what’ of things rather than the more important consideration of the ‘know-why’ (p.87). That is, there is more emphasis on the acquisition of knowledge and on memorization, than on problem-solving and critical thinking skills (ADB & WB, 1999; Carino, 1993). In 2002, basic literacy among Filipinos was reported at 93.9% but functional literacy was 83.8% (Mendoza, 2002). A know-what approach may seem to be working in terms of attaining a high basic literacy rate, but Mendoza (2002) claims that this high rate does not translate to practical knowledge that students apply outside the context of school. For example, a typical Grade 4 Filipino student is unable to calculate the exact change from a store purchase.

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21 Basic literacy refers to the ability of Filipinos 10 years and above to read and write, while functional literacy indicates the ability to think critically and to apply school-based learning to daily living (Mendoza, 2002).
The choice of the language of instruction is a very complex issue that has long been a source of contention in Philippine education. There is no consensus on whether the Filipino national language, which is mainly based on the Tagalog language, should be mandated as the medium of teaching because other local or provincial languages are spoken in the country. English was widely used as the language of instruction in schools and universities from the early 1900s until the 1980s. The revised 1987 Philippine Constitution identified Filipino as the national language, and both Filipino and English as the official languages. In 1990, there was a gradual easing out of the use of English as government offices were directed to use Filipino in official documents, and education leaders advocated for the shift to Filipino as the medium of college teaching (Dolan, 1993). However, as of 2004, English was still the medium of teaching in most private elementary and secondary schools, and in colleges and universities. Filipino leaders continue to debate over the merits of using English or Filipino as the language of instruction. There are science educators and industry leaders who claim that it is important to learn to communicate in English, particularly in the fields of commerce, science and technology, because this is a competitive advantage for the learner’s future career in the global community (e.g., Sycip, 2000). Other educators however, counter that the use of English for instructional purposes impedes student learning as the child struggles to learn English as a second or a third language. Still some leaders and historians argue that the continued use of English in schools hampers the development of the Filipino’s sense of national identity and culture (e.g., Constantino, et al., 1991).

The people caught in the middle of the debates over instructional language policies are the teachers, and ultimately the students. In public schools, Filipinos are taught in the local language until Grade 2, and then in a bilingual system of instruction that uses Filipino and
English in the succeeding grade levels. Despite the mandated bilingual system, it is common for elementary and secondary school teachers to teach in the local language because of the lack of textbooks and classroom resources written in Filipino, and the teachers' unfamiliarity with English (ADB & WB, 1999). According to a study conducted by the Asian Development Bank and World Bank (1999), the government's bilingual approach to education hoped to foster national identity and literacy through use of the Filipino language, and to "promote English as the language of science and technology, of regional commerce and of international communication" (p. 34). These goals still need to be realized as Filipino students continue to perform poorly in both Filipino and English as indicated by the average national assessment test scores (Department of Education, 2003).

The average Filipino places a high value on education because of the perception, perpetuated by the American colonizers, that upward social and economic mobility is possible through education (Garcia, Zulueta & Caritativo, 1984). Conscious of their status in the community's social hierarchy, Filipino families go through great sacrifices to invest in the best education for their children (Gochenour, 1990). However, the quality of education varies from region to region. Filipino graduates are not always able to secure the jobs that they aspire for. Support for this claim comes from my examination of major Philippine newspapers that shows that stable and good-paying jobs in most multinational companies are often available only to graduates from the top three reputable universities in the country. Added to the problem of limited employment options for graduates due to the inequity in educational experiences across the country are the issues around high levels of unemployment that is attributed to the nation's unstable economic and political situation. Thus, education has not been the equalizer of social status in the Philippines.
In the 1990's, government and education leaders identified a number of problems in the Philippine educational system (see e.g., ADB & WB, 1999; Cariño, 1993; Dolan, 1993) that continue in the 21st century. Problems included: the poor quality of education; inadequate school facilities and textbooks; lack of qualified teachers; learning difficulties related to the range of languages used in the classroom; persistence of the traditional teaching (lecturing) method; overall poverty that affects dropout rate and attendance; and great inequity in the distribution of resources across schools and ethnic communities. The Philippine government's emphasis on educational reforms in the fields of science and technology is evidence of a prevalent notion that improving the scientific background and technological know-how of its citizens will alleviate the Filipinos' mass poverty and advance the nation's economic recovery.

Science and Technology Education in the Philippines

In this section, I discuss the historical context and the characteristics of Science and Technology Education in the Philippines. I provide an overview of Philippine government programs that highlight the role of science and technology education in the nation's economic development. I then describe specific government initiatives implemented in the 1990s that focused on streaming students into different schools, and on providing specialized science-technology-mathematics curricula to those who were deemed talented to pursue future science and engineering careers. This section provides the context for the development of the Technology Research Curriculum at the Philippine Science High School, which is the focus for my study.

The Historical Perspective

Science and Technology Education occupy an important status in the Philippine government's socioeconomic agenda. The view that science and technology play vital roles in
the advancement of national development took root in the 1957 Sputnik launch that spurred the National Science Foundation-funded curriculum reforms in the U.S. that I discussed in Chapter 2 (Ibe & Ogena, 1998). The strong North American influence in the Philippines led to the implementation of similar government initiatives to strengthen the country's science and technology programs. But in addition to increasing literacy among its citizens, the Philippine government aimed to use science and technology education as a vehicle to spur the country's economic growth. Thus, the Science Foundation of the Philippines and the National Science Development Board were established in the late 1950s to improve Philippine science education and to develop scientific and technological projects that would help solve the nation's economic problems (Hubler, 1964). The National Science Development Board went through a number of renaming over the course of its existence, with the DOST as its most recent name established in 1987. From hereon, the National Science Development Board will be referred to as the DOST.

Starting in 1957, the Philippine government mandated all schools to teach science, and convened a National Committee for Science Education in 1958 to develop the country's science education programs (Hernandez, 1996). This era in Philippine education also saw the establishment of the country's first high schools devoted to advancing education in the sciences. The Manila Science High School was established in 1959 and recruited students in Manila, and a national science high school, the Philippine Science High School, was established in 1964 and enrolled students from around the country. Both schools were patterned after the Bronx High School of Science\textsuperscript{22} in that they cater to youth who are gifted in the sciences and mathematics. The schools' mission statements reflected the Filipino government's mandate to provide a science - technology - mathematics program that would develop future scientists and engineers to support the country's workforce needs ("Manila
In the early 1960s, Filipino scientists and education leaders called for an improvement in the quality of science education in schools to address the shortage of scientists in the country (Hernandez, 1996). However, Filipino teachers felt that they lacked the necessary training to teach science because of the inadequate science courses offered in the secondary and the normal schools. Thus, science education experts and Peace Corps volunteers from the U.S. were brought into the country to train the Filipino teachers in English, science and mathematics. University of the Philippines President, Carlos P. Romulo advocated for the creation of the Science Teaching Center\textsuperscript{23}, which was established in 1964 through a Ford Foundation grant. The Center served to train Filipino teachers in science curriculum and textbook development, and in science teaching innovations adopted from the U.S.A. and the U.K. curriculum projects (Hernandez, 1996). The Center also provided a site for the development of a science curriculum and accompanying teaching resources that were adapted to the Philippine setting (Hernandez, 1974). A number of educators, for example, developed and piloted local adaptations of the \textit{Biological Sciences Curriculum Study} textbook and workbook (Hernandez, 1996). With its predominantly North American influences, science in the Philippines was well on its way to being taught using Western curriculum models, classroom examples and textbooks. In addition, English was in the process of being established as the language of Philippine science.

The 1970s brought further growth to Philippine science education in the form of curriculum reforms copied from the American, British, Australian and Japanese educational

\begin{footnotesize}
\begin{enumerate}
\item The Bronx High School of Science is a specialized school for New York students who are intellectually gifted in science and mathematics. The school selects its students through a comprehensive examination process (Kopelman, 1988).
\item The function of the Center was later expanded to include the upgrade of Philippine basic science and mathematics education, and was renamed the National Institute for Science and Mathematics Education
\end{enumerate}
\end{footnotesize}
systems. During this era in Philippine Science and Mathematics Education, science education leaders and reformers introduced innovative teaching practices including science inquiry, the “discovery method” and a spiral instructional approach (Ibe & Ogena, 1998). Nine Regional Science Teaching Centers24 funded by UNICEF and the DOST were established by 1974. Concurrently, the development of local teacher training programs was underway. Seeking ways to provide access to science teacher training opportunities and new equipment particularly to the rural provinces, the government established Regional Centers, referred to as “centers of excellence” (Hernandez, 1974, p. 15), in major universities across the nation. There was extensive development and piloting of locally produced textbooks and other educational resources during this period of reform in Philippine Science Education (Hernandez, 1996).

Beginning in the late 1980s and continuing through the 1990s, an increased emphasis on improving learning in Science, Mathematics and English occurred in schools (Ibe & Punzalan, 1997). These were subjects in which Filipino students consistently ranked low in national competency assessments (see also Department of Education, 2003), and international comparison studies such as the Third International Science and Mathematics Study (DECS, DOST-SEI, & UP-NISMED, 2000a, 2000b). With an increased focus on “Education for All”, the Philippine school programs sought to increase scientific, mathematical, and English literacy among all Filipinos (Ibe & Punzalan, 1997). These were the skills considered necessary in a technology-driven, global economy.

Philippine Science and Technology Education for National Development

In the 1990s and continuing into the new millennium, Philippine government officials

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24 As of August 2001, there were 15 Regional Science Teaching Centers serving the 16 administrative regions of the Philippines (DOST-SEI, n.d.).
and educators renewed calls for a school curriculum that highlighted the value of science and technology in society, to encourage students to enter careers in these fields, and help advance the country's economic development (see DOST-SEI, 1993; DOST-SEI, 2000; Yager, 1993). A statement made by the former secretary of the Department of Education captured the sentiment of the time: “For industrialization to take place there must be a ready pool of scientist, technologists and vocationally trained personnel. Without them, industrialization will not take off from the ground. This is a required base for industrial development” (Carino, 1993, p. 109). This view was echoed by international funding agencies such as the Asian Development Bank and World Bank (1999) who claimed that “enhancing scientific and technological research and development has been an important factor in building the competitiveness of several countries in East Asia. An important component of this is science and engineering education” (p. 6).

In 1993, the Philippine President, Fidel Ramos, rallied behind the slogan “Philippines 2000” as he called upon government agencies to develop programs that would help elevate the Philippines to the status of a newly industrializing country (NIC) by the turn of the century. “NIC-hood” became a buzzword at that time. In support of the President’s “Philippines 2000” vision, the DOST proposed a project called the Science and Technology Agenda for National Development or “STAND Philippines 2000”. The STAND Philippines 2000 project outlined a series of strategies geared to strengthen Philippine science and technology in support of the goal of attaining NIC-status. STAND was approved by President Ramos on April 20, 1993 and became part of a national technology agenda that he envisioned would:

- teach our people, especially ordinary Filipinos, to use technology to enhance our skills and optimize our productivity; to give us greater access and control of our resources in
people and in nature; and to propel us into modernized agriculture and an industrialized status. (cited in DOST Regional Office 5, n.d.)

The action plan in the STAND project included: “utilization of emerging technologies; increasing private sector participation; networking [among industry, government, private, and non-government\textsuperscript{25} institutions]; manpower [sic] development; review of policies affecting science and technology; and technological dynamism and monitoring” (DOST Regional Office 5, n.d.). In line with this national agenda, the government viewed science and technology education as an important agent in the country’s modernization efforts and attainment of a newly-industrializing country status. The assumption that a nation’s economic growth was dependent on the number of engineers and scientists serving the population underpinned a move to introduce Technology courses in school curricula and to strengthen Science Education in schools (Sapnu, 1997).

Three types of school-based programs that promote science and technology education in the Philippines began to emerge in the early 1990s. Distinct from the regular public schools, the government established three systems of science high schools\textsuperscript{26} in different regions of the country in the hope of upgrading the quality of Science and Technology Education, providing equity in access to resources across the country, and responding to the country’s economic needs. The three systems of science high schools were the science & technology-oriented high schools, the Regional Science High Schools, and the Philippine Science High Schools (Somerset, 1999).

Science and technology-oriented schools, or what are also referred to as node or network schools were established in 1994 through a World Bank loan. With this fund, the

\textsuperscript{25} A number of non-government organizations (NGOs) exist in the Philippines. International groups or agencies typically fund these non-profit organizations.

\textsuperscript{26} Henceforth, I refer to Philippine public secondary schools where a special science and technology-oriented curriculum is implemented as “science high schools”.

97
DOST Engineering and Science Education Project transformed 110 existing high schools across the Philippines into node schools. The Project provided funding for two science laboratories, equipment and textbooks, and for the training of the science and mathematics teachers for each of the node schools. Node schools retained regular, non-science-specialized classes, but enrolled selected students in one or two science classes per grade level. These schools administered a competitive examination to determine which students from within the school division would be selected for the specialized science classes.

A second group of science high schools called the Regional Science High Schools were established through initial funding from the DOST Project or the local government. With these monies, the Department of Education established one Regional Science High School in each of the 16 administrative regions of the country. The 16 regional schools implemented a specialized science curriculum across all classes in all grade levels. Compared to the node schools, these regional schools conducted a more stringent student selection process through a competitive examination across the region.

In addition to the systems of node schools and Regional Science High Schools, the government created a third system of specialized high schools. The PSHS System was established through the Republic Act No. 8496. The Act aimed to expand the PSHS programs started around the country in 1964 into one larger system. The goal was to standardize the PSHS academic program and establish future campuses. Patterned after the original PSHS campus, the other PSHS campuses would screen students through two competitive national examinations and offer “scholarships to deserving students who shall be admitted and trained under a curriculum especially designed to prepare them for careers in S & T [science and technology]” (PSHS System Act, 1997).
The science and technology-oriented schools, the Regional Science High Schools, and
the PSHS schools represented the three-pronged approach to a specialized science and
technology program for Filipino students. In contrast to the regular public high schools in the
country that taught one science course, i.e., Earth Science, Biology, Chemistry or Physics, in a
grade level, the specialized science high schools taught two or more science courses in each
grade level. Computer Science and Research courses were also part of the specialized
curriculum. Appendix B provides an overview of science and technology programs taught in
each of the specialized school systems, and compares these programs with the curriculum
taught in regular public high schools.

In the preceding section, I outlined the historical and social context for both the general
and the science-technology education programs in the Philippines. In the next section, I
describe the curriculum reform and implementation process that contributed to the development
of a technology-infused curriculum at PSHS, which is the focus of my case study. I explain the
contexts for students’ pedagogical experiences and practices with the technology research
learning approach. I also discuss the implications of a technology-based science program on
students’ future career choices.

Development of the PSHS Technology-Enriched Science Program:
A Move Towards a Practical Curriculum

In 1988, the Science Education Institute (henceforth referred to as DOST-SEI) was
established as a DOST agency to assess and upgrade Philippine science and technology
education. In 1993, the DOST-SEI was granted approval by the Philippine Science and
Technology Coordinating Council, and a cabinet-level Committee on Social Development to
embark on a Science and Technology Education Plan (STEP) to support the government’s
national development agenda. The STEP aimed “1) to develop a scientifically and
technologically literate citizenry; and, 2) accelerate the development of S&T [science and technology] manpower needed for social and economic growth” (DOST-SEI, 1993, p.ix). To accomplish its goals, the Plan identified a number of intervention strategies and programs that directly focused on the learner, the teacher, and the delivery mode\textsuperscript{27}. It was envisioned that the 10,997.21 million pesos\textsuperscript{28} cost of the STEP would be paid for by the Philippine government (15.3\% share), foreign assistance (84.68\%) and non-government organizations (0.02\%) (DOST-SEI, 1993). In a country like the Philippines where government funding for education is limited, the high value attributed to science and technology education was reflected in the cost invested in the Plan.

**Introduction of Technology Education into the Science Curriculum**

One of the programs under the Science and Technology Education Plan was a three-year, 100 million peso-budgeted\textsuperscript{29} project called the “Development of Technology-based Curriculum as Feeder Program for Engineering”. The overall goal of the project was “to improve the quality of science teaching at the secondary schools with the development of a technology-based curriculum which would provide relevant training for students as feeders for tertiary engineering and technology programs” (PSHS, 1993, p. 1). The specific objective of the project was the design and implementation of a technology-enriched science curriculum that would teach high school students the skills needed in manufacturing industries such as technological design, machine operation and equipment maintenance (E. Bustamante, personal communication, September 9, 2003). A PSHS director at that time stated that Technology Education was introduced into the curriculum because the DOST-SEI found the PSHS curriculum “heavy in the basic sciences but lacking in the technology aspect” (V.F. Reyes,

\textsuperscript{27} Refers to access to science education through non-traditional approaches like distance and online learning.

\textsuperscript{28} In 2004, this was equivalent to approximately CA $273.4 million

\textsuperscript{29} In 2004, this was equivalent to approximately CA $2.5 million.
personal communication, July 31, 2003). The collaborating institutions for the project were the DOST, the Department of Education, and the three public high schools that would pilot the curriculum: a Metro Manila-based, science high school; a rural-based, vocational high school; and one of the PSHS campuses.

To achieve the objective, the DOST-SEI director created and chaired a project management committee composed of a Department of Education official, a PSHS director, DOST consultants, a technology teacher, a retired science educator, and PSHS alumni-engineers. The committee defined the project policies and implementation strategies, and conducted a seminar-workshop wherein representative teachers from the pilot schools were to create technology-enriched versions of the science curriculum. At this point, the project was renamed the “Development of Technology-based Curriculum for the Engineering and Technical Education Stream for Special Science High Schools”. The committee envisioned that upon successful implementation of the technology-enriched academic program at the pilot schools, it would extend the project to include the Philippines’ 110 node schools (DOST-SEI, 1993; PSHS, 1993).

The four-day seminar-workshop to initiate the curriculum revision, spearheaded by the PSHS Director and administrative staff, took place in April of 1993. Attendees at the workshop included invited speaker-facilitators who were considered experts in their fields, and teacher-participants who were expected to revise the existing curriculum at the end of the workshop. The invited facilitator group consisted of leaders in Philippine science education, parents involved with industry, and PSHS alumni who were part of the project management committee.

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30 Three alumni were university professors.
31 The DOST-SEI clarified that at the onset, SEI planned to implement the revised curriculum only in the three pilot schools but if requested, SEI would provide technical assistance to other schools who may decide to implement the curriculum (E. Bustamante, personal communication, September 9, 2003).
The facilitators supported the curriculum revision and the need to develop the scientific and technological workforce in the Philippines. They called for a move away from purely theoretical science courses towards a more practical science program. For example, one alumnus-facilitator stated that he learned a lot from his high school chemistry, but noted that he did not need to know all the details of the periodic table to be good at his present job as a materials science engineer.

The 24 teachers invited to participate as curriculum developers at the workshop consisted of lead teachers in Mathematics, Biology, Chemistry, Physics, Computer Science and Art from each of the three pilot schools. These teachers discussed the implications of the technology-enrichment project and raised concerns about the challenge of technology infusion, including the introduction of new courses and topics into an already overloaded timetable and curriculum; the implications of the revision for non-science courses; the teacher's lack of expertise to teach the new topics; and the funding needed for new computers, workshop tools and other equipment. Despite these misgivings, a decision was made to move ahead and the curriculum developers revised the existing curriculum and course syllabi. At the end of the workshop, the group achieved consensus and a new technology-oriented science curriculum was born.

The Framework of the Revised Curriculum

The new technology-oriented science curriculum developed by teachers in the seminar-workshop was designed to actively engage learners in "thinking, designing, planning, inventing, creating, experimenting, testing and problem-solving. . . . [using] materials, tools, machines, devices, computers, construction kits, [and] equipment" (PSHS, 1993, p. 4). The technology-enrichment of the revised curriculum involved two parallel strategies. One strategy

32 In the case of the PSHS group where I was the only Biology teacher representative, the PSHS administrators recruited the participants based on the teacher's seniority or availability to attend the workshop.
was the infusion of technology topics into the existing Science and Arts course syllabi. The second approach was the development and implementation of a series of practical elective courses under what was referred to as the Technology and Science Streams.

Technology-Enriched Courses

The intent behind the technology-infusion approach was to introduce technology-oriented topics, laboratory activities or projects into lessons and courses at all year levels, not simply to teach how to use technology such as computers. Curriculum developers at the seminar-workshop interpreted this technology integration in different ways. For example, in the Biology teachers' group where I was a participant, the integration was interpreted to mean the infusion of biotechnology topics or computer-based activities into the existing syllabus. We envisioned that if a Biology teacher wished to present a lesson on the genetic material and the technology of DNA fingerprinting she could choose to do so through a lecture, a hands-on activity or a computer simulation. Other topics that our team incorporated into the proposed Biology syllabus included "low technology" (i.e., non-digital) applications within the Philippine local setting such as seaweed farming and hydroponics (PSHS, 1993).

Integration of technology in the curriculum was handled a bit differently by every group of teacher-curriculum developers. For example, the Integrated Science curriculum design team rewrote the syllabus to introduce technology through topics such as, the paddle boat (for teaching about forces), and hot air balloons and stethoscope (forms and transformations of energy). Chemistry teachers added topics like the design of a spectroscope to teach about atomic structures. The Physics curriculum team revised the original syllabus to incorporate activities that challenged students to design and/or build structures using ordinary materials like straw or aluminum foil. For example, they added classroom tasks of building a bridge to teach
about stress and strain, barge construction to illustrate fluid pressure, and design of a cooler to depict conservation of energy. Thus, technology was incorporated into the existing syllabi through a range of strategies: by way of lectures on the practical applications of science, hands-on laboratory activities using technology, and design-and-construct tasks (PSHS, 1993).

Science/Technology Electives and Streaming

In tandem with the infusion of technology topics into the existing syllabi, the curriculum developers proposed a new set of courses and electives that focused on the practical uses of science and technology. For this second aspect of the curriculum revision, however, the teachers developed a specialized technology-enriched curriculum unique to the PSHS program, and a more generalized version for the other two pilot schools. They proposed that two distinct curricula be implemented because the PSHS System was recognized as having a more science-intensive academic program with more required science courses per year, and better-equipped laboratories, as compared to the other two schools. Thus, it was assumed that the PSHS campuses could accommodate more extensive changes to their academic program than the other two pilot schools (PSHS, 1993).

For the general technology-based curriculum, the old core courses were augmented by a new set of technology electives. At PSHS, the specialized curriculum introduced science and technology electives and a tracking program that enrolled students into one of two groupings or streams, the Science Stream or the Technology Stream. The science and technology electives added to each Stream are listed in Table 2.

The new electives were designed to expose the students to the practical links between science and technology. Science electives were intended to address topics and introduce activities that dealt with the application of science in industry and day-to-day life. For example,
### Table 2. PSHS Technology-Enriched Science Curriculum

<table>
<thead>
<tr>
<th>COURSES</th>
<th>Units</th>
<th>COURSES</th>
<th>Units</th>
<th>COURSES</th>
<th>Units</th>
<th>COURSES</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FIRST YEAR</strong></td>
<td></td>
<td><strong>SECOND YEAR</strong></td>
<td></td>
<td><strong>THIRD YEAR</strong></td>
<td></td>
<td><strong>FOURTH YEAR</strong></td>
<td></td>
</tr>
<tr>
<td>CORE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Integrated Sciences</td>
<td>2</td>
<td>Introduction to Biology</td>
<td>2</td>
<td>Advanced Biology</td>
<td>(1)</td>
<td>Advanced Chemistry</td>
<td>(1)</td>
</tr>
<tr>
<td>Elementary Algebra</td>
<td>2</td>
<td>General Physics</td>
<td>1</td>
<td>Inorganic Chemistry</td>
<td>2</td>
<td>Adv. Topics in Physics</td>
<td>2</td>
</tr>
<tr>
<td>Communication Arts</td>
<td>2</td>
<td>Plane Geometry</td>
<td>1</td>
<td>Advanced Topics in Physics</td>
<td>1</td>
<td>Mathematics Elementary Analysis</td>
<td>1</td>
</tr>
<tr>
<td>Introduction to Computer Science</td>
<td>1</td>
<td>Advanced Algebra 1</td>
<td>1</td>
<td>Advanced Algebra 2 and Trigonometry</td>
<td>1</td>
<td>Adv. Computer Science</td>
<td>(0.5)</td>
</tr>
<tr>
<td>Filipino 1</td>
<td>1</td>
<td>Intro. to Programming</td>
<td>1</td>
<td>Computer Software Project Planning</td>
<td>(1)</td>
<td>Communication Arts 4</td>
<td>1</td>
</tr>
<tr>
<td>Philippine History and Government</td>
<td>1</td>
<td>Communication Arts 2</td>
<td>1</td>
<td>Communications Arts 3</td>
<td>(0.25)</td>
<td>Filipino 4</td>
<td>1</td>
</tr>
<tr>
<td>Introduction to Values Education</td>
<td>1</td>
<td>Filipino 2</td>
<td>1</td>
<td>Filipino 3</td>
<td>1</td>
<td>Economics</td>
<td>1</td>
</tr>
<tr>
<td>PE, Health, &amp; Music 1</td>
<td>1</td>
<td>Asian Studies</td>
<td>1</td>
<td>World History</td>
<td>1</td>
<td>PE &amp; Health</td>
<td>1</td>
</tr>
<tr>
<td><strong>Electives</strong></td>
<td></td>
<td><strong>Science Elective choices</strong></td>
<td></td>
<td><strong>Science Elective choices</strong></td>
<td></td>
<td><strong>Elective courses</strong></td>
<td></td>
</tr>
<tr>
<td>Art and Drafting d</td>
<td>1</td>
<td>Microbiology</td>
<td>1</td>
<td>Microbiology</td>
<td>1</td>
<td>Consumer Chemistry</td>
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<td>Earth Science</td>
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<td>Food Science</td>
<td>1</td>
<td>Food Science</td>
<td>1</td>
<td>Industrial Chemistry</td>
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<tr>
<td>Technology Skills</td>
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<td>Advanced Group Theory</td>
<td>1</td>
<td>Digital Design</td>
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<tr>
<td>Science Electives b</td>
<td></td>
<td>Microprocessing</td>
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<td>Microprocessing</td>
<td>1</td>
<td>Visual Communication</td>
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<td>Advanced Number Theory</td>
<td>1</td>
<td>Advanced Number Theory</td>
<td>1</td>
<td>Cell &amp; Molecular Biology</td>
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</tr>
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<td>Journalism 1</td>
<td>1</td>
<td>Journalism 1</td>
<td>1</td>
<td>Journalism 2</td>
<td>1</td>
</tr>
<tr>
<td>Drafting &amp; Computer Aided Design</td>
<td>1</td>
<td>Advanced Biology</td>
<td>1</td>
<td>Advanced Biology</td>
<td>1</td>
<td>Advanced Mathematics</td>
<td>1</td>
</tr>
<tr>
<td>Woodcraft &amp; Metalcraft</td>
<td>1</td>
<td>Summer Field Biology</td>
<td>1</td>
<td>Summer Field Biology</td>
<td>1</td>
<td>Advanced Mathematics</td>
<td>1</td>
</tr>
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<td>Core Courses</td>
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<td>Summer Internship</td>
<td>12</td>
<td>Summer Internship</td>
<td>1</td>
<td>Advanced Mathematics</td>
<td>1</td>
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<tr>
<td>Science/Tech. Electives</td>
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<td></td>
<td>2</td>
<td></td>
<td>1</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>TOTAL UNITS</strong></td>
<td>(11)</td>
<td>(11) / 135</td>
<td>(11)</td>
<td>(11) / 13</td>
<td>(11.25)</td>
<td>(10.5) / 12</td>
<td></td>
</tr>
</tbody>
</table>

**Note.** Highlighted courses were the proposed additions to the technology-enriched science curriculum. Items (italicized and in parentheses) represent old courses that were deleted or their equivalent academic units were adjusted to accommodate new courses being offered. aElective courses for all students. bElective courses for Science Stream students. cElective courses for Technology Stream students. dPreviously taught only as Art. eOriginally offered to all 2nd year students but was now offered as an elective to the students in the Science Stream only. fThe old curriculum offered Science Research 1 and 2. Under the new curriculum, Technology Research 1 and 2 versions were introduced for students in the Technology Stream.
lessons in yogurt-making, tissue culture and composting were taught in Microbiology; human genome project, and enzyme engineering were discussed as Special Topics in the Life Sciences; ice cream-making and packaging were dealt with in Food Chemistry; and water purification, soap making, and plastic manufacturing techniques were introduced in Industrial Chemistry.

The introduction of Science and Technology streaming was accompanied by corresponding changes in the Research 1 and Research 2 courses described previously (see Chapter 3). These research courses, which were initially taught to all third and fourth-year students with a science-only focus, were modified into two different formats. One format retained the science research theme (Science Research 1 and 2) and the other took on a technology research focus (Technology Research 1 and 2). The new Technology Research courses utilized a combination of design-and-build and project-based learning approach. The design and construction of a technical device or artifact constituted the culminating project.

Table 2 shows an overview of the old PSHS science curriculum, and highlights the proposed technology-enrichment changes that were made.

The Case of Implementation in PSHS: An Overview

Following the seminar-workshop in April 1993, the PSHS Director and the Board of Trustees approved the revised curriculum and mandated adoption for the 1993-1994 school year. The Director presented this decision to move ahead with the technology-enriched curriculum at the first faculty meeting of the school year in June of 1993. At the meeting, the PSHS teachers, most of whom were just learning of the changes for the first time, raised issues similar to those discussed by curriculum developers at the workshop. In particular, teachers were concerned about the additional school hours required to implement the new curriculum.
The teachers were extremely uncomfortable with the changes and no unit was willing to give up class hours to make time for the new electives (V.F. Reyes, personal communication, July 31, 2003). In the end, school administrators reduced the hours spent in traditional subjects like Art and Science to accommodate the additional hours needed for new elective courses.

Ultimately, the school director decided to implement the new curriculum and the streaming process in stages because some teachers resisted the abrupt changes in the academic program that they felt did not follow the required process of extensive faculty consultation. In the final sections of this chapter, I describe the implementation of the adopted technology-enriched science program in PSHS classrooms.

Implementing the Technology-Enriched Science Courses

The incorporation of the new technology topics progressed more smoothly in some courses than in others. Physics, Chemistry and Integrated Science teachers found that design-and-build activities easily fit into their existing curricula and lessons. Thus, competitions to design and construct the fastest running model cars, the most stable model building, and the best flying kite became favorite activities in Physics and Integrated Science (L. Alcid, personal communication, July 21, 2003). Chemistry teachers introduced new design and technology activities wherein students were required to outline a blueprint and construct models that exhibited some Chemistry concept or principle (S.M. Baguio, personal communication, July 26, 2003). Anecdotal data from the subject teachers suggested that students actively engaged with and enjoyed the new classroom activities. Teachers also maintained that changes in the number

33 The PSHS subject teachers are grouped into academic units (e.g., Art Unit, Chemistry Unit) that are equivalent to departments in a university.
34 Art was originally taught to all first-year and second-year students for one school year. Under the implemented science-technology streaming, first-year students take up Art and Drafting for one semester each. In the second year level, Science Stream students would take up Art, while Technology Stream students would enroll in drafting for one school year.
and type of questions their students raised in class indicated that technology-infusion
contributed an increased interest in the topics being taught (L. Alcid, personal communication, July 21, 2003).

Introduction of the new curriculum required the acquisition of additional computers for science classrooms, as the Computer Science classes needed the school computer laboratories. By 1998, science classrooms contained six to ten computers per class of 30 students. In addition to computers, the school purchased shop equipment and technological devices to support the curriculum changes. Despite the addition of new equipment, infusion of technology-related activities and lessons into science courses was less than what was anticipated. Computer interface devices such as temperature or pressure sensors were readily adopted in Physics classes but less so in Chemistry, Biology or Mathematics lessons. This may have something to do with the nature of the laboratory experiments in Physics or with the teachers’ (un)willingness to learn and integrate new technologies in their classrooms. More success in infusing technology was apparent in the electives for both science and technology streams. I surmise that this success was because the electives were new courses that the elective teachers themselves had to develop in response to the reform initiative to make the curriculum technology-enriched.

**Implementing Streaming and Electives in the Curriculum**

Adoption of the technology-infused curriculum at PSHS meant the implementation of a streaming program and the new elective courses. Implementing the Technology Stream initially created an administrative problem, since a majority of the students wanted to enroll in the Technology electives, and yet few teachers at PSHS felt qualified to teach the new Technology electives. This teaching expertise problem however, did not deter reform
proponents from proceeding with the proposed curriculum changes. To solve the expertise problem the administration limited the number of Technology-streamed sections to two per year during the first years of program implementation. More teachers with an engineering or technical background were subsequently hired and in 1996-1997 one Technology section was added for the first year students (S.M. Baguio, personal communication, July 26, 2003).

In 2003, the PSHS students who had completed their first-year of high school were assigned to either one of the Technology Stream sections or the Science Stream sections based on three main criteria: the student’s subject interests or personal preferences (60%); their score on a set of written, multiple choice examinations called the Differential Aptitude Tests or DAT (20%); and their first-year grades in Sciences, Mathematics, English and Technology courses (20%). Also considered in the streaming process were the recommendations from the student’s Technology and Art teachers (S.M. Baguio, personal communication, July 26, 2003). The DAT is a set of individual tests used to evaluate students’ verbal, abstract and mechanical reasoning; numerical and space relation abilities; clerical speed and accuracy; spelling; and language usage (Bennett, Seashore, & Wesman, 1972). To determine students’ technical aptitude in order to select students for the Technology Stream, the PSHS Guidance Office administered the 70-item Mechanical Reasoning and the 60-item Space Relations portions of the DAT (L.Ulep, personal communication, August 8, 2003). Students who asked to be enrolled in the Science Stream but who scored high in the tests were also assigned to the Technology Stream because of the students’ perceived aptitude for technological skills. The value that school administrators assigned technology education is evident in the preferential selection of students with high academic marks, and DAT scores into the Technology Stream. Once tracked into the Technology sections, students enlisted in technology-based electives and
the Technology Research courses. Students however, were allowed to transfer from one specialization stream to another at the end of the school year. This switch took place if a student did not like the chosen or assigned stream, or if teachers suggested the move based on the student's academic performance. Such transfers were rare.

To implement technology integration through the electives, most Technology elective teachers taught with a design-and-construct approach. Students worked on projects such as: balloon-powered air sleds, lamps, three-legged stools in the Technology Skills course; robot sensors, and gear systems in the Robotics classes; and circuit boards, fuse, and switches in Electronics. Curriculum developers believed that students' exposure to technological and practical work was important in developing the technical skills required for their Technology Research projects. The design-and-build activities were also seen as a way to elicit students' interest in future careers in engineering (Reyes, 1994).

To date, implementation of the technology-enriched science curriculum has not been formally evaluated. This study begins that process. I explore the implications of implementing a technology-enriched science curriculum by investigating one significant portion of the program, the Technology Research 2 course. I investigate students' experiences with and their motivations for choosing to be in the Technology Stream. Although my study is not a formal evaluation of the curriculum change process or the implemented technology-enriched curriculum, it does examine the assumptions and rationale associated with using science and technology to promote a country's economic growth and development.

35 At the time that I was writing this dissertation, a DOST-SEI-funded project on the “Evaluation of the Technology-Based Curriculum of the PSHS” was on-going (E. Bustamante, personal communication, September 9, 2003).
CHAPTER FIVE
RESULTS AND DISCUSSION

In this chapter, I present my research findings as classroom narratives and interview quotes. To answer my second research question on what pedagogical practices characterize learning in a Technology Research Program in a Filipino context, I describe the classroom setting and the student activities during the progress of one component of the program, the Technology Research 2 course (TR2). I also examine the course instructors' teaching practices to provide context for students' learning experiences in the course. To address my third research question, I present students' views on learning in the TR2 course as revealed by their interviews. Finally, I discuss the students' reasons for choosing the Technology Stream and relate these to their choice of university courses.

The Technology Research 2 Classroom

On a typical day in the TR2 class, students are already seated when the teacher, Maria or Juana, comes in to start the class. The teacher occupies the big desk fronting the blackboard. Occasionally, the overhead projector and screen are brought into the classroom for special lectures on transparencies or Powerpoint presentations. Students sit randomly or according to their research groups, as they fill the student desks facing the teacher. Sinks, group lockers and counter space are located on both sides of the room, and science laboratory equipment such as stoves, beakers on hotplates, pipettes on iron stands and similar equipment are strewn on top of the side counters. Some students from the class or from the other Research 2 sections may be seen working at the side counters while the class is in progress. Students conducting ongoing technology projects bring their own materials to class, e.g., soldering guns, internal circuit boards, robotics equipment, wires, batteries, and occasionally, their laptops.

Maria and Juana start their respective classes by greeting the students and checking
The teachers then write important announcements and reminders on the board, or verbally explain the activities and goals for the day. When I first sat in and observed the classes, the following outline of requirements and deadlines for the rest of the year was written on the blackboard (field notes, January 7, 2002):

<table>
<thead>
<tr>
<th>Third Quarter requirements:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance (55%)</td>
</tr>
<tr>
<td>Individual performance - 15%</td>
</tr>
<tr>
<td>Project results - 15%</td>
</tr>
<tr>
<td>Project report - 20%</td>
</tr>
<tr>
<td>Attendance - 5%</td>
</tr>
<tr>
<td>Research Paper (20%)</td>
</tr>
<tr>
<td>Abstract (5%)</td>
</tr>
<tr>
<td>Work Plan (5%)</td>
</tr>
<tr>
<td>Oral Presentations and Audience Participation (15%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fourth Quarter requirements:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oral Defense (2-minute Powerpoint presentation) (25%)</td>
</tr>
<tr>
<td>Science Fair Poster Exhibit (25%)</td>
</tr>
<tr>
<td>Project Evaluation - Science Fair Score (15%)</td>
</tr>
<tr>
<td>Comprehensive Examination (15%)</td>
</tr>
<tr>
<td>Final Research Paper (20%)</td>
</tr>
</tbody>
</table>

Figure 2. Science/Technology Research 2 course requirements.

This listing of course requirements served as a reminder for the students who recently came back from their Christmas vacation. At the start of the school year, all the Science/Technology Research 2 teachers had discussed and agreed upon the course schedule, deadlines and requirements as the standards for both the Technology and the Science Research 2 classes. However, it was evident during the months that followed that despite the initial consensus among the Research teachers, individual teachers took the initiative to reassign the percentages or to delete certain requirements altogether based on how students were progressing in their projects. The blackboard listing shown in Figure 2 also illustrated a noteworthy aspect of the STR2 course namely that a large percentage of the students’ marks was based on group work.
rather than on individual performance. These reminders regarding requirements and deadlines stayed on the blackboard for one or two weeks until they were replaced with new announcements about the course.

Although students reported during the interviews that their teacher lectured on the principles of statistics at the beginning of the school year, it was rare for Maria or Juana to lecture in their TR2 course during the nine months of my classroom visits. The few lectures that these two teachers conducted were not content delivery sessions. Juana used a "lecture format" to explain the requirements for the course, the mechanics for the Science Fair, and some pointers on giving an oral presentation. Maria presented lectures to clarify the parts of a research paper, components of a research poster, and samples of posters for the Science Fair. There were no class presentations on the basics of the technological design or the research inquiry approach. Instead of lecturing on these topics, the teacher used consultation and small group sessions to guide and facilitate the students learning of the research process as they worked to improve and complete their projects.

For the most part, students in both Maria's and Juana's classes had the freedom to choose their research topics, to set their own timelines for their projects and to direct the course of their research. Students stated that one of the more challenging and time-consuming aspect of the course was finding a research project that was novel, feasible, and practical, and at the same time provided a simple solution to a problem. Students tried various methods to locate a topic that the Research 2 teacher would approve based on the aforementioned criteria. In their quest for the ideal research project, students explored the Internet, read books and journals, consulted with their science teachers and parents, and visited research institutions. Even after the approved research projects were underway, some teams changed topics when they found
that their proposed methodologies were not feasible, or that the materials they needed were either not locally available, or too expensive. Once the students’ research work was in progress, the teacher provided feedback on the methodology for the projects through small group consultations held within or outside the TR2 class periods. The teachers also encouraged the students to search the Internet and library resources for literature related to their projects, and to consult and work with outside experts in the research facilities of universities or government institutions working on similar projects. Appendix C provides a list of the students’ Technology Research topics during school year 2001-2002.

Since the students’ work on their chosen projects was underway by the time I began my research of the Technology Research course, most meetings I observed were small group work sessions and student-teacher consultations in and out of the class. During some sessions, the individual research groups presented their project updates to the entire class. These class presentations provided opportunities for the students to receive feedback and suggestions from their peers who asked questions about the objectives, significance, methodology, or expected results of each research project. The teachers presided at these presentations and encouraged students to critique their classmates’ scientific research work or technological products. Peer presentations occurred regularly in Maria’s class and were less frequent in Juana’s classroom. The TR2 teachers also devoted some class meetings to help students prepare for presentations of their work at the school’s annual Science and Technology Fair. The activities students participated in during group work sessions, consultation meetings and Science Fair events were intended to provide students with a sense of what engineers and scientists experience as they engage in technological inventions and/or scientific investigations.

To provide a sense of the learning environment in the Technology Research course, I
describe the three main elements of the course, group work sessions, consultation meetings, and Science Fair activities, in more detail in the next sections. Then, I analyze the events that took place in these three elements of the TR2 course to develop a richer understanding of the technology research learning approach in the Filipino context.

Small Group Work Sessions

Students worked in groups of threes or fours to complete their Technology Research projects during and outside of class time. As an observer and a teacher myself, I expected the students to complete most of their research-related tasks in class, but this did not appear to be happening with many of the groups I observed. I noticed groups in what seemed to be periods of “inactivity” during class time and when asked about these, some students explained that they worked on their projects at home or in the dormitories where they could set up their experiments or technological artifacts without fear of tampering by other students. Other groups said they conducted their research in laboratories off campus to make use of the facilities and technical expertise not available in the school. Students also explained that the class period was too short for them to accomplish significant parts of their project during class time. Thus, some students allotted a weekend or an overnight to meet at a team member’s house and finish the tasks that needed to be done. Others preferred to work during the longer breaks between classes. While most students got their projects done, a few students appeared to procrastinate about their work. I discussed this with Maria on Day 1 of Week 6, when she had left class time unstructured to give the students the chance to work on their projects. Except for a team of students who consulted with her during the period, no other group came into the laboratory to work on their projects. Maria pointed out the challenges that some students seem to face:

Some students have good ideas but they can’t foresee how much work needs to
be done. They tend to talk through the project, but can’t really get the work
done at this stage. Some students did not start working early enough. (Post-
class discussion, January 28, 2002)

Because I was provided with an office beside the TR2 laboratory room for the duration
of my research study, I was able to observe the students who came into the classroom during
their free class periods to continue their project work. Students worked on their projects
individually, in pairs or as a whole group. Following are some vignettes of how the students
conducted these group work sessions.

Vignette 1: Group 10 Students Manufacturing Gas-Detecting Pellets. (Field notes, January 29,
2002, Group work outside the TR2 class period)

![Figure 3. Group 10 working on gas-detecting pellets.](image)

All members of the team, Trixie, Jonathan and Matias, were busy working on
their project. Part of the conversation *(speaking in Filipino)* went on as follows:

Trixie: Hey, I don’t want to clean up after we work today.
Jonathan: Matias, you’ll be the one to clean up after! *(said in a “commanding”
tone)*
Matias: No, I won’t!
Juan *(the laboratory technician)*: You can clean up [your work area] tomorrow.
Jessamyn *(researcher-author)*: What are you doing?
Jonathan *(who was working by the fume hood)*: We’re making the pellets and
testing them.
Jessamyn: How does it work? What is it supposed to do?
Jonathan: The manufactured pellet has a resistance as indicated on the ohmmeter and the resistance reading changes with time as it picks up the gas from the atmosphere. So these pellets can be used to detect the presence of toxic gases in the air.

The next day, only Jonathan’s group was working in the laboratory room during the informal TR2 class session. (Field notes, January 30, 2002)

Trixie and Matias were busy molding pellets by hand. Jonathan was again working by the fume hood.

Matias: Who will clean up after we work today? Yesterday no one cleaned up.
Jessamyn: Are you sure that those (referring to the pellets that Trixie holds in her bare hands) are not toxic?
Trixie: Not really.
Matias: (Asking Trixie) Why aren’t you using the beaker [to pour out the solution into the pellet molder]?
Trixie: This is how I’ve done it in the past. Do we have an assignment in Math? (No one responds.)
Matias: Why are the pellets I’m making so small?
Trixie: Why aren’t these pellets sticking together very well? Matias, where are the ones you made? (Proceeds to examine the pellets that Matias produced.) Can you measure some ferrous solution again please? (She later proceeds to make a new batch of pellets from the fresh ferrous solution.)
Jonathan: Trixie, can you record the readings from the ohmmeter while I test the pellets? (Trixie proceeds to the fume hood area and records the readings that Jonathan dictates at certain time intervals.)

This vignette illustrates that members of a research group developed areas of expertise while working on their project. Team members designated tasks based on whether a student was good at refining the research methods or product based on previous training or on science/technical aptitude, conducting library searches, or (re)writing the research paper. Usually, the member with the least expertise became the group’s gofer (e.g., Matias) or the project’s main finance provider (Anthony, interview, March 14, 2002). Although not all the students were personally and intellectually engaged with their project, most of the group members had a general sense of the direction of their research work. When two or three
teammates were working, someone in the group directed the next stage in the project. When I asked the students about this observation, it was evident that there was more than one way that a group leader emerged. The students confirmed that leadership was either "assumed" by a more directive individual, or was informally assigned by the group members based on any one of the following criteria: the person suggested the research topic, discovered an important stage in the project, had some expertise on the project due to past training or interest, or showed high motivation to finish the research tasks on time. In the next vignette, Steve’s teammates acknowledge his leadership role because he suggested their research project. Steve had some previous training on the uses of chitosan in a cancer research laboratory in Singapore during a summer internship program in his third year (Vanessa, interview, March 6, 2002).

Vignette 2: Group 6 Manufacturing Chitosan Beads (Field notes, January 28, 2002, Group work outside the TR2 class period)

All three members of the group were working on their project. The students use a medicine dropper to produce beads by dripping chitosan solution into a dish with sodium hydroxide (NaOH) and letting the beads solidify. As tiny beads form, they sink to the bottom of the dish. The students harvested and washed the beads, in preparation for later use in testing the beads' ability to absorb heavy metals in wastewater.

When I ask the team members how they discovered the technique for forming the beads, they reply that it was by trial and error. The students explain that they used varying sizes of syringes and droppers until they chanced upon the right dropper size and technique.

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36 Chitosan is a substance extracted from the shell of shrimp, crab, and other shellfish.
During our interview session, Vanessa describes the process to me in greater detail:

We initially did not know how to manufacture the beads. Then Steve found a technique described in a book or manual, but they used lactic acid. But it didn't work when we tried it. Finally Steve suggested that we use acetic acid instead. When we worked with acetic acid, we tried different concentrations, but it still didn't work. Then one time, Steve weighed a certain amount [of chitosan], we dropped it into the NaOH solution, and then the beads formed. We got it! I guess it took us about a week or more of trial and error before we finally succeeded. Then, at first it took a long time to form the beads. So we talked about how to speed up the process. We thought of mounting a syringe on an iron stand and placing a heavy weight on top of the plunger so that [the chitosan solution] would slowly drip. But it took such a long time for the solution to drip and form the beads. Then one of us just thought, "why not use a medicine dropper?" We had to try different sizes of medicine droppers to get the right size of beads that we wanted.\textsuperscript{37} (Vanessa, interview, March 6, 2002)

Vignettes 1 and 2 show how group learning dynamics varied across individual teams and personalities within the teams. The group work sessions provided rich opportunities for students to develop teamwork, collaboration, and leadership skills. These skills will be

\textsuperscript{37} The chitosan team won as one of the top 10 projects in the PSHS Science Fair, and as a finalist in an Environmental Research Competition conducted by a local university.
discussed in greater detail in a later section, where student interview comments will reveal that most students valued the lessons learned through the group interactions.

Vanessa’s narrative in vignette 2 also highlights how students experienced firsthand the role of trial and error in research work and the serendipitous nature of the scientific inquiry process in the course of completing their projects. In the next two vignettes, Elen and Ana describe how their groups went through similar experiences.

Vignette 3: Group Producing Dopant Sensors

In designing our project, it was like trial and error. Especially in [choosing] lead oxide – we just thought about it and experimented with it. Isabel did some research on [the use of] tin oxide [in sensors]. But we couldn’t find any tin oxide [among the school’s laboratory chemicals]. So we thought of looking for a substitute that was also a metallic oxide – we found lead oxide and zinc oxide. We chose lead oxide because someone else had already used zinc oxide [in a similar project]. We just tried it and it worked – that was really fortunate. ... So what did I learn in this course? That more often, things happen because of luck. (Elen, interview, February 14, 2002)

Vignette 4: Group Synthesizing Artificial Muscles

Of the three experiments we conducted, the first two failed - the solution didn’t polymerize. We were getting frustrated because we tried different concentrations, prepared a lot of chemicals ... and it seemed like we had tried every possible way to make [the solution] polymerize – we used a vacuum, and [the solution] stayed liquid. Then on our last trial, the pyrrole polymerized to polypyrrole, but the acrylamide didn’t – it was still watery. We were running out of chemicals so we just experimented with what were available. Since in every experiment we’re using different chemicals, this time we added this other chemical. “Maybe this is what’s lacking.” Then [the gel] formed. We really didn’t expect it. Then the good thing about it, the fun part – when we passed a current through it, it expanded. That was the cool thing! ... So yes, that was really lucky. And usually people who discover things, they really do so because of luck, by accident. (Ana, interview, March 5, 2002)

Elen’s and Ana’s comments show that the role of luck or serendipity in science was a revelation for some students. The two girls realized that while the “scientific method” was not necessarily linear, it could lead to an uncharted, sometimes fortunate, path. Others like Christina, whose
group worked on the characterization of native plant fibers, learned to apply experimental logic, and analytical thinking as she engaged in scientific research:

Now, we totally get the scientific method... that there’s really a way of going about things in a systematic and efficient manner... Like finding a solution to a problem, going about an experiment, analyzing data, [and] learning to work with other people. (Christina, interview feedback, April 7, 2003)

Through the small group work sessions, students gained a deeper understanding of scientific and technological concepts, and their applications. For example, Elen (vignette 3), Ana (vignette 4) and their teammates learned about the chemical properties of certain substances while Jonathan’s group (vignette 1) demonstrated an understanding of physics concepts and laws. The students then applied their knowledge of science concepts to manufacture and to refine their research products. Some students like Roland and Jomari, learned electronic principles and computer programming skills in the process of completing their technological devices.

[To produce our robotic minesweeper] we programmed the microchip for the location of the motors and sensors. We also programmed how fast the motor would run and how far it could detect an object. Then we incorporated the infrared and metal detector to the motor. The metal detector is just like an on-off switch. We programmed it such that when the metal detector gives an input of 1, it will stop, and then it will mark [the location of the metal]. The most meticulous and difficult task was programming the microchip. (Roland, interview, March 19, 2002)

[Working on our automated styrofoam cutter project] I learned a lot. Like programming – I didn’t know anything about programming, so I had to learn Visual Basics [for our project]. I think that I’m now also an expert on stepper motor drives, and circuits... and what transistors to use. (Jomari, interview, March 1, 2002)

In addition, as the students learned about the practices of “doing science” and “doing technology”, they developed their own understanding of both the distinction and the relationship between science and technology.

Technology is something that should be useful to people. So if you do a
technological project and it’s not going to help people, what’s the use? In Science, you have to find out about things even though you don’t know how to make it useful, which is technology’s job. Though [science] will still be useful because without science there will be no technology. So for me, [science and technology] are not two separate things. They’re intertwined but technology is more the practical side of science, and science is more the researching part of technology. But technology [also] has its own niche, a research part. Because when you develop an invention, you still have to work out the details, that science cannot provide. You don’t start from what science gives you, but you use what science gives you to develop a [technological] system on your own [emphasis added]. (Aaron, interview, March 4, 2002)

In coming up with a technology project, you don’t have a methodology. You’re the one making the “recipe”. You apply what you learned in science so that you can produce a technological innovation. So unlike in Sci [Research] projects where it’s something like “here’s the methodology, do it”, in Tech [Research], it’s more “how do I go about this?” – you have to think. If this is the old methodology, you have to change it. ... In this course, I learned about both science and technology. You need to learn first the science, then apply it [to the technology project]. Topics from different fields in science and technology can be used in different ways to come up with a research project. (Cherry, interview, March 1, 2002)

Through these students’ commentary we see how they saw the integrated relationship between technology and science.

The students enacted and learned iterative procedures similar to those of a scientist engaged in experimenting and refining research methods and/or of an engineer in designing-making-appraising technological products. These learning activities and outcomes were among the intended goals of the STR course (Cruz, 1996).

Consultation Meetings

Juana and Maria spent a number of class periods in consultation with the individual research teams. For these consultations, Juana typically asked students to come to her desk to sit and talk about the group’s progress in their research project. In contrast, Maria tended to leave her desk, and meet with students at their work stations or desks to talk with them about
their projects. During these sessions, the teachers solicited students' ideas on the project, monitored the group's timetable, asked questions about the methodology or the product design, and suggested changes or improvements to the project. When necessary, Juana and Maria also referred students to other teachers or experienced researchers who could assist in the project. While the teachers conferred with a particular group, the other teams continued to work at their desks discussing their research project with their group mates, writing research journal entries\(^{38}\), and working on their research set-up. For the most part students stayed focused on their class work. But, on occasion students did engage in off-task behaviours such as reading the school paper or a pocketbook, completing an assignment for another class, or chatting about non-research related topics.

Student activity peaked during Week 5 of my observation period. That time was the final two weeks before the PSHS Science and Technology Fair where students would be presenting their research projects for judging and public viewing. During that week, I also overheard some of the groups make plans to stay overnight at a teammate's house to finish constructing and testing their products in preparation for the Science Fair.

In Table 3, I provide a graphical representation of the events that took place on week 5 of Juana's TR2 class. In column 1 of the table, I describe the groups' topics of research. Column 2 refers to the three TR2 class meetings of week 5. In column 3, I document events that took place within technology research groups as they consulted with Juana and worked on their projects. In column 4, I analyze the group events described in column 3 to identify the elements of research that are taking place in the classroom. In the section that follows, I refer to the information depicted on the table, first, to illustrate the nature of the activities that

\(^{38}\) Students kept a research journal where they were expected to outline their timetable, compile research findings and data, record research expenses, and complete daily, weekly and monthly progress reports.
characterize the TR2 learning approach; and second, to highlight the important role that the
teacher plays in scaffolding student learning in the course.

In analyzing both the number of teacher-student consultations (from column 2), and the
TR2 group events (column 3) that took place in Juana’s classroom, I observed a variability
among the teams in terms of motivation, commitment and involvement in completing their
projects. For example, the Table shows that of the nine groups in Juana’s class, eight were
visibly working during that week. Among the working teams, only group 6 accomplished all
their planned activities for each of the three class meetings.

**Nature of the Technology Research Activities**

An examination of the activities listed in column 4 shows that elements of research in
the TR2 classrooms closely parallel the ITEA standards for technological literacy (ITEA,
2000). For example, groups 1 and 4 engaged in design-and-construct activity to manufacture
the pest sound detector and the robotic minesweeper, respectively. This activity involved
students in the iterative tasks of designing, making, testing and appraising their research
product. Through these tasks, students experienced firsthand that inventing a technology
device involves an understanding of design principles such as product efficiency, constraints
and trade-offs.

A closer inspection of the students’ research projects revealed something else about the
nature of the research activities in the TR2 classroom. While some projects could be
characterized as traditional technology design projects, others could also be classified as
scientific investigations. In these team projects, students designed and conducted traditional
scientific experiments where they formulated hypotheses, tested variables against a control,
Table 3. Sample group activities and consultations in Juana’s class.

<table>
<thead>
<tr>
<th>Group Project Topics</th>
<th>Class Meeting</th>
<th>Technology Research Group Events</th>
<th>Elements of Research Activities</th>
</tr>
</thead>
</table>
| Group 1: Construction of an agricultural pest sound detector | 1 | The students report to Juana that they need to purchase a transformer for their machine prototype; they found an Indonesian website that gave some suggestions on what the machine might look like; they also consulted with some scientists at the International Rice Research Institute; and they had spent 3,000 pesos (CA $75) so far for the materials needed in their project. | • Students design-and-construct  
• Students seek and gather information  
• Scientists scaffold student learning  
• Students deal with design specifications, limits and constraints (e.g., costs) |
| Group 2: Design and construction of a controller unit for a kidney stone disintegrator | 1 | The group reports to Juana that they plan to bring in their materials the next day and to work on assembling the machine prototype in class. | • Students plan and organize their own learning. |
| Group 3: Design and construction of a mechanized compost bin | 1 | The team of three female students reports to Juana that the father of one of the girls was looking for someone to help construct and weld the compost bin they designed. Juana said, “Yes, because you are not being trained to be skilled workers.” | • Adults scaffold student learning  
• Teacher values the designing over the constructing tasks |
| Group 4: Design and construction of a robotic minesweeper | 1 | Roland’s team of four male students presents a computer printout of the program being written by one of its members. [The computer program was intended to direct the robot as it searched for and marked the location of the landmines in a field.] The students report that they plan to finish programming the robot in time for a demonstration of the robot’s abilities by Thursday. | • Students design-and-build  
• Students collaborate among team members  
• Students share ideas and expertise  
• Students use tools and equipment  
• Students engage in iterative stages of designing, constructing, testing, appraising and refining the research product/invention |
| | 2 | The students have been assembling the circuit board to be installed in the robot, and testing the robotic hardware for sound emission. They explain to me (as I sat in this consultation session) that they still need to construct the robot, but for now, they were working on completing the circuit board, and the computer program. |  

<table>
<thead>
<tr>
<th>Group 5: Synthesis of an artificial muscle gel for robots using polymers</th>
<th>3</th>
<th>Roland, the student assigned to assemble the circuit board, shows the partly completed circuit board. One team member reports that he had finished writing the computer program, and that the group would integrate the programmed computer chip into the circuit board once the latter was completed. The group plans to work on Saturday. [Note: The students were unable to finish the robot in time for the class presentation they planned to have that day.]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 6: Heavy metal remediation of wastewater using chitosan beads</td>
<td>1</td>
<td>The team of three female students, report to Juana that they were still testing different combinations of the polymers in an attempt to form a gel. They also inform her that the research assistant at the University of the Philippines Department of Chemistry was providing them with valuable assistance at this stage in their project.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Students use trial and error</td>
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<tr>
<td></td>
<td></td>
<td>Students create and innovate</td>
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<td></td>
<td></td>
<td>Students test variables</td>
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<tr>
<td></td>
<td></td>
<td>Students collaborate with their peers, teacher, and other adult experts</td>
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<td>Students use technology</td>
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<td></td>
<td></td>
<td>Teacher gives a suggestion to scaffold student learning</td>
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<td>Students design and build new technologies</td>
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<tr>
<td></td>
<td></td>
<td>Students plan and conduct an investigation to find a solution to a real world problem</td>
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<tr>
<td></td>
<td>3</td>
<td>Steve washes the chitosan beads by the sink counter while the class session, a lecture on the Science and Technology Fair requirements and schedule, continues on.</td>
</tr>
<tr>
<td>Group 7 Video as motion programmer for robots</td>
<td>2</td>
<td>Students work on the computer program that allows the use of video inputs to control robotic movement.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Students continue writing the computer program for their video project.</td>
</tr>
<tr>
<td>Group 8 Polystyrene (styrofoam) salvaging using d-limonene</td>
<td>1</td>
<td>The team reports that they performed confirmatory tests and found that d-limonene effectively dissolves Styrofoam. The students have spent $60 to purchase the d-limonene.</td>
</tr>
<tr>
<td></td>
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<td>Students conduct scientific experiments to test their hypothesis</td>
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collected and interpreted data, and presented their research findings to the teacher and the public. Science education standards and science literacy documents have described these project activities as attributes of the process of scientific inquiry (AAAS, 1993; Council of Ministers of Education Canada, 1997; National Research Council, 1996). For example, group 5 students experimented with different concentrations of the chemicals by trial-and-error to polymerize the gel into a muscle-like substance (see also vignette 4 in the previous section). Team 6, the chitosan group, conducted a similar procedure to produce chitosan beads of the right consistency for their remediation experiment (vignette 2). These students then performed experiments to test and analyze the properties of their research products against a known controlled variable.

Some team projects seemed to meet the criteria for both technological design and scientific inquiry. For example, projects conducted by teams 3, 5 and 6 addressed standards for scientific inquiry, but also fit the standards for technological design. These science and technological research projects demonstrate that the standards or criteria for distinguishing inquiry from design are not clear-cut.

Regardless of whether the projects are characterized as having a technological design or a scientific experiment, all TR2 students were involved in formulating a research question that dealt with a real world problem. Students then planned and conducted investigations to find an innovative solution to their research problem. Students in all the teams also collaborated with their peers, teacher, and other experienced researchers to complete their projects. In the process of conducting their technological research, students learned about the enterprise of science and technology, and the work of scientists and engineers. As a byproduct of the learning in the course and regardless of the project that they worked on, students were involved in decision-
making, independent learning, critical thinking, problem-solving and analyzing. I discuss these learning outcomes of the Technology Research course in a later section of this chapter.

Juana’s comment to Group 3 as shown in Table 3, indicates that this Technology Research teacher values the development of cognitive skills such as creative designing, problem-solving, analyzing, reasoning, justifying as much as constructing the technological artifact itself. Juana explained the rationale for this:

[In TR2, what’s more important], is the idea and the design because in the execution [of the design], they can have somebody fabricate it. These are bright students. These are not supposed to be skilled people, they’re supposed to be thinking people. They’re going to be the future leaders. So we should orient them in the same manner: as future leaders, designers, or innovators... The product is needed as proof of the design, so one still has to see the actual product. You won’t know if your design works if you don’t actually test it, after all. But the way the product was made or designed is the meat of the [Technology Research] exercise. (Juana, interviews, December 2001 & June 6, 2003)

I examine more closely the crucial role that the teacher plays in the TR2 classroom in the next section.

**Student-Teacher Interactions**

Analyses of the small group consultation sessions revealed that the teacher played a supportive rather than a directive role in the Technology Research classroom. During the student-teacher consultations, Juana asked questions that encouraged students to independently seek information they needed for their research work. Although Juana also offered her own suggestions (see e.g., Group 6, Day 1 on Table 3), she tended to ask probing questions of the students. If no response was forthcoming, she challenged them with statements like: “Find out” or “That’s why you are Tech[ology Stream] students, you are supposed to know this”, rather than directing students on how to proceed or providing them with the answer to her question.

Generally, the small group consultations with Maria were structured similarly to those
conducted in Juana’s class. That is, the students provided the teacher with an update on their research work, and the teacher would ask some clarifying questions or would give suggestions on how to best proceed. However, Maria tended to ask more “leading questions” of her students with the goal of seeking the “right answer”. An example of this approach by Maria is illustrated by an exchange that took place during Maria’s consultation session with a group of students manufacturing a gas-detecting pellet (field notes, January 21, 2002):

Maria requests that Jonathan’s group (*Jonathan, Trixie and Matias*) give her an update on the progress of their project. Jonathan explains that they want to simplify their project by working only on certain combinations of the solutions used to make the pellets. Jonathan mainly discusses the group’s research work with Maria, as he reports on what they have done so far, and what they want to change in their project proposal. Trixie contributes to the discussion from time to time, and Matias did not contribute at all.

Maria: Okay, what would make your project more significant [to the environmental problem you are trying to address]?

Jonathan: (Pause) I give up. What?

Maria: You need to choose a pellet with the best combination of characteristics to be used as a semiconductor. Like, maybe you need to read the research paper of Andre or of Isabel’s group (*referring to students from the other research classes who worked on similar projects*). See what results they got and use the [chemical] combinations they suggest in their papers. What else should you do?

Jonathan: Test the pellets using different gases?

Maria: Like what?

(No response from the members of the group.)

Maria: Test it using LPG [liquefied petroleum gas].

Although both teachers asked provocative questions and critiqued the students’ work, here, Maria was clearly directing her students on what they should do to proceed with the project. By providing specific suggestions for the students’ next course of action, Maria’s approach seemed to be focusing the students on the doing of research, rather than modeling thinking about *how to do* research. She tended to view the end products of the research as the goal, rather than the process of research. In contrast, Juana provided fewer answers and prompted students to seek their own solutions to questions.
Juana’s strategies during the consultation sessions are illustrated by the following students’ quotes:

She (Juana) always criticizes our project, and it really works because you get to think of ways of improving it. In other subjects, you keep on working just so you can submit something. But not when you think of Ma’am (referring to Juana) [and this course] because you know that you have to make sure that [your project] has no flaws. And for us it’s an honor when she doesn’t see any flaws. (Steve, interview, February 13, 2002)

You can’t come up with just any sort of story or explanation [on the project] with Ma’am (referring to Juana). So when we are able to convince Ma’am about [the merits of] our project, we can be proud of it because it passed [her assessment]. In a sense it develops our confidence, that we can do it. (Anthony, interview, March 14, 2002)

Students like Anthony and Steve saw value in Juana’s guiding comments and probing questions as these challenged them to critically examine their research design methodology and to independently seek answers to her questions. Juana’s encouraging statements also helped boost these students’ confidence in their work. It was evident that the student-teacher consultation meetings served as important venues for the teacher not only to give inputs to students’ work, but to challenge learners to think through the research process. Some educators claim that when teachers pose a question, seek clarification, encourage interaction, give hints or offer suggestions, these practices promote student thinking and scaffold inquiry learning (Hogan & Pressley, 1997; Roehler & Cantlon, 1997). Although Juana and Maria utilized different teaching approaches, they both applied these inquiry-scaffolding practices in the TR2 classroom.

Science Fair Activities

The STR2 course required students to exhibit their research projects through a poster and a short Powerpoint presentation at the PSHS annual Science and Technology Fair. In the weeks prior to the annual fair, students worked busily to complete their prototype products or
experimental results in time for the Science Fair. Most of the students brought the poster materials and the research project setup to school as they prepared their poster presentations in the days before the Science Fair exhibits. During the Science Fair, students were stationed at the exhibit booths as they showcased their research work to the school community and guests from other schools. Explaining the goals and results of their research projects enabled students to gain a deeper understanding of the significance and practical applications of their research work. The TR2 students recognized that the interactions with teachers, students and other visitors at the Science Fair were valuable exercises in improving their communication and social skills.

One of the things I liked about Tech Research was the Science Fair. I liked explaining our project on a one-on-one basis with the drawings [on our poster] - when I can demonstrate or show them something and [explain] how it works. I think that I enjoyed that because I suddenly realized when I was talking “Hey, our project makes sense!” (Richelle, interview, March 12, 2002)

The poster and oral defense presentations were important because I was able to present my project to other people, verbally and visually. We have to let other people know what we researched on because where's the value in doing research if no one else learns about what we did? It’s like [if someone asks you] “Why did you do this project?” [Will we say] “Because it’s for our own benefit, we just wanted to do it. We won’t share it with other people?” That doesn’t make sense! … Also, the presentations allowed us to practice our communication skills. (Raul, interview, February 21, 2002)

The comments of Richelle and Raul also indicate that students recognized that public sharing of research knowledge was important. The Science Fair presentations helped students see that “doing technology research” was making a contribution to the discovery of new knowledge.

As a highlight of the Fair, the teachers invited a panel of judges consisting of practicing researchers, scientists and engineers to assess the merits of the science and technology projects. The judges interviewed the students about their research and chose the 10 most promising projects based on the criteria set by the STR2 teachers. The project evaluation criteria included...
the manner of presentation (e.g., clear and informative presentation, answers to open forum questions) and the merits of the project (i.e., novelty, significance, methodology, analysis).

Students valued the Science Fair presentations for the learning that took place as they interacted with the judges who were considered "experts" in their fields.

In a way, I didn't really know everything about our project. I knew that polypyrrole had some chemical characteristics but didn't fully understand the structure of polypyrrole. I knew that it's a conducting polymer, but how will it conduct? We researched about it, but we still couldn't totally get it because there was no picture of the chemical structure. We just found out how polypyrrole acts as a conductor when it was time for the [Science Fair] judging. One of the judges did some research on polypyrrole and he explained the structure to us. Ah, so that's how it works! That was cool. (Ana, interview, March 5, 2002)

Other students saw the significance of the Science Fair activities when the judges provided feedback and validation for their student projects.

One of the judges (referring to an engineer) said that our [automated styrofoam cutter] project was one of his dream projects. That it was a project that he really wanted to do. So he gave us some suggestions - just a few improvements on our program and our design would be okay. ... I realized that what we did was valuable and it's like an accomplishment. Because when I think of it, our project is almost one that's for college [level work]. So it's really okay! (Jomari, interview, March 1, 2002)

Through their participation in the Science Fair, students also learned that the exercise of presenting one's work to the research community is important to the work of a researcher.

In research, you need to have an oral defense. You don't just report, or publish in a magazine. You should defend it because people think differently and other people can think of things that you have never thought about. And that could be another outlet for improving your project...[or] for rejecting your project. What if your project is actually wrong and you thought all along it was fine? In science there's no room for misconceptions. As much as possible, everything should be right. [The oral defense is] important because other people can make things right. Instead of this becoming a 'misconception' project, it could be improved, it could be corrected, a lot of things could be done to it. (Steve, interview, February 13, 2002)
Figure 5. Science and Technology Fair Activities. L-R  a) Poster display area. b) An all female group presents the highlights of their research work to one of the judges. c) Science/ Technology Research student explains her team’s project to students from other schools. d) The students conduct an oral defense before a panel of judges who will choose the 10 best research projects.
The STR 2 teachers encouraged their students to participate in regional, national and International Science Fairs where they presented their research projects. Following a format similar to the PSHS Fair, these competitions provided students with additional opportunities to present their work to the science community and the general public. Nine of the participants in this research study actively competed in these Science Fairs.

The student responses indicate that the Science and Technology Fair was an integral part of the Technology Research learning environment. The Science Fair interactions and presentations provided an important learning space where students added to their science and technology knowledge and acquired a deeper understanding of how research is conducted. The judges' validation of the student projects also enabled students to see that their research work in the classroom had practical applications in real-world contexts.

Students' Views on Learning in the Technology Research Course

During interviews, the students shared their perspectives on learning in the Technology Research course. Their responses suggest that aside from the scientific and technological concepts and skills that they learned while working on their projects, the inquiry approach used within the context of STR Program helped them to develop lifelong learning skills, to nurture higher order thinking skills, and to integrate and apply knowledge learned from other school subjects. From the students' stories and reflections, it was evident that students learned to value alternative pedagogical roles and practices in the TR2 classrooms. I summarize the students' views of the technology-based, research approach in the next sections.

Developing Lifelong Learning Skills

Students found their Technology Research course valuable and interesting. Pedagogical practices and activities in the research classrooms helped develop team collaboration,
communication, social and leadership skills among the students. The students also found that
the independent learning approach inherent in the TR2 classroom prompted them to be more
self-disciplined and organized.

What I liked best about Tech Res, in one word: [it’s] interesting!...You learn
how to be organized, you learn to analyze and in doing so, you get to be more
disciplined. So doing research is really different from my other science courses
– it instilled a different kind of discipline in me. (Steve, interview, February 13,
2002)

I feel that there’s a deeper meaning to Tech Research. It’s not only about the
project but it teaches you other things. I just realized that it teaches you not just
to be innovative, but also how to write, to speak, to be fluent, to be sociable. [In
this course] we learned to be resourceful, to look for people we could consult
with [about our project]. We talked to people from the Department of Energy,
the Philippine Coconut Authority. So we really learned to be sociable and to
communicate with people that we didn’t even know. (Xander, interview, March
6, 2002)

Comments by some of the students show that the group work sessions in the
TR2 class also improved their teamwork, collaboration, and leadership skills.

[Working on our research project] I learned teamwork: how to work with a
group, learning to do our part, how to take responsibility as you are accountable
to others...and learning also to listen to others’ ideas. (Vanessa, interview,
March 6, 2002)

If you’re working in a group, you learn group ethics. You learn how to get along
with others. And for example, [in our research team] there’s one group mate
who’s dominating. That’s me. So if they ask me, “What are we going to do?”
Of course I can’t say, “I also don’t know”? So I try to figure out what we have
to do next... Sometimes I have this feeling that I want to do everything on my
own because I want it done right. I have my own perceptions of what’s right
and what’s wrong [for the project] and it’ll be done right if I do it myself. But I
learned to trust [in my teammates] because I found out that they’re very
competent, very able, and I sometimes let them do it on their own. (Steve,
interview, February 13, 2002)

The students’ research activities were venues for learning how to balance their roles as
members and/or leaders in the team as they worked towards their project goals. The following
comments from Aaron and Christina demonstrate the challenges of working in a group.
[In Technology Research] I learned a lot of things on a personal level because you had to interact with a lot of people. With groupmates maybe you really have to interact, it’s not a monologue. If you’re acting as the leader of a group, you have to give your people a chance. Like what I did with Carl during the oral defense. I didn’t want to monopolize everything. You have to talk with your people because you have to make sure that they’re also knowledgeable about the project. Because if you’re doing all the writing and then they’re not doing anything to learn, then they won’t feel that it’s their project. So what’s the point in working as a group? (Aaron, interview, March 4, 2002)

[While working on our project], I would remind the group about what needed to get done. I have this habit that I really pride myself in doing things on time. So I guess I am the leader type. But not in the sense that I don’t consult those I lead about what they want. I offer them my ideas. And if they want to change something, that’s fine with me. But I can’t take it when we don’t finish something when it has to be done. I learned that to be a leader, it’s important to respect your colleagues and that you have to gain your group’s trust and respect because they won’t follow you if they don’t have faith in you. Also, different members of the group have different personalities. You don’t always agree on the same things. So I think that one has to always discuss to avoid conflict. (Christina, interview, March 1, 2002)

These comments illustrate that students recognized the value of accountability, interdependence, cooperation, mutual respect, and equal responsibility in achieving successful team collaboration. In the case of Aaron, his comments also illustrate a form of mentorship that occurred in some of the research teams.

Language Issues

Although most of the students acknowledged that the Technology Research course enhanced their written and oral communication skills, it was interesting to note that students did not always deliver their oral presentations in English, which is the medium of instruction in the TR2 course. Among the 27 student-participants in the study only four (3 boys and 1 girl) chose to respond in English during our interview sessions. Even among these four students who exhibited ease in conversing in English, their interview responses were still interspersed with phrases in the native language. It is evident that a majority of the students in the TR2 class
were more comfortable delivering oral presentations in their native language than in English.

We really had a lot of practice speaking [before visitors and judges] at the Science Fair. ... I presented mostly in [the local dialect] because I can’t speak in straight English sometimes. (Xander, interview, March 6, 2002)

For our group, it was Ninna who presented during the oral defence. . . . because I’m not fluent in English. I stutter and nonsensical words come out in the process. I can’t speak in straight English. It’s like, I suddenly run out of words. (Ann, interview, March 5, 2002)

I highlight this observation because, as mentioned in Chapter 4, the Philippine government has identified English as the official language for science and technology learning in schools. Yet among this group of students who are identified as gifted, only a few were comfortable enough with the language to speak it informally in the interviews, and formally in TR2 class sessions and Science Fair presentations.

The government policy that requires the use of English for classroom interactions was not being successfully implemented in these Technology Research classrooms because of complexities around the language issue. While it is true that students’ problems with speaking English in the TR classroom did not hamper their learning, it was apparent that even in a gifted school the need to teach both the science and technology contents and the English skills made it difficult for all concerned. If implementation of the policy is important because of the notion that learning to communicate in English is crucial for science and technology workers to be globally competitive, then school administrators may need to address the problems of language in the classroom. For example, some school interventions could include more English training for the students and teachers. In a broader context, the observations suggest that government and education leaders may need to re-evaluate the language policy and examine the issues around the mandated use of the colonizer’s language to teach science and technology among a people who are more fluent with and prefer to speak in one or two local languages (see e.g.,
The students’ experiences in the Technology Research classroom enhanced the development of skills in independent learning, communication, team collaboration, problem-solving, leadership, and higher cognition. These skills are important in equipping students to become lifelong learners, empowered to direct their own learning and apply their knowledge and skills beyond the context of school (Hawkey, 2002).

Nurturing Higher Order Thinking Skills

The students claimed that the Technology Research course encouraged them to be innovative, critical thinkers. To complete their research projects, students engaged in the problem-posing and problem-solving, experimenting and/or designing-and-building, that helped improve their analytical skills.

[This course] encouraged students to be innovative thinkers, definitely! We had to rack our brains thinking of a project that no one else had done before, and it had to have some significance...then you have to use knowledge you’ve learned in other subjects, not just in science... It’s also fun that you get to see how you think as you analyze [the data] you have. (Christina, interview, March 1, 2002)

For me the best part of Tech Research would be before actual construction of the [pest detector] project began because that was when we’re talking and discussing what we’re going to do with the project. That’s more the thinking part of the project itself. We were thinking if we were going to do a square box that the farmer will use for pesticide application. Or we were thinking of applying certain mathematical principles for the algorithm [of the pest sound detector]. (Aaron, interview, March 4, 2002)

Student responses also illustrate that the research-related activities helped nurture students’ creativity, imagination, resourcefulness and problem-solving skills. Cherry and Richelle felt this was a valuable part of their experiences in designing their projects:

It’s like we get to use our creativity. [Designing], it’s a creative process. Given that you have a set of limited resources, limited materials, what can you produce? It’s like we became more resourceful because of the [constraining] situation. (Cherry, interview, March 1, 2002)
I liked the designing part of Tech Research. We first made a model of our [coconut defibering machine] project. I think I really needed a model to get to think of something. I had to see things – to play with things, to imagine them and see that it had to work. I did something with the straws – different sizes of straws, one shoebox, and toilet paper cardboard. I also made the gears so I only had to move one and then everything else moved. So I thought, if we could do this [with the model], why can’t we do it with the real gears? I mean, if we could use real gears, it could work. And then we thought, how about [a] hand-cranked [defibering machine]? But that was too difficult [to crank]. Why not use your legs [instead]? (Richelle, interview, March 12, 2002) [This group of students ended up with a bicycle-type defibering machine.]

The responses of these students show that manual tasks associated with the technology-based research approach were not mindless routines, but cognitively stimulating activities for the students. The head-hand and academic-practical distinction that is equated with the science versus technology dichotomy seems to blur when examining the students’ learning experiences in the Technology Research course. In schools, science teachers are often not keen to relinquish their discipline-based courses in place of integrated academic-technical courses, similar to the TR2 course, because they think that the subject matter covered would need ‘dumbing down’. This perception of a requisite dilution in terms of breadth and depth of subject matter stems from a belief that the students enrolled in practical, technical courses may be academically ‘slower’ and less motivated as compared to those learners in pure science programs (Steinberg, 1998; Young, 1998). Resistance to a focus on applied or practical learning in schools is linked to the debate over liberal arts and vocational education or what educators refer to as the head versus hand issue (Layton, 1984). A traditional liberal education favors the emphasis on courses that support classical knowledge while a technical education focuses on teaching manual and job-related skills. Having institutionalized the myth that science knowledge is pure and value-free, scientists and university educators are strong advocates for keeping science “uncontaminated” and dissociated from societal and industrial
influences (Gaskell, 2001; Layton, 1984). Students' experiences in the TR2 courses belie claims that applied, technical education programs threaten the academic rigor of the curriculum.

Learning to Integrate and Apply Knowledge

Unlike other science subjects where there is a tendency for students to memorize isolated bits of information, the technology research activities prompted students to integrate concepts and skills they learned from different academic subjects, and to find applications for these in real-world contexts outside of school. For these students, this holistic, interdisciplinary and practical approach made science and technology learning relevant and interesting.

The things we learn in Chem or Math, for example, it’s in this course that we really get to apply them. In Chem, why do they teach us to titrate vinegar to determine its acidity when you can actually read that [information] off the [bottle] label? It doesn’t make sense!... Then we had to do our own acidity tests and computations while working on our project [to produce an edible film], and that’s when we realized titration’s practical applications. (Gail, interview, February 26, 2002)

Bio is too theoretical for me. It’s really hard to apply [the things I learn in Bio]. But in our research project [on the production of coconut-oil diesel fuel], there were a lot of Bio and a lot of Chem [concepts]. Like about [chemical] reactions, lipids and stuff. So that’s when I realized that “Wow, this [concept] is actually important”. I appreciated working on our project because it also helped me understand Bio and Chem better. (John, interview, March 7, 2002)

Technology Research 2 students like Gail and John clearly gained a better understanding of abstract knowledge and skills learned in their discipline-based courses when they discovered practical applications for these concepts and skills in their research projects. For other students, the application of scientific and technological knowledge to a project with economic significance provided a sense of accomplishment and gave purpose to their learning.

At first we’re working on our project [the characterization of some native plant fibers] mainly because it was a requirement. It was frustrating in the beginning when we had to look for resources and people that can help us. But once we got started and made contact with the PTRI [Philippine Textile Research Institute], it became interesting because we realized that somehow our research work was going to be important. No one has ever done the project before and the
researchers at the PTRI were really interested in what our results would be. (Christina, interview, March 1, 2002)

It’s in this course that we now get to apply what we’ve learned in the past four years to the problems of the world so we can help others. Being able to apply what we’ve learned is the sense of learning. Let’s say you study Physics – sometimes I wonder: If a ball is falling, will I want to measure how fast it falls? But when I see our [composting bin] project [I think] “that’s the product of all the things I’ve learned from Advanced Electronics, and the other subjects.” For example, I can now find a way to apply the concepts I understand in Bio – that through composting we can reduce biodegradable waste matter, which can be used for other things. It’s like this course teaches us to apply what we’ve learned to be able to think of ways that we can help, that we can improve the lives of people today. (Diana, interview, February 19, 2002)

These students’ comments and experiences in the TR2 course provide strong support for the claims of science educators and researchers that learning activities with a science-technology-society (STS), project-based approach engage students, increase students’ interest in science learning, and enhance learners’ conceptual understanding (see e.g., Aikenhead, 1994a; Krajcik, et al., 2003; Yager, 1996a). Diana’s quote shows that lessons students learned through STS-oriented activities can prompt them to think about their roles and responsibilities in society (Aikenhead, 1994c). These students’ perspectives further support the claims of contextual learning advocates who indicate that providing students with classroom activities situated within the context of the real world (e.g., work-related situations) renders learning interesting and more relevant to the students (Berryman, 1993; Gaskell & Tsai, 2000; Steinberg, 1998).

Valuing Alternative Pedagogical Practices

Most students in this study recognized that the non-traditional teaching practices they experienced enhanced their learning in the Technology Research classroom. Learners observed that the teacher spent less time on lecture-based or teacher-directed class instruction. The students were also aware that the teacher adopted learner-centered teaching strategies that encouraged them to think independently, to seek out answers to their own questions, and to
interact and solve problems collaboratively.

In this course the teacher doesn’t tell us what to do because if she does then how will we be encouraged to be innovative? The students have to learn to think. (Xander, interview, March 6, 2002)

For me, Tech Research was the subject that I had the most liberty of what I’m supposed to do. ‘Coz I thought of what I’m gonna do, what [our project’s] gonna do, what it’s not going to be able to do, all that. And it’s not like that in most of the other subjects. Sort of like the first time we’re generally free to learn what we want to learn. (Frank, interview, March 7, 2002)

The teachers posed probing and clarifying questions, and provided guidance and scaffolding to the individual teams as they worked on their projects. Some students, like Cherry and Aaron, valued and embraced this teaching strategy because it encouraged them to become autonomous learners.

This way of teaching takes some getting used to at first, but I think that this kind of teaching is needed so that students will be more independent. (Cherry, interview, March 1, 2002)

We weren’t really ‘taught’ because we had to do it on our own. It was more [like the teacher] guiding, advising... [this course] encourages me to work because you really have to push yourself. You’re not given everything that you need and so you have to find things on your own. (Aaron, interview, March 4, 2002)

Aaron’s views also suggest that he did not relate guiding and advising to teaching. Further probing revealed that for him, “teaching” was synonymous to “lecturing”. Other students recognized that they had to learn differently for this course, but struggled with their new roles in the Technology Research classroom.

Yes, I learned a lot from this course, but it was difficult [learning this way]. And we had to do everything on our own. If we had chosen to work on a simpler project, or if we had somebody guiding as all the way, then our work would have been easier. Then we wouldn’t have to learn some things on our own and it wouldn’t have been as stressful. (Jomari, interview, March 1, 2002)

The teacher is just guiding us because basically we’re the ones who thought of our own projects. This is fine as long as guidance is constantly given and you are not left totally on your own. It’s different from other subjects where it’s
really lecture and you have a syllabus. ...I think it's a good way [to learn] because it develops initiative and independence. (Vanessa, interview, March 6, 2002)

Students like Jomari and Vanessa acknowledge that they gained valuable knowledge and skills from the course but were not totally convinced that this was the best way to learn. Comments of these students also demonstrate the need for the teacher to create the right balance between support and challenge in scaffolding novice learning. Some educators claim that as the teacher scaffolds student learning, students gain confidence in the processes of problem-posing and solving, collaborating and independent thinking, until they are able to take responsibility for their own learning (see e.g., Roehler & Cantlon, 1997). Some of these scaffolding practices were evident in the TR2 classroom. For example, by enabling students to focus attention away from instruction and information to investigation and inquiry (Hawkey, 2002), Juana and Maria helped enhance students' autonomous thinking and learning abilities.

Learning differently for the course also meant that students had to build upon the knowledge and expertise of their team members and peers as they collaborated on their projects. Students, like Richelle, recognized the value of learning with and from their peers.

It’s difficult sometimes – you have to sit for days thinking of what we’re going to do. And then when you get (i.e., understand) what you want to do, it becomes easier. When [the group] talks about what to do next, it becomes difficult again. Sometimes we get stuck. Like after we made the models [for the defibring machine], we couldn’t decide which design to use so we asked our classmates, our friends, what they thought because we were stuck. Different people [helped] but the big help came from Aaron (who was from another section). I sat down with him and asked him about our designs. He said, “Okay, that could work.” We started having these conversations... our group talked about what he said ...then finally our group discussed how we could do [our project based on his suggestions]. (Richelle, interview, March 12, 2002)

Through their experiences in the TR2 course, students acknowledged that having less teacher-directed instruction effectively encouraged them to approach learning differently.
Students took a more active role in their learning as they explored alternative paradigms for teaching and learning in the TR2 classroom.

A small group of learners (n=3) with more traditional ideas about how science should be taught did not find work on their technology-based research projects valuable. Unlike students who enjoyed and felt empowered in this course, these individuals felt frustrated that the teacher was “not teaching” them. Comments by James and Jomari illustrate their strongly held views about what is the appropriate role of the teacher.

There’s no teaching in this course because you have to do things on your own. What the teacher does is only monitor what you’re doing. [She asks us] “What have you worked on? How are your results?” The only thing that she taught (i.e., lectured on) was Stat. If that’s the only thing that she does, then why meet in class at all? I think it’s a waste of the money that’s being paid to her. (James, interview, February 15, 2002)

The teaching wasn’t really that effective because the teacher wasn’t teaching you theories and testing you on them. Instead, you just went to the teacher for consultations and she would refer you to another person or agency. I would have preferred that she gave me the information that I needed to work on our project. (Jomari, interview, March 1, 2002)

James’ and Jomari’s passive views of learning and preference for more teacher-directed approaches to learning are typical of many secondary and post-secondary science students (Baird & Northfield, 1995; Yazon, Mayer-Smith & Redfield, 2002). Traditional teaching practices such as lecturing, focusing on the memorization of terms and information, and demonstrating experiments are common in science classrooms around the world (Martin, et al., 2000) and particularly in the Philippines (van den Berg, Alfaara, & Dalman, 1997; Ibe & Ogena, 1998). Filipino science teachers prefer lecture presentations (even dictations) and laboratory demonstrations to student-centered activities because these are deemed as effective time- and resource-saving practices (van den Berg, Alfaara, & Dalman, 1997; DECS, DOST-SEI, & UP-NISMED, 2000a). Unfortunately, the tendency for some teachers to lecture and to
direct class work may be responsible for perpetuating the kind of views students have about their passive roles as learners.

Although James’ and Jomari’s views about the teacher’s role in the Technology Research course were not shared by most of their classmates, a closer examination of the interview responses reveals that some students who valued the independent learning experiences in the course still held traditional notions of the teacher’s and student’s roles in the classroom. This group of students did not think that the TR2 learning approach would be effective in their other courses. Aaron’s comments exemplify these students’ sentiments:

[This learning approach] is good for Research because you really had to put it on your own. But for other subjects like Physics, maybe, it’s not going to be applicable. Because if you just let the students work and find what they’re supposed to learn, and you just guide them and give them handouts on what they’re supposed to read, it’s hard. It’s still better if someone is in front of the blackboard telling you this and that, because it’s easier to remember if someone is telling you, you’re not just reading it, right? When you’re going to do it alone maybe you can talk with other people but it’s still different if there’s someone constantly checking on you [or] someone’s always trying to remind you this, tell you that this is that. (Aaron, interview, March 4, 2002)

Filipino socio-cultural norms may play a role in these students’ views of the teacher as the authority figure in the classroom whose expertise a learner seeks and never questions (Arellano, et al., 2001). Although the PSHS curriculum encourages critical thinking and independent learning among its students, it is also difficult to undo the influence of six or seven years of primary schooling where the teacher may have directed most of the student’s learning activities. Some PSHS science teachers also appear to be unwilling to explore new ways of teaching that would encourage students’ autonomous learning and thinking. These teachers prefer to act as the expert in the classroom and place less value on the student’s role in the learning process. As Aaron candidly stated:

With our experiences here [at PSHS], there were some teachers who when you tell them something and they don’t agree, [then] they don’t agree! They’re really
not open to discussion and to the ideas of the students. And some teachers, when it comes to class discussion, they just talk and talk and talk and talk. And we don’t even get to ask questions sometimes. … it’s not really a class discussion as much as sermons. I think from our perspective, we saw that it’s like [the teacher] really didn’t care whether we learned the subject or not.
(Aaron, interview, March 4, 2002)

Empirical studies on the application of science inquiry practices in traditional (i.e., teacher-directed), non-Western classrooms show that socio-cultural practices and norms deter students from questioning the teacher as they engage in inquiry learning (Akatugba & Wallace, 1999; Lee, 2002; Shumba, 1999). The comments of some of the students in this research study indicate that the same observations may apply to Filipino classrooms. In the Filipino culture, most parents do not encourage their children to ask questions at home and inquisitive students are not viewed as well-behaved (Licuanan, 1998). Younger members of Filipino society do not debate with, criticize or question the ideas of elders and people in authority. To do so is considered to be disrespectful and rude. Thus, it is important for Filipino science teachers to recognize how these values from the home and community may impinge on inquiry and independent learning practices they want to cultivate in the classroom. Educators who have worked with children from diverse cultural backgrounds argue that it is the teacher’s crucial role to set up the ‘rules’ of engagements and to provide scaffolds for learning within these non-Western contexts (see e.g., Lee, 2002). Although TR2 teachers provided guidelines for student activities at the start of the course, I did not observe the teachers having ongoing conversations with the students to prepare them for the shift in pedagogical roles that characterized the research course.
Technology Research Curriculum: Is it Technological Design?

In order to better understand the nature of the Technology Research Curriculum that was implemented in these PSHS classrooms, I asked Maria and Juana their interpretations of the curriculum reform initiative. I was interested in finding out how the two teachers understood the rationale behind implementation of the program.

Technology Preparation (refers to a course that teaches metal craft, and woodworking) was introduced in 1996 because at that time technology was hot. Dr. X (the school director) made ways to obtain [technology-based industrial equipment] and there was a grant-in-aid from DOST. I remember Dr. X used to say, our students should learn how to change a light bulb, fix electrical gadgets at home and all that stuff. She was into having the kids experience the theories. Of course, in the end, [Maria and I] realized that we're not supposed to be developing skilled manpower, but future leaders, so although we support Dr. X's vision of the students having a hands-on experience, we're emphasizing more on the design and management aspect [of technology research]. (Juana, July 2, 2003, interview feedback)

I didn’t know what the school wanted, why there was a tech stream. I just swallowed the explanation that it’s [to encourage students] for engineering and that there’s a presidential thrust. Okay, so there’s a presidential thrust – so what? Juana just explained the streaming concept to me, on my first day, walking from the front lobby to the research lab... an estimated 3-minute explanation...then the whole streaming rationale was explained in several faculty meetings. ... At first I had misgivings [about teaching Technology Research]. Like, “what’s this technology-science stream?” Coz my concept of technology was still tech - vocational. But, since everything was new and people were open to “whatever you want to do, do it” sort of attitude. ... The idea of tech research was a bit unfamiliar so I just based it on my experience of research in high school, and on fundamental principles shared with “science” research. Then after the first few classes [it became] research with a design approach. (Maria, interview, June 19, 2002; interview feedback, April 28, 2003)

The comments of Juana and Maria reveal that these two teachers came to accept the curriculum despite their non-involvement in the 1993 reform initiative. At the same time, they saw fit to interpret and to re-design the program based on their personal backgrounds, technical expertise and experiences as alumna of the school. They made the curriculum their personal

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39 Maria and Juana were not yet teaching at PSHS in 1993.
own. When asked what they thought were the goals for the Technology streamed curriculum, Maria's response was more tentative than Juana's.

Our goal [in Technology Research] is to make [students] use the skills that they've learned and apply it into looking for solutions to a current problem – [use] skills in electronics, metal and wood crafts, [apply] materials evaluation, use concepts learned in Physics, etc. At the same time, applying the scientific process. ... Another goal [of the program] is to encourage them into technology [degrees]. I just don't know how effective [we are at it]. (Juana, interview, April 3, 2002)

I never thought about the goal for the course. Except to carry out an investigatory project in a year's time. So (pause)... the goal would be to (pause) be able to answer that [research] problem, to be able to prove your solution... to be able to assess the quality of your solution, whether it's good or bad. ... At the end of the year, it doesn't matter whether their [research project] results are positive or negative. What matters is that they've done the 'finding out' in a scientific way. (Maria, interviews, June 19 and August 27, 2002)

Whether they were aware of it or not, Maria and Juana acted as important change agents as they re-interpreted the proposed curriculum and developed it into a highly creative and powerful space for students to learn not just about technology, but also about science.

Although both teachers were specifically asked to describe the goals of the Technology Research program, they each made reference to the scientific process as a means to achieving these goals. Their responses indicate that for Maria and Juana, the processes of scientific inquiry and of technology design overlap and can be integrated, as was apparent in their classrooms. Asked to differentiate between technology and science, the two teachers had these responses:

I orient the students at the start of the school year [to the difference between science and technology]. Technology is a tool. Science is the theory that runs these technologies. For me, [technology] is definitely an applied science. For us in Tech Research, technical writing is different from [writing] a scientific paper. The statement of the problem isn't hypothesis-based. You start with a real-life problem, then you come up with a solution. It's not theory [testing] but [finding] a solution that has basis. ... Getting data out of a tech research project is very different from getting data in science research projects. In a science
project, replication and treatment are obvious. These are also found in Tech projects, but it's not as obvious. Students have a hard time identifying the treatments and replications in a tech project. (Juana, interview, April 3, 2002)

For me, there’s no difference between science and technology because the process is the same and the thinking skills are basically the same. But for the students, I think there’s a distinction in their minds. (Maria, interview, August 27, 2002)

These responses indicate that for both Juana and Maria, the definition of what constitutes technology research and science research is not as clearly defined as the streaming program suggests. Some educators claim that views similar to Juana’s, where technology is defined as applied science, are typical in science curriculum documents where the technology topics are inserted into the program to make science interesting for students or to initiate discussion on the science concepts that underpin the technology (Fensham & Gardner, 1994; Layton, 1993b). Although these authors recognize that science and technology are closely linked, they do not agree with the ontological relationship of “science before technology” (Fensham & Gardner, 1994, p. 163) that this view espouses. They argue that the view of ‘technology as applied science’ implies that technology needs science to exist and this relationship creates curricular debates on the perceived status of these two disciplines.

Maria’s comments support my own observations of the Technology Research classrooms in this study where the students’ projects exhibited both the processes of technological design and of scientific inquiry. What distinguishes a technology from a science project was not easily discernable when examining the overlaps that occurred in the students’ technology research work. The boundaries between science and technology blurred, as a seamless continuum became apparent in the processes, skills, and knowledge students learned about technology and science. These “student technologists” needed to gather information (i.e., conduct research) about the problem that the technological device addresses. They then
proceeded to investigate or inquire into the kinds of materials that would be suitable for use, and designed and constructed the device needed to solve the problem. Testing and redesigning the technological device, and communicating their findings to peers were also part of these technologists' work (Eggleston, 1994). A parallel process occurs among scientists engaged in scientific inquiry. Scientists observe and gather preliminary data regarding the phenomenon or problem they want to solve. Working within a hypothesis, they then design and conduct an experiment to test their hypothesis, gather data to verify or refute their hypothesis, and draw conclusions. Scientists also redesign the experiment when appropriate, and report their findings to the scientific community (National Research Council, 2000). These same practices of doing science and doing technology were evident in the students' Technology Research projects. Furthermore, the thinking skills of problem-solving, designing, analyzing, and evaluating common to both technology design and scientific inquiry were seen in the students' practices as they completed their research work.

Thus, distinguishing between technological design and scientific inquiry was not clear-cut in these Technology Research classrooms. This observation suggests that educators may need to re-consider how the disciplines of technology and science are presented in the curriculum. The distinction between technology as applied and vocational, and science as pure and academic may not be useful. The manual versus intellectual label also needs re-evaluation since both hands-on and minds-on tasks are evident in Technology Research students' experiences.

Instead of reinforcing the distinctions between science and technology through curricular reforms such as the streaming program, educators should focus on curriculum that integrates and forges a partnership between science and technology. Some educators have also

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49 The relationship between technology studies and science education in the curriculum are explored in greater detail by Fensham & Gardner (1994) and by Layton (1993a).
recognized the need for this integration based on the close links and the similarities that exist between science and technology (see e.g., Cajas, 2001; Fensham & Gardner, 1994; Gaskell & Hepburn, 1997; Layton, 1993b; Roth, 2001). For example, Layton (1993a, 1993b), and Gaskell and Hepburn (1997) argue for the integration of vocational and academic goals through the melding of science and technology education. Cajas (2001) and Roth (2001) encourage the use of technology design activities in science education because they claim that designing provides a rich context for students to learn about science. Based on the findings from this study, I strongly support these educators’ claims. I also concur with science/technology educators and researchers who note that teaching of science and technology — whether in social (e.g., an STS approach) or in work-related (e.g., Applied Academics) contexts — offers a more holistic, relevant approach to teaching students scientific and technical concepts and skills (e.g., Gaskell & Hepburn, 1997; Layton, 1984, 1993a; Zuga, 1996). These contexts also provide students with a richer understanding of how both science and technology impacts the values, needs and goals of our fast-changing global community.

**Does the Streaming Program Prepare Students for Science and Technology Careers?**

The PSHS implemented the Technology-Enriched Science Curriculum in 1993 to prepare and encourage more students to enter technology-related courses and careers. In this final section of the chapter, I address my third research question by examining students’ motivations for choosing the Technology Stream in relation to their future college program and career choices.
Choosing the Technology Stream

School administrators conducted an orientation seminar for students at the end of their first year at PSHS, to present the two academic Stream options. After attending the seminar, students were asked to choose the Stream program they would prefer to join in their second year. I interviewed 27 students about why they chose to enter the Technology Stream. As summarized in Table 4, student responses were classified into six categories: interest in technology (n=12); preference for hands-on or interactive learning (n=6); desire to be among friends (n=5); sense of “prestige” or challenge to be in the Technology Stream (n=5); disinterest with memorization and lecture-based learning associated with Science (n=3); and perception that the Technology Track was fun (n=2) or easier (n=2). Three students stated that they did not choose to be in the Technology Stream but were assigned to it. This last group of students added that they did not regret being assigned to the Technology Stream. I analyze and discuss students’ decisions for choosing the Technology Stream in the next sections of this chapter.

Interest in “Techy” Topics

The most popular reason that students (n=12) cited for enrolling in the Technology Stream was their interest in technology-related topics such as electronics and computers, or in activities dealing with what some referred to as “techy” stuff.

I like technology, gadgets. I am fascinated to learn about a digital camera or a computer, for example. (Jomari, interview, March 1, 2002)

I became interested with electronics as a field - tinkering with gadgets and stuff. (Raul, interview, February 21, 2002)

Some students in this group expressed a fondness for playing with wires and circuit boards, constructing cardboard models, or pulling apart and fixing broken gadgets at home. Three of
Table 4. Reasons Why Students Chose the Technology Rather than the Science Stream

<table>
<thead>
<tr>
<th>“Why I Chose to be in the Technology Stream”</th>
<th>No. of Respondents$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boys</td>
</tr>
<tr>
<td><strong>Interest in Technology</strong></td>
<td></td>
</tr>
<tr>
<td>• I’m interested in... electronics as a field.</td>
<td>3</td>
</tr>
<tr>
<td>• I’m thinking of taking an engineering course [in college].</td>
<td>2</td>
</tr>
<tr>
<td>• I was originally assigned to the Science Stream but requested a transfer because I felt that the Technology Stream was more interesting.</td>
<td>1</td>
</tr>
<tr>
<td><strong>Prefer Hands-on or Interactive Learning</strong></td>
<td></td>
</tr>
<tr>
<td>• I’m more interested in applied sciences than theoretical sciences where you read and read. I prefer to work with my hands. I learn about what I’m doing and in the end I really produce something.</td>
<td>3</td>
</tr>
<tr>
<td><strong>Social</strong></td>
<td></td>
</tr>
<tr>
<td>• Most of my friends or the people I like chose to be in the Technology Stream too.</td>
<td>1</td>
</tr>
<tr>
<td>• Students become close-knit because we’re a smaller group [compared to the Science Stream].$^b$</td>
<td>1</td>
</tr>
<tr>
<td><strong>More Status/ Challenge</strong></td>
<td></td>
</tr>
<tr>
<td>• Other people say that the smarter students are in the Technology Stream... and I knew it would be harder to get into the Technology Stream. So it seemed more challenging for me... and I think that I belong to that group... and I should be in a group where people are smarter.</td>
<td>1</td>
</tr>
<tr>
<td>• At that time, there was this information technology hype.</td>
<td>1</td>
</tr>
<tr>
<td><strong>Disinterest with the Science Stream</strong></td>
<td></td>
</tr>
<tr>
<td>• They say that in Science you have to memorize a lot of information and I’m not good at memorization.</td>
<td>2</td>
</tr>
<tr>
<td>• I didn’t want the Science Stream because when I think of Science it’s like the teacher just lectures, it’s like [a] History [course].</td>
<td>1</td>
</tr>
<tr>
<td>• I didn’t like some of the courses offered under the Science Stream.</td>
<td>1</td>
</tr>
<tr>
<td>• There are already a lot of people in the Science Stream.$^b$</td>
<td>1</td>
</tr>
<tr>
<td><strong>Fun / Easier</strong></td>
<td></td>
</tr>
<tr>
<td>• It seemed more fun in the Tech Stream [than the Science Stream].</td>
<td>2</td>
</tr>
<tr>
<td>• The Technology Stream students from the older batches said that the Technology electives are easier than the Science electives.</td>
<td>1</td>
</tr>
<tr>
<td>• My father and older brothers are in Technology-related fields so I was thinking that they would be able to help me.</td>
<td>1</td>
</tr>
<tr>
<td><strong>Did not Choose</strong></td>
<td></td>
</tr>
<tr>
<td>• I didn’t choose to be in the Technology Stream, I was assigned.</td>
<td>2</td>
</tr>
<tr>
<td>• I actually chose to be in Science because they have more electives [to choose from] including Mathematics, but I was still assigned to the Technology Stream.</td>
<td>1</td>
</tr>
</tbody>
</table>

Note. $^aN=27$; Some student participants stated more than one reason for choosing the Technology over the Science Stream. $^b$In 2002, there were less 4th-year Technology class sections than Science sections.
the students in this group also said that taking courses under the Technology Strand would prepare them for the engineering degree they were planning to pursue in college.

In my second year, I requested the Registrar’s office to transfer me to Tech because I felt that it’s more interesting. I liked it. I was fascinated by what they were doing in Tech [Stream]. And another reason was that I was interested in going into an engineering course. (Ana, interview, March 5, 2002)

I really wanted Tech because I want to go into Civil or Computer Engineering. I was thinking that it would help to be in Tech because [learning about] internal circuits would give me an idea of how they work so I can use those ideas when I get to college. (Eric, interview, February 19, 2002)

Based on the students’ responses, the Technology Streaming program seemed to successfully attract students that wanted to prepare for technology-oriented careers.

**Pedagogical Preference**

Some students chose to be in the Technology Stream because they preferred the “learning style” they perceived was associated with the Technology Track (n=6) and/or were disinterested with the Science Stream (n=5). Students who cited a preference for the pedagogical strategy in the Technology Stream, said that they appreciated the hands-on, interactive and practical approach in the Technology courses. Rhodora’s comments exemplified this group’s sentiments:

I’m more interested in Tech, more on applied sciences than theoretical sciences where you read and read. I prefer to work with my hands, I get burned, or something but I learn about what I’m doing and in the end you really produce something (Rhodora, interview, March 7, 2002)

For this group of students, making something and learning from the experience of manual work were more interesting and rewarding than reading or listening to a lecture about science.

Academic-wise [the Tech Stream] seems more interesting. You just don’t learn about new things, but you make things. (Steve, interview, February 13, 2002)

I just like doing something with my hands and thinking about things. (Richelle,
The comments of Rhodora, Steve and Richelle remind us that not only do students have distinct learning styles but that they value different aspects of the learning process. Some students prefer the interactive learning process because of the hands-on approach, while others find value in the resulting product as well.

Three of the hands-on learners in this group also stated that they associated Science courses with memorization and lecture-based teaching, which they did not like or they were not good at.

What I heard before was that in Science [Stream] you have to memorize a lot of information. I'm not good at memorization. And with Tech [Stream] it's more hands-on and I can see the results of what I'm doing. Whereas, with Science it's more theoretical only. So for example, the [Science] research projects aren't appealing [to me]. (Noel, interview, February 13, 2002)

I chose to be in the Tech Stream, yes, because then I already knew that I didn't want [to be studying] species, memorizing things. Because Bio and Chem, specifically, had much memorization to do. I didn't want to do a lot of memorization. So I chose to go for Tech Stream. (Aaron, interview, March 4, 2002)

The views of Noel and Aaron are interesting in light of the fact that the Technology-enriched Science Curriculum at PSHS was also designed to include practical, technology-based activities and lessons into the traditional science courses. These students' comments suggest either that the science courses they had experienced continued to emphasize factual knowledge despite the mandate to include hands-on, technology topics, or that students perceived that memorization was valued in the Science Stream courses.

I chose Tech [Stream] because I heard that all they do are projects. I like the sound of just doing projects because you have to do a lot of things. For me [being in the] Science [Stream] is like the teacher just instructing you, it's like [someone teaching about] History whereas in Tech, it's more interactive. (Anthony, interview, March 14, 2002)

The views of the three students support the claims of some government and education leaders
that didactic science teaching that continues to focus on factual recall may contribute to the learners’ image of science as difficult and boring.

**Socialization**

In choosing the Technology Track, another common reason that students \((n=5)\) cited was social in nature. Students said that they chose the Technology Stream to be with their friends, or to give in to peer pressure.

I would say that I was at least interested in technology and Tech Research, but knew that I wouldn’t pursue a career in it. I chose the Tech Stream because Tech students become a close-knit group because we’re a smaller group - and because most of my friends chose the Tech Stream too. (Christina, interview, March 1, 2002)

I actually did not want to be in the Tech Stream. I wanted to be in the Science Stream because I wanted to take up the Food Science elective. But my friends said that they wanted us to be together in one section, so we all chose Tech [Stream]. We were six in the group who were classmates in the first year. Then two of us who were the ones reluctant to go into Tech, we’re the only two that were assigned to Tech Stream, the other four were assigned into Science. So it was kind of ironic. (Diana, interview, February 19, 2002)

It seemed that for this group of students, the socialization aspect of school was as important, (or was even more important in the case of Diana and her friend), as what they learned in the classroom. These students’ comments also refute the assumption inherent in the Streaming program since not all students choose to be in the Technology Stream because they are interested in pursuing a technical-oriented degree.

**Prestige and Challenge**

Some students chose the Technology Stream because it was their perception that it was more prestigious or challenging to be in the Technology Track \((n=5)\).

I chose to be in Tech [Stream] because they say that’s where the bright ones are. I guess it’s because I knew that it would be harder to get into Tech, so it seemed
more challenging for me. (Cherry, interview, March 1, 2002)

They say that those in Tech [Stream] are smarter. So I should be where people are smarter, right? (Trixie, interview, March 1, 2002)

The prestigious status associated with the Technology Stream may be attributed to the fact that a number of the top and brightest students normally ended up in the Technology Track. In 2002, 11 of the 14 honor students at the graduation ceremonies came from the Technology Stream. When I asked Juana about the real or perceived higher status linked to the Technology Stream, she stated that the DAT did seem to choose technically inclined students from the upper academic level, i.e., the "cream of the crop". However, the DAT does not ask whether a given student likes technology or the basic sciences. This was the reason why at some point in the implementation of the streaming program, the school administrators felt that it was important to include the student’s preference in the streaming criteria. Even with the inclusion of students’ preferences, the perceived higher status persisted, especially among the students. Cherry, one of the top 10 students in her graduating class, had this to say about being in the Technology section:

Students in Tech are more brilliant [compared to the Science students]. There are really a lot of smart people, especially in my class. It’s really amazing, so much so that I feel embarrassed if I don’t study because my classmates are really diligent. ... So naturally these people have an influence on me. It’s like you encourage one another to excel in class, academically speaking. (Cherry, interview, March 1, 2002)

While it is outside the scope of this study to inspect the differences in the stream preferences between genders, it is interesting to note that majority of the students who stated that they chose the Technology Stream either for its prestigious, challenging status, or for social reasons (see previous section), were girls. Being one among the few girls in the Technology Stream where a two-to-one ratio of boys-to-girls exists compared to a one-to-one ratio in the Science sections may have also contributed to this perceived higher degree of status for females.
chosen for the Technology Stream. The female students’ preference to enter the same stream as their friends is noteworthy. It might be possible to use this ‘social-interest goal’ as a recruitment strategy to encourage groups of girls to enroll together in technology-oriented school programs that typically attract more male students than females.

The ‘Easy’ Stream

A few students (n=2) stated that the Technology Stream courses seemed more appealing and ‘fun’ than the Science Track because of its hands-on gadgets and activities.

It seemed more fun in the Tech Stream because when we viewed the Science Fair exhibits during our first year, we had fun and got to appreciate more the techy stuff. (Maggie, interview, February 26, 2002)

I chose the Tech Stream because of my friends from Batch 99 who recommended it - because they said that it’s more fun. (Christina, interview, March 1, 2002)

These students’ comments support the observation of Layton (1993b) that historically, the introduction of practical, technology-oriented topics into science programs was prompted by the perceived need to make science learning exciting and interesting for the students.

Another reason one student cited for choosing the Technology Stream was the perception that it was “easier” than the Science Stream. As Roland explained:

I asked some Batch 99 alumni which one was better. They said that it would be easier if I took up Tech [Stream] because the Tech electives are easier [than the Science Stream electives]. (Roland, interview, March 19, 2002)

Interestingly, Roland’s perspective appears contradictory to the comments of Cherry and Trixie in the previous section. Although Roland did not elaborate on why he believed that the Technology electives were easier, anecdotal data from the students indicate that some teachers in the Science electives had a reputation of being more rigorous in their testing and grade requirements than their counterparts in the Technology Stream (Juana, interview, April 3,
Another student based his decision on the fact that his father and older brothers had a technical background and thus could assist him in the technology courses. It was unclear if this person chose the Technology Stream because he thought that it would be easier since he had his family's expertise to support him or because his family background influenced him. Familial influence also plays a role in some of the students' future career plans, as discussed in the next section.

**Students' Career Goals**

To examine the goals of the Science and Technology Streaming and the STR programs, vis-à-vis the students' future educational and occupational plans, I asked the students during our interview sessions whether the Technology Research course had any influence on their future university and career choices. Except for a few students (n=3) who were still undecided at the time of the study, most students had a general sense of their intended career goals after college. The majority of the student-participants stated that their interest in pursuing science or technology-related courses and careers was not positively or negatively affected by the activities that they engaged with in the course. Most of the participants claimed that their future university course and career interests were established prior to their enrollment in Technology Research. Fifteen (56%) and twelve (44%) students planned to enroll in technology and non-technology-related college programs, respectively, regardless of their experiences in the TR2 course (see Table 5). The 15 students choosing technology-related degree programs envisioned having future jobs dealing with engineering (n=7), computers (n=3), business or management (n=3), or industry (n=1). Among the 12 students planning to enter science or mathematics-related university programs, some aspired to pursue a career in medicine (n=6), actuary (n=2), business (n=1), or research (n=1). These data indicate that while students
were attracted and motivated to enroll in the Technology Stream, not all of them envisioned working in engineering or technical fields in the future.

**Determiners of Student Career-Decision Making**

Students identified a variety of factors or issues that influenced their planning for their post-secondary education and future careers. These included: personal interest (n=20); familial influence (e.g., professions of parents or older siblings, advice from family members, n=9); employment opportunities (n=4); future financial rewards (i.e., high-paying jobs, n=4); academic aptitude (n=3); prestigious career status (n=2); and service to society (n=1). The student responses support career decision-making theories and studies that suggest that career goals and decisions are not solely influenced by interest or aptitude, but also by other confounding factors such as the student personality, school curriculum, socio-economic status, and social cognition or belief systems (Arulmani, van Laar & Easton, 2003; Lent, Brown & Hackett, 1994; Woolnough & Guo, 1997). Social cognitive influences that come from the perception of self, parental values and attitudes, and socio-cultural beliefs may interact to shape students’ strongly held views about career options (Arulmani, et al., 2003; Lankard, 1995). For example, some studies suggest that socio-economic status affects a student’s self-esteem, which in turn may influence his or her perceived efficacy to pursue further education and a high-status job (e.g., Arulmani, et al., 2003; Rojewski & Kim, 2003). Research studies across cultural groups have shown that parental influence (e.g., socio-economic background, values and attitudes, degree of involvement, expectations) is one of the most significant determinants of young people’s educational and occupational aspirations (see e.g., Garg, Kauppi, Lewko & Urajnik, 2002; Lankard, 1995; Lightbody, Nicholson, Siann, & Walsh, 1997, Tang, 2002). Cultural background also exerts an influence on the development of the youth’s career-related
Table 5. Undergraduate Degree Programs in the University of the Philippines Taken by PSHS 2002 Graduates

<table>
<thead>
<tr>
<th>UNDERGRADUATE DEGREE PROGRAM TAKEN</th>
<th>PERCENTAGE OF STUDENTS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Research Study Participants</td>
<td>Technology Stream</td>
</tr>
<tr>
<td>Engineering degree programs&lt;sup&gt;a&lt;/sup&gt;</td>
<td>56%</td>
<td>65%</td>
</tr>
<tr>
<td>Science/ Mathematics degree programs&lt;sup&gt;b&lt;/sup&gt;</td>
<td>44%</td>
<td>35%</td>
</tr>
<tr>
<td>Others</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

<sup>a</sup>Engineering or Technology-related Programs
- B.S. Computer Science
- B.S. Computer Engineering
- B.S. Chemical Engineering
- B.S. Electronics & Communication Engineering
- B.S. Industrial Engineering
- B.S. Civil Engineering
- B.S. Electrical Engineering
- B.S. Materials Engineering
- B.S. Mechanical Engineering
- B.S. Metallurgical Engineering

<sup>b</sup>Science or Mathematics-related Programs
- B.S. Biology
- B.S. Molecular Biology & Biotechnology
- B.S. Mathematics
- B.S. Chemistry
- B.S. Biochemistry
- B.S. Applied Physics
- B.S. Geology
- B.S. Industrial Pharmacy

Others
- Non-quota programs<sup>c</sup>
- B.S. Business Administration & Accountancy
- B.S. Clothing Technology

Note. <sup>c</sup>Admission to non-quota programs at this University is less competitive compared to the other programs in this Table, i.e. a non-quota program has more available slots than applicants.
beliefs and decisions (Arulmani, et al., 2003; Lightbody, et al., 1997; Tang, 2002).

Student responses in this case study confirm the aforementioned research findings.

Filipinos, who tend to seek the opinion of their parents and older family members on important life decisions, value these elders’ views on what careers to pursue. The career decision-making experiences of Raul and Frank exemplify this Filipino practice:

Actually my dad is an English teacher and my mom is an assistant principal in preschool. Before, what I really wanted was to teach. Even if I take up MBB (Molecular Biology & Biotechnology), I really plan to teach. I spent three summers teaching kids at the preschool. And every summer for the past two years, I’ve been part of this youth club that holds summer tutorial [classes] where some of us from PSHS teach other high school students. I really want to teach but my parents have discouraged me from teaching... first, because they say there’s no money in teaching. They said, “We’re already teachers, so why would you want to be a teacher too?” But they also said, “It’s fine. If you want to teach, [then] teach, but get a second field [of study].” Ever since I was younger I also thought of becoming a doctor, so I am still deciding about my future. (Raul enrolled in the Intarmed program, which is a competitive, 7-year, Integrated Arts and Medicine degree course, at a Philippine university.) (Raul, interview, February 21, 2002)

I’m planning to take up MIS (Management Information System) because I’m interested in the subject – it’s about databases. Then my dad’s very supportive of the [degree] course because he’s [working] in a [telecommunications] corporation. Although people are saying that [the program] teaches common knowledge, my dad says otherwise. He says it’s the next thing after finance, production, human resources – IT’s the next thing according to him. He’s so supportive and so it makes me feel better [choosing this degree program]. (Frank, interview, March 7, 2002)

Research studies show that the practice of seeking parental approval or acceding to familial expectations regarding one’s chosen career is more prevalent in Asian cultural communities than in Western society (Lankard, 1995; Tang, 2002; Tang, Frouad, & Smith, 1999). As can be gleaned from Frank’s comments, the family and cultural community also exert influence on the youth’s perception of what constitutes a “good course” or a “good job.” In my research study, engineering and pre-medicine degree courses were the most popular choices and were considered prestigious among the students.
I want to take up MBB as a pre-med course. ... because, first, it’s biotechnology and I want to choose something related to technology. And they say that it’s [a] prestigious [program] in UP (University of the Philippines), so of course, you must aim for the best. So I’ll try to see if I can make it. (Rhodora, interview, March 7, 2002)

I plan to take up Chemical Engineering because I enjoy Math and the idea of being in engineering makes me happy. Then when I graduate, I’ll have the title of ‘Engineer’ to my name. (Maggie, interview, February 26, 2002)

Maggie’s comments highlight the Filipino traditional practice of using appropriate titles when addressing people in authority or of a higher status (see Chapter 4). Even in informal conversations, Filipinos append a title (e.g., “Doctor”, “Engineer”, “Professor”, or “Attorney”) to a person’s name to convey respect for the person deemed to be of a higher educational, professional or social status. The pride Maggie attributes to being called “Engineer” indicates how young people have been acculturated to the community’s social norms and beliefs on what are regarded as respectable occupations. The responses of students like Rhodora and Maggie also support research that indicates that among Asian students, career preferences are limited to a few types of occupations (e.g., Tang, et al., 1999). For example, South Asian students tend to choose careers that their parents or cultural community regard as respectable and prestigious such as medicine and law (Lightbody, et al., 1997). Tang and co-researchers (Tang 2002; Tang, et al., 1999) observe that Southeast Asian students choose to shy away from occupations of a social nature and to pursue what the researchers classify as “investigative” types of careers such as that of an engineer, medical doctor or computer scientist. The majority of students in this research study (and in the whole PSHS sampling population as discussed in the next section) selected these same three academic tracks among their top choices. Tang and co-researchers (Tang, et al., 1999) suggest that these types of occupations might be stereotypical of the Asian ethno-cultural groups because of familial encouragement to pursue these careers or of successful role modeling by older members of the community. Filipino parents are urging their
children towards occupations seen to be financially rewarding.

It is important to note that for the twelve TR2 students in the study who indicated that they do not intend to take up a technology-related degree course, many of them also did not consider scientific research as a career option. Only one of the 12 students indicated her interest in becoming a research scientist. The reason for this appears to be complex. A career in science encompasses a range of activities, some of which are seen to be more prestigious than others. For example, medicine would be seen as a high status and attractive “science career”. However, a position as a scientific researcher would be respectable but less attractive because of the more limited financial rewards associated with the profession. Nebres and Intal (1998) note that in the Philippines, working as a scientist is not necessarily valued by society as evidenced by both the low civil service status and salary scale associated with the position.

Students also think that doing science research in the Philippines is difficult and limited in scope because of the perceived lack of government support in terms of research equipment and facilities. As Ana notes:

Here in the Philippines, it’s hard to do research. If you [plan to do research] work on something that’s complicated and hi-tech, those things don’t seem to have an impact. Because the equipment we need for research itself, we don’t have them. [Still] it depends on your project. Like for some researches, if you use chitosan beads or rice for example, those are available. But the real [research] equipment, they are not available. (Ana, interview, March 5, 2002)\(^41\)

Jomari, who was choosing from among four career path options, was considering becoming a researcher but had this to say about the status of doing science research in the Philippines:

One option for me is to go into research, possibly biotechnology or biochemical engineering. But I applied [for undergraduate studies] in the U.S. because I’m thinking that here in the Philippines biotechnology is not well developed. Biotechnology here is more agricultural. I’m thinking that if I go to the States, the knowledge base and the facilities are okay. ... Whereas here in the Philippines, our resources are so limited... it’s useless. (Jomari, interview, March 1, 2002)\(^41\)

\(^41\) Ana decided to pursue an engineering degree in Singapore, while Jomari is enrolled in a biology degree program in a U.S. university.
It is evident from the foregoing analyses that complexity underpins students’ career decisions that go beyond the influence of participating in a program such as the Technology Research Curriculum. The views of students in this study indicate that personal, parental, socio-economic, and ethno-cultural factors are influential mediators of students’ future vocational options and decisions. My findings strongly suggest that career direction interventions like the STR and the Streaming programs that seek to develop the student’s academic interest and aptitude alone are not enough. To be effective, these programs must also address the other factors that impinge on students’ career choices and plans.

**Student Career Options and the Merits of Science-Technology Streaming**

To obtain a complete understanding of the issues associated with having the streamed program in the school, I examined the university degree courses chosen by all students in the different components of the program: the TR2 student-participants, the Technology Stream, the Science Stream and the entire Batch 2002 cohort. Table 5 presents a comparison of these groups of students and their university degree choices (see Appendix D for students’ degree choices by gender). The table illustrates that 65% of the Technology Stream students chose either an engineering or a computer science degree program, and 35% opted for either a science or a mathematics college program. Among the Science Stream students, the enrollment ratio in these technology and non-technology-related degree programs were 47% and 53%, respectively. Examining the data for the entire Batch 2002 cohort (i.e., regardless of what Stream they came from), a little over half of the students (54%) decided to enlist in either engineering or computer science, while 45% were in non-engineering programs. A quick comparison of these percentages suggests that the program may have moved students to enroll in the “desired” university degrees. A closer inspection of the specific degree courses chosen
by students shows that the “effectiveness” of the program is not as clear-cut (see Table 6). For example, among all students from the Technology sections, 17% chose Computer Engineering, 16% Computer Science and 12% Molecular Biology & Biotechnology. In the Science Stream, the most preferred university degree programs were Biology (21%), Mathematics, Chemical Engineering (at 12% each) and Computer Science (9%). These data, in conjunction with the students’ claims made earlier concerning what determined their career choices, suggest that tracking the students into either the Science or the Technology Stream did not necessarily encourage them to pursue degree courses corresponding to their chosen (or assigned) Stream. Although Table 5 shows that the proportion of students choosing to enter either engineering or technology-related degree programs is higher in the Technology Stream (65%) than in the Science Stream (47%), one can argue that the percentage difference is not high enough to warrant a separate Streaming Program.

However, students’ positive experiences with and views on the Technology Research course lend support to the continuance of the TR Program. Although the TR program is not influential in students’ career decisions, it is a rich environment for learning both technology and science that has valuable learning outcomes. This program that provides students with science and technology knowledge, as well as work-related skills in problem-solving, leadership, communication, teamwork and collaboration can enhance the learning experience of all students.

As business and corporate firms provide feedback to universities and schools regarding their expectations of scientific and technological skilled workers (see Berryman, 1993; Coles, 1998; Lynch, 1993), educators are called upon to bridge the gap between school and work (Hurd, 1997, 1998). Industry and education leaders highlight the need to graduate students who
Table 6. Top 5 Undergraduate Degree Programs in the University of the Philippines that Students Chose to Enrol in

<table>
<thead>
<tr>
<th>Technology Stream Students</th>
<th>Science Stream Students</th>
<th>All Students in the Batch 2002 Cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree Programs</td>
<td>% of Students</td>
<td>Degree Programs</td>
</tr>
<tr>
<td>B.S. Computer Engineering</td>
<td>17</td>
<td>B.S. Biology</td>
</tr>
<tr>
<td>B.S. Computer Science</td>
<td>16</td>
<td>B.S. Mathematics</td>
</tr>
<tr>
<td>B.S. Molecular Biology &amp;</td>
<td>12</td>
<td>B.S. Chemical Engineering</td>
</tr>
<tr>
<td>Biotechnology</td>
<td></td>
<td>B.S. Computer Science</td>
</tr>
<tr>
<td>B.S. Biology</td>
<td>11</td>
<td>B.S. Computer Science</td>
</tr>
<tr>
<td>B.S. Chemical Engineering</td>
<td>10</td>
<td>B.S. Industrial Engineering</td>
</tr>
</tbody>
</table>
are not only scientifically and technologically literate, but who are also equipped with thinking,
learning, social and occupational skills that will make them both critical thinking workers and
leaders in their future workplace (e.g., Carnavale, 1992; Gaskell, 2001; Hurd, 1998; Kincheloe,
1995; 1999, c1995). The Technology Research program is a rich learning environment that
starts to address this need through the integration of the academic and the occupational goals of
education. Students' engagements with their technology research projects help to nurture their
scientific expertise and technological know-how and to encourage student interest in science
and technology careers. In addition, the Technology Research program provides opportunities
for the students' personal and social development, learners who can use their knowledge for
their individual empowerment and for the betterment of society.
CHAPTER SIX
SUMMARY, CONCLUSIONS, AND FUTURE RESEARCH

My research characterized the nature of Technology Research Curriculum as defined in a Filipino setting. I examined the historical, political and social contexts underpinning the design and implementation of the Curriculum in a Philippine secondary school. The study explored the pedagogical practices of teachers and students in a Technology Research Program at the Philippine Science High School in order to determine how those practices facilitated or impeded student learning in science and technology. Students’ narratives of their Technology Research experiences revealed that the TR program enhanced students’ understanding of science and technology, and helped them develop lifelong learning and higher-level cognitive skills. The Curriculum appeared to support students’ interests in pursuing technology-based academic degrees and careers. The student responses further indicated that culture played a mediating role in student-teacher interactions and in students’ future career decisions.

In this chapter I present a summary of the study findings by returning to the research questions that guided the inquiry:

1. What is the nature of a Technology Research Curriculum as defined in a Filipino context?

2. What are Filipino students' experiences with and views on Technology Research pedagogy?

3. How does participation in a technology-enriched science curriculum influence Filipino students’ interest in science and technology-oriented careers?

I conclude the chapter with a discussion of the implications of my research findings and an outline of recommendations for future research.
Research Question 1: What is the nature of a Technology Research Curriculum as defined in a Filipino context?

I examined curriculum documents and interviewed school administrators and teachers to explore the assumptions behind the introduction of a Technology Research Curriculum introduced into the Filipino school system. To gain a situated understanding of how Technology Research Curriculum was enacted in the classroom, I observed students' and teachers' pedagogical practices in a technology research course in PSHS.

Analyses of the social, political and historical underpinnings of the Technology Research Curriculum revealed that since the 1960s, Filipino government and education leaders have consistently advocated for the development of specialized educational programs to support and advance students with high aptitude and interest in science and technology. These leaders believe that Philippine economic growth and industrialization can be accelerated if more Filipino youth are encouraged and supported to pursue careers as scientists and technologists. Investing extensive government resources and funds in these programs, Filipino education leaders promoted the implementation of science and technology curricula patterned after Western models. An example of such an initiative is the Technology-Enriched Science Curriculum and the Science/ Technology Research (STR) Program developed at PSHS. Through the Technology Research component of the STR Program, teachers engaged students in technological design research projects that offer practical solutions to real-world problems. Participation in the Technology Research Program was intended to motivate students to enter technology-related careers.

This case study of a PSHS Technology Research Curriculum showed that learning took place in three distinct environments: small group work sessions, student-teacher
interactions, and Science and Technology Fair activities. Data revealed that these three environments served as rich learning spaces where students developed a deeper understanding of the principles of technological design, scientific inquiry, and research; and participated in work similar to that of technologists and of scientists.

Technology Research students chose their preferred academic stream and project topic. Students established their own research project timeline, designed technological tools and procedures, and conducted scientific experiments as they sought a solution to an authentic problem. Through small group work sessions and teacher consultations, students developed a deeper understanding of science and technology concepts and skills. The open structures of these sessions fostered the development of collaboration and leadership skills. The Science and Technology Fair activities created a space for students to showcase and communicate their research findings to the public through discussions with the PSHS community, and the teachers and students from other schools.

The Filipino Technology Research Curriculum as practiced in the PSHS classroom setting was characterized by a combination of technological design and scientific inquiry activities, and by non-traditional pedagogical practices.

Students engaged in technological design. Working in collaborative teams, PSHS students enrolled in the Technology Research course investigated authentic problems whose solutions required the design of new technologies. The design-and-construct practices that they engaged in involved a series of iterative tasks. Students collected background information about the problem; identified materials needed for the project; designed mental and physical models of the artifact; presented and critiqued designs; and constructed, assessed and refined their devices. Through their participation in these research activities, students acquired
firsthand experience with engineering practices and learned technological design principles that included product efficiency, design constraints, and artifact trade-offs (ITEA, 2000).

Students participated in scientific inquiry. Scientific inquiry was an inherent part of the technological research process. Some Technology Research student teams designed and conducted scientific investigations as they sought answers to their real world problems. Students performed experiments; tested variables; engaged in trial-and-error activities; tested research hypotheses; measured, collected, and analyzed research data; drew conclusions; and presented research findings. In the process of applying this “scientific inquiry” (National Research Council, 2000) or investigative approach, students learned scientific concepts and developed expertise in conducting laboratory procedures.

Teachers and students adopted alternative pedagogical practices. Technology Research teachers used non-traditional instructional approaches that facilitated students’ learning of design and inquiry principles and skills. The teachers provided students with freedom and flexibility in the program. Students selected their research topics, created their own design for technology devices and science experiments, and established their own project timelines. The teachers reduced time spent on direct instruction and lectures, and devoted more time to providing guidance and direction to the students as needed. This reduction in didactic practices and increase in student-centered teaching strategies prompted students to explore new roles in the learning environment. Students adopted active roles in their learning as they sought answers to their own questions, solved research-related problems, and collaborated with their peers.

The Technology Research Program provided an integrated learning environment where blending of technological design and scientific inquiry was evident. In the PSHS context of
this study, Technology Research learning exhibited elements of technological design and scientific inquiry learning approaches. Students completed their projects by mentally and manually engaging in the research processes of investigating, discovering, inventing, testing, data-gathering, analyzing, problem-solving, critiquing and collaborating. These research elements are inherent in both technological design and inquiry learning. Although teachers encouraged students to undertake "technology research", it was difficult to identify projects that were purely technology-based. In the final analysis, the label applied to the project was irrelevant since the science and the technology goals in the projects were so closely aligned that the boundaries between scientific inquiry and technological design learning blur in the Technology Research classrooms. The blending of the two learning practices was significant as it promoted a richer environment for students to learn principles and skills in both science and technology.

Research Question 2: What are Filipino students’ experiences with and views on the Technology Research pedagogy?

Student interview responses revealed that the hands-on, project-based Technology Research program was a powerful, practical learning environment that students found valuable and interesting.

Students believed that the Technology Research Program enhanced their understanding of scientific and technological concepts and skills. Students recognized that in the process of inventing technological devices and conducting scientific investigations, they learned science and technology concepts and practical applications of these concepts. Students also noted that they gained a richer understanding of the interconnectedness between science and technology.
Students recognized that the Technology Research Program helped them integrate and apply the knowledge and skills they learned from their science and other school subjects. The students valued the holistic, interdisciplinary and practical orientation of the course, which made science and technology learning more relevant and interesting. Through active participation in their team projects, students discovered that school-based knowledge had applications in the real world outside the classroom.

Students found that their involvement in technology research encouraged them to become creative and critical thinkers and problem-solvers. Students engaged in investigative research activities where they identified and solved a problem, designed a science experiment or a technological device, conducted an experiment, constructed a gadget, collected and analyzed data, and critiqued projects. Students claimed that these activities enhanced their creative thinking and problem-solving skills.

Students acknowledged that the Technology Research activities helped them develop independent learning strategies, and promoted group collaborations, as well as communication, social, and leadership skills. Students found that the research project activities prompted them to learn independently, work collaboratively with peers, balance group roles and responsibilities, assume team leadership, improve social skills, and develop oral and written communication competencies. These knowledge and skills equip students for lifelong learning.

Students observed that Technology Research teachers' use of alternative instructional strategies prompted them to adopt new learning practices and roles. The students noted that non-traditional, learner-centered teaching practices in the course helped promote autonomous learning and thinking. The teachers asked probing and clarifying questions to guide and
By seeking answers to their own questions and solutions to their research problems, students took a more active and self-directed role in their learning. Students also valued the collaborative learning that took place as they worked with their peers, the teacher and other scientists and technologists to complete their research projects.

Some students found it challenging to adjust to the non-traditional pedagogical practices in the Technology Research classroom. A small group of students expressed the opinion that the Technology Research program was ineffective because the teacher was “not teaching” and providing the information that they needed to complete their projects. These students preferred a more passive approach to learning that is typical in the Filipino classroom, where the teacher is viewed as the authority and purveyor of knowledge. These students were unwilling to explore alternative learning approaches or adopt the new roles and responsibilities required in the Technology Research Program.

Research Question 3: How does participation in a technology-enriched science curriculum influence Filipino students’ interest in science and technology-oriented careers?

An examination of students’ reasons for choosing the Technology over the Science Stream in the PSHS technology-enriched curriculum indicates that they did not select the Technology Stream based solely on their academic interest or aptitude. A variety of personal, familial, pedagogical and socio-cultural factors influenced students’ academic stream preference. Students’ educational and occupational preferences also reveal that family and Filipino cultural norms play a major role in influencing students’ career decision-making.

Most Technology Research students interviewed in this study stated that they had decided on their educational and occupational goals prior to entering the Technology Research and the Science/Technology Streaming Programs. These students felt that the Technology
Research and Streaming programs supported their interest (or disinterest) to pursue science and technology-related courses and careers but it did not influence their prior decisions. Other than academic interest, students also cited aptitude, socio-cultural factors, and economic issues as bases for their career decisions.

Overall, the total number of Technology Stream students pursuing engineering or technical degree programs was slightly higher than the number enrolling in non-technology-related degree courses. These findings indicate that despite the views held by students, the Streaming Program may have been successful in encouraging some Technology students’ career decisions.

**Implications of the Research Study Findings**

Findings from this research study have important implications for school-based programs that attempt to integrate science with technology education or academic-vocational learning. The study also has significant implications for science reform initiatives undertaken to address cultural diversity in Western classrooms, and for school or government intervention programs that aim to influence student career goals.

In this study, regardless of the type of research project conducted, students gained expertise in both scientific and technological knowledge and skills, and in the practices of scientists and engineers. This suggests that in the context of this study, science and technology were so closely linked that the distinctions between the two disciplines blur. The study findings imply that there is a need to re-examine educators’ definitions of technology and science. It may no longer be useful to distinguish between technology as “doing” and science as “understanding” (Cajas, 2001). Similarly, notions of technology and science as hand vs. head (Layton, 1984), or as design vs. inquiry learning (Layton, 1993b) need to be revisited. This study also suggests that streaming students into technology or science specializations may
diminish the richness and value of learning and experiencing firsthand the interactions between science, technology and society.

This research study illustrated that integration of science education and technology studies can create a powerful environment that combines educational goals of academic learning and vocational preparation, scientific and technological literacy, and development of lifelong learning and higher cognitive skills. My findings show that an integrated approach can enhance students’ appreciation for the relevance of classroom learning to the real world of home, community and society. Students’ participation in this technology-enriched science program was found to advance their understanding and interest in both science and technology. The Technology Research Program also helped to prepare students for their future roles in the workplace. Thus, this study supports and illustrates the validity of initiatives such as the PSHS Science/Technology Research Program\(^{42}\) that implement integrated science and technology curricula. Study findings about this reform initiative are particularly significant in the Philippines where the poor performance of science students in international assessment studies is a growing concern (Beasley, 1999; Ibe & Ogena, 1998).

The study revealed that students with a more traditional, teacher-dependent approach to learning found the Technology Research pedagogical practices difficult or challenging. This research finding suggests that substantial teacher scaffolding and guidance must accompany the introduction of inquiry or investigative research practices in science classrooms not only in Asian contexts, but also in Western, multicultural settings. The rules of engagement in an investigative research classroom should be made clear to all students and particularly to those coming from traditional, non-Western learning contexts where the teacher’s authoritarian role may impede students’ active involvement in research inquiry (see also Lee, 2002). There is a

\(^{42}\) The STR Program is not mandated by the national curriculum and not required for admission to universities. However, it is a requirement for graduation from PSHS and other regional science high schools.
need for the teacher to orient students to the non-conventional learning and teaching approaches they will experience in the process of doing research. The teacher can also provide more direct and obvious guidance and support at the onset of the research work, with a gradual handing over of control for the learning process to the students as they grow confident in their use of investigative research practices (Hawkey, 1993; Lee, 2002).

Another important finding in this study was that Streaming and the STR Programs supported, but did not necessarily influence, students’ career goals. This finding suggests that career direction interventions targeting interest and aptitude alone may be ineffective change agents unless these programs also explore other issues exerting influence on students’ academic and occupational goals. This study finding implies that there is a need for career counselors and vocational educators to identify and address the personal, familial, economic and socio-cultural issues and beliefs that mediate students’ career decision-making. For example, some parental and cultural biases could be critically examined through school and guidance programs that include the parents in the career decision-making process. Governments that call for an increased scientific and technical workforce to support a nation’s economic goals should examine and address socio-economic issues that discourage students from entering these professions. In the Philippines, this might mean encouraging interest in science and technology careers by supporting scientific knowledge, and the work of scientists and engineers through increased civil service status and pay benefits for these professions (Nebres & Intal, 1998). For example, government leaders could legislate for an increased budget to support education and research in science and technology, and equip science classrooms and research laboratories. Such government interventions might improve the quality of science and technology education and research in the Philippines, and support the science and technology career aspirations of the Filipino youth.
Recommendations for Further Research

This case study focused on defining Technology Research Curriculum based on the experiences and practices of two teachers and 27 students in a Filipino school for the gifted. Because this study was conducted in one specific learning environment, it would be important to conduct a similar research study with a different group of students developing technological design projects in another local setting. For example, a study on the Technology Research Program practices among students in other PSHS campuses may reveal similarities or differences in research findings. In a broader educational context, it would also be valuable to conduct more studies on the technological design learning approach in a variety of settings to explore whether the blurring of boundaries between “doing technology” and “doing science” also exists in these settings. Such studies would provide information on the generalizability of the findings from this case study.

Conducting a parallel study that examines the pedagogical practices and experiences of students and teachers in the Science Research component of the STR Program would also be valuable. A similar case study of the Science Research program may reveal whether Science Stream students develop narrower or similar views about science, technology and the research process in comparison to their Technology Stream counterparts. Findings from such a study have the potential to inform school administrators on the merits and/or challenges of the Streaming and the STR Programs. Data from this type of study can also contribute to the discussions around the benefits and disadvantages of merging technology and science curricula.

Another recommendation would be to conduct follow-up interviews with students graduating from both the Technology and the Science Streams to determine their reasons for choosing their academic courses and future careers. These interviews would provide a bigger database for understanding how the Streaming and the Research Programs mediate
students' career decisions. A follow-up study that monitors students' occupational goals after four or more years of university education could provide additional feedback on whether the STR- and Streaming-related experiences continue to support students' career interests beyond high school. Findings from these studies would yield valuable insights for the re/design of the Science/ Technology Streaming and the STR Programs. Such studies may also give further evidence (or refutation) for the validity of curriculum programs designed to target students' academic and professional choices.

Conclusions

This study of a Technology Research Curriculum reveals that Filipino students' active involvement in research design projects and experiments enhanced their learning and understanding of both scientific and technological knowledge and practices. The study provides evidence that despite its "technology" label, the curriculum espoused an integrated technology design and scientific inquiry-based learning approach as the boundaries between the two learning strategies blurred in the Technology Research classrooms. The integrated learning environment provided a rich space for students to acquire both scientific and technological literacy. This space also helped promote independent thinking and self-directed learning, developed team collaboration and leadership roles, and enhanced higher cognition among the students. The study also reveals that an investigative research learning approach coupled with non-traditional teaching practices can serve as powerful tools in encouraging Filipino students to move away from their passive roles as learners. This study further indicates that teacher scaffolding and guidance during initial stages of an investigative research process can prompt students in traditional, didactic classrooms to assume a more active role in their learning.

This research study provides strong evidence that an academic-vocational, technology-enriched science program can be effectively designed to support students' interest to enter
technology-related careers and to prepare students to be critical thinking workers and leaders in their future workplaces.

**Final Comments**

This research study of a Technology Research Curriculum has prompted reflection and discussion of Philippine educational programs premised on Western models that have gone uninspected for years. The study provided a rich space for conversations with students, teachers and administrators about pedagogical practices, experiences, and roles in science-technology classrooms. This study also created opportunities for dialogue concerning gender-related issues in the classroom, alternative pedagogical practices, and the value and status of technology education. It is my hope that the findings and messages of this research project will serve as the foundation for future discussions on science and technology educational practices in the Philippines and elsewhere.
BIBLIOGRAPHY


190


Penick, J. (2002). Doing real science while integrating science and technology. Science


APPENDIX A

Interview Questions

A. Student Interview Questions

Part I. Personal Background & Career Goals
1. Please talk a little about yourself and your background.
2. What academic subjects are you most interested in? Why?
3. What academic subjects are you not very interested in? Why?
4. Please talk about what degree and course specialisation you plan to take up at the university.
5. What do you plan to do after you graduate from the university? Why?

Part II. Perceptions about the Technology Research Course
1. What are your general impressions about the course? What stands out for you?
2. What do you like about the Technology Research course?
3. What do you dislike about the Technology Research course?
4. Was this an easy or a difficult course for you? Why?
5. Let’s discuss the different components of the course. What do you think is the purpose of doing the following and what are your thoughts about each of these components of the course?
   a) designing and constructing a technology project
   b) Science & Technology Fair poster presentation
   c) presenting an oral defence of the project
   d) the final examination
6. What have you learned from this course?
7. How would you compare this course to your other courses?
8. What can you comment about the teaching in this course?
9. Do you think that this is an important course? Why?
10. Is there anything that could be done in any of these course components that would help you learn better in this course? Why?
11. If you were allowed to choose, which course would you have taken: the science research or technology research course? Why?
12. Do you think that this should be a required course for all students? Explain.
13. What would you tell a friend who will be taking this course next year?

Part III. Perceptions about Technology Research
1. Let’s talk about your views about learning in science and technology:
   a) Do you think it is important to learn about technology research? Why?
   b) What about technology research should the informed citizen need to know?
   c) Do you think that this course achieves the goals you mention in a & b?
2. What do you think is the role of science & technology in the future?
3. Has your technology research project won in any regional, national or international Science & Technology Fair competitions? If yes, when and what award did you win? How did this winning affect you personally?
4. Has taking this course influenced your decision about what degree to take in college? Why?
5. Do you think that what you are learning in this course will be useful for you now or in the future?
6. Has taking this course changed your understanding and interest about technology research? Why and if yes, in what ways?

B. Teacher Interview Questions

Part I. Personal Background & Career Goals
1. Please talk a little about yourself and your background.
2. Please talk about what degree and course specialisation you took up at the university.
3. Why did you decide to teach?
4. What are your future career plans?

Part II. Perceptions about the Technology Research Course
1. What are your general impressions of the course to date?
2. What do you see as the goals of this course?
3. Do you think that this is an important course for the students? Why?
4. What do you want students to learn from taking this course?
5. Is the way you teach this course different from that in your other courses? Explain.
6. Do you think you’re qualified to teach this course?
7. How different is this course from the Science Research version (structure and organisation)? Why do you think this option was introduced into the program?
8. What do you see as the advantages of this course in terms of the preparation it provides for students?
9. What do you see as the disadvantage of this course in terms of the preparation it provides for students?
10. Do you think this course is equally suitable for male and female students?
11. Do you think that this should be a required course for all students?
12. What relationship do you see between this course and an education in science?
13. What changes, if any, would you make to this course?
APPENDIX B
A Comparison of PSHS and Other Types of Public High Schools in the Philippines

<table>
<thead>
<tr>
<th></th>
<th>Regular Public High Schools</th>
<th>Science &amp; Technology-Oriented High Schools</th>
<th>Regional Science High Schools</th>
<th>PSHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Schools</td>
<td>4,503^a</td>
<td>110</td>
<td>16</td>
<td>8 (as of 2004)</td>
</tr>
<tr>
<td>Level of Selection^b</td>
<td>open selection</td>
<td>school division</td>
<td>administrative region</td>
<td>Main campus: nationwide Other campuses: region</td>
</tr>
<tr>
<td>Year Established</td>
<td>Various</td>
<td>1994</td>
<td>1994</td>
<td>1964 – Main Campus 1988 – Establishment of other campuses began</td>
</tr>
<tr>
<td>Managed and Financed by</td>
<td>Department of Education</td>
<td>Department of Education^c</td>
<td>Department of Education^c</td>
<td>Department of Science and Technology (DOST)</td>
</tr>
<tr>
<td>Required Science Courses Offered</td>
<td>To all students</td>
<td>To 1 or 2 science sections only</td>
<td>To all students</td>
<td>To all students</td>
</tr>
<tr>
<td>First Year</td>
<td>General Science^d</td>
<td>General Science^d</td>
<td>General Science^d</td>
<td>Integrated Science^e</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Earth Science</td>
<td>Earth Science</td>
<td>Earth Science</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Computer Science I</td>
<td>Computer Science I</td>
</tr>
<tr>
<td>Second Year</td>
<td>Biology I^d</td>
<td>Biology I^d</td>
<td>Biology I^d</td>
<td>Biology I^f</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Computer Education I</td>
<td>Chemistry I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Research I</td>
<td>Physics I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Computer Science II</td>
</tr>
<tr>
<td>Third Year</td>
<td>Chemistry I^d</td>
<td>Biology II</td>
<td>Biology II</td>
<td>Biology II^g</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chemistry I^d</td>
<td>Chemistry I^d</td>
<td>Chemistry II^e</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Research I</td>
<td>Physics I</td>
<td>Physics II</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Research IA</td>
<td>Computer Science III</td>
</tr>
<tr>
<td>Fourth Year</td>
<td>Physics I^d</td>
<td>Chemistry II</td>
<td>Chemistry II</td>
<td>Biology III</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Physics I^d</td>
<td>Physics II^d</td>
<td>Chemistry III</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Research II</td>
<td>Physics III^e</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Computer Science IV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Research II</td>
</tr>
</tbody>
</table>

Note. ^aFrom the Basic Education Statistics for 2002-2003 (Department of Education, 2003). ^bScience high schools select students with science aptitude through a divisional, regional or national level examination. ^cInitial funding to establish the science sections or schools was provided by the DOST through a World Bank loan. ^dThese courses meet daily for 80-minute class periods; all other courses meet for 40-minute periods. ^eThese courses meet daily for 50-minute periods; all other courses meet for three, 50-minute periods a week. Modified from Mathematics and Science Education in the Philippines [Technical Background Paper No. 5] (p. 19), by A. Somerset, 1999, Manila, Philippines, Asian Development Bank.
### APPENDIX C

#### List of Student Participants and Their Technology Research Projects

<table>
<thead>
<tr>
<th>Group No.</th>
<th>Research Study Participants-Proponents</th>
<th>Title of Technology Research Project</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Section A (Teacher: Juana)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Aaron, Anthony</td>
<td>Pest Detector: Integrated Pest Management System</td>
</tr>
<tr>
<td>2</td>
<td>Raul</td>
<td>Design and Construction of the Controller Unit for the Muraclast, a Pneumatic Intracorporeal Lithotriptor</td>
</tr>
<tr>
<td>3</td>
<td>Diana</td>
<td>Design and Construction of a Mechanized Compost Bin that Maximizes Aerobic Decomposition</td>
</tr>
<tr>
<td>4</td>
<td>Roland</td>
<td>Robotic Minesweeper</td>
</tr>
<tr>
<td>5</td>
<td>Ana, Cherry</td>
<td>Contractile Polymer Gels Doped with Polypyrrole for Artificial Muscle Application</td>
</tr>
<tr>
<td>6</td>
<td>Rosario, Steve, Vanessa</td>
<td>Heavy Metal Remediation of Wastewater Through the Use of Chitosan Beads</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Video as Motion Programmer for Instructing Robot Easily (V.A.M.P.I.R.E.)</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>SMS Link: Secured Transmission of Data Through SMS</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>Chemical Hauling of Unstable Oils for Polystyrene Salvaging</td>
</tr>
<tr>
<td><strong>Section B (Teacher: Maria)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Jonathan, Trixie</td>
<td>The Design and Construction of Common Metal Gas Sensor Array</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Quality Assurance of Herbal Medicines Using Nuclear Magnetic Resonance</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Autonomous Robotic System with Collaborative / Unified Environmental Perception</td>
</tr>
<tr>
<td>4</td>
<td>Richelle</td>
<td>Small Scale De-fibering Machine</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>Decibels</td>
</tr>
<tr>
<td>6</td>
<td>Christina, Rhodora</td>
<td>The Influence of the Crystalline Structure and Molecular Properties of Abaca, Banana and Pineapple on their Textile Processing Performance</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Seatbelt Alarm System</td>
</tr>
<tr>
<td>8</td>
<td>Jomari</td>
<td>Automated 2 – D Styrofoam Cutter</td>
</tr>
<tr>
<td><strong>Section C (Teacher: Maria)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>John, Xander</td>
<td>The Production of a Coconut Oil-Based Biodiesel as an Alternative for Fossil Fuel</td>
</tr>
<tr>
<td>2</td>
<td>Elen, Isabel</td>
<td>Development of Gas Detecting Pellet</td>
</tr>
<tr>
<td>3</td>
<td>Frank</td>
<td>SWISH: An Alternative Locally Produced Target Shooting Paper</td>
</tr>
<tr>
<td>4</td>
<td>James, Eric</td>
<td>Drug Release Indication Through Elicitors</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>B-Cut: The Design and Implementation of an Effective Bulalo Cutter</td>
</tr>
<tr>
<td>6</td>
<td>Noel, Nikki</td>
<td>Robotag: The Implementation of a Robotic Kit with a Programming Environment that Combines Primitive Behavior to Perform Higher Level of Competence</td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>Musical Information Retrieval from a Music Database Through Human Humming</td>
</tr>
<tr>
<td>8</td>
<td>Maggie, Gail</td>
<td>The Production of an Amylase-Based Edible Film for Fruit Packaging</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>The Use of IR Technology for the Prevention of Mild Vehicular Collisions</td>
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</tbody>
</table>
## APPENDIX D
Undergraduate Degree Programs of PSHS 2002 Graduates (by Gender)

<table>
<thead>
<tr>
<th>UNDERGRADUATE DEGREE PROGRAM TAKEN</th>
<th>PERCENTAGE OF STUDENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Research Study Participants</td>
</tr>
<tr>
<td></td>
<td>Boys</td>
</tr>
<tr>
<td>Engineering degree programs&lt;sup&gt;a&lt;/sup&gt;</td>
<td>54%</td>
</tr>
<tr>
<td>Science/ Mathematics degree programs&lt;sup&gt;b&lt;/sup&gt;</td>
<td>46%</td>
</tr>
<tr>
<td>Others</td>
<td>0%</td>
</tr>
</tbody>
</table>

<sup>a</sup>Engineering or Technology-related Programs
- B.S. Computer Science
- B.S. Computer Engineering
- B.S. Chemical Engineering
- B.S. Electronics & Communication Engineering
- B.S. Industrial Engineering
- B.S. Civil Engineering
- B.S. Electrical Engineering
- B.S. Materials Engineering
- B.S. Mechanical Engineering
- B.S. Metallurgical Engineering

<sup>b</sup>Science or Mathematics-related Programs
- B.S. Biology
- B.S. Molecular Biology & Biotechnology
- B.S. Mathematics
- B.S. Chemistry
- B.S. Biochemistry
- B.S. Applied Physics
- B.S. Geology
- B.S. Industrial Pharmacy

Others
- Non-quota programs<sup>c</sup>
- B.S. Business Administration & Accountancy
- B.S. Clothing Technology

Note. <sup>c</sup>Admission to non-quota programs at this University is less competitive compared to the other programs in this Table, i.e. a non-quota program has more available slots than applicants.