STEM Standards-Based Reform Initiatives: The Impact on Student Learning and the Curricular, Instructional, and Assessment Practices of Teachers

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To Mikey

Abstract

National standards in science (NRC, 1996), mathematics (NCTM 1989, 2000), and technology (NETS, 2000) have informed the direction of reform efforts to guide curriculum development, improve the instructional practices of teachers and increase student learning. *STEM Standards-Based Reform Initiatives: The Impact on Student Learning and the Curricular, Instructional, and Assessment Practices of Teachers,* involves a series of three studies completed around the theme of science, technology, engineering, and mathematics (STEM) standards-based reform initiatives and the impact on teacher curricular and instructional practices and student learning. Study 1, *Block Scheduling and Mathematics: Enhancing Standards-Based Instruction* (Flynn, Lawrenz & Shultz, 2005), is a quantitative study investigating differences in eighth-grade mathematics students' engagement in standards-based curriculum and instruction practices between block- and traditional-schedule schools. Results indicate there are few differences in curriculum and instruction based on the type of school schedule. Study 2, *Building a Successful Middle School Outreach Effort: Microscopy Camp* (Penn, Flynn & Johnson, 2007), focuses on the development and implementation of curriculum and instruction based on national and state standards designed to assist middle school science learners in their understanding of the atomic structure of solid crystals and the design and use of an assessment tool to monitor student understanding of the topic. Qualitative results indicate improved post-camp understanding of students' understanding of the atomic structure of solid crystals. Study 3, *Integrating Technology into a Secondary Science Licensure Program: Modeling Students' Competencies to Use and Teach with Technology over the Course of the Program*, is a longitudinal study modeling secondary science student teachers changes in their technology competencies over the course of their program. Results indicate teachers self-reported competencies in skill to use and preparedness to teach with technology in their science classrooms increased. Barriers to technology integration due to physical resources, knowledge and skills, and school supports are reported. Collectively, the three studies inform future research and practice in the area of STEM standards-based reform initiatives by highlighting the impact of implementation efforts across multiple disciplines and settings. Researchers and practitioners may use the research design, curriculum framework, instructional practices, assessment techniques, and results and conclusions of these studies to advance their own research and practice.

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CHAPTER ONE

Introduction

STEM Standards-Based Reform Initiatives: The Impact on Student Learning and the Curricular, Instructional, and Assessment Practices of Teachers involves a series of three studies completed during the Ph.D. program at the University of Minnesota. The studies encompass the central theme of examining the impact of standards-based reform initiatives grounded in national reform documents and mathematics (NCTM, 1989, 2000) science (NRC, 1996; AAAS, 2001) and technology (NETS, 2000) standards examining teacher curricular, instructional, and assessment practices and student learning. The studies illustrate growth in the student's interests, methodologies, curriculum design, and interdisciplinary collaborations. Collectively, the three studies inform future research and practice in the area of STEM standards-based reform initiatives by highlighting the impact of implementation efforts across multiple disciplines and settings. Researchers and practitioners may use the research design, curriculum framework, instructional practices, assessment techniques, and results and conclusions of these studies to advance their own research and practice across STEM fields. The three studies presented are: Study 1, *Block Scheduling and Mathematics: Enhancing Standards-Based Instruction;* Study 2, *Building a Successful Middle School Outreach Effort: Microscopy Camp*; and Study 3, *Integrating Technology into a Secondary Science Licensure Program: Modeling Students' Competencies to Use and Teach with Technology over the Course of the Program*. Cumulatively, the three studies presented show how the student's research skills and degree of involvement in research studies has evolved over the course of graduate study as a result of the research experience and how the studies contribute to informing future research and practice in the field of STEM education reform.

Overview of the three studies

Study 1, Block Scheduling and Mathematics: Enhancing Standards-Based Instruction? National Association of Secondary School Principals, 89(642), Flynn, L., Lawrenz, F., & Schultz, M. (2005).

Study 1, *Block Scheduling and Mathematics: Enhancing Standards-Based Instruction?* (Flynn, Lawrenz, & Schultz, 2005) explored mathematics teacher engagement in national standards-based curriculum and instructional practices grounded in reform documents (NCTM, 1989, 2000; NSF, 1993, 1996; Newman, 1997) based on type of school schedule (block versus traditional). This quantitative study analyzed survey data from 156 middle level mathematics teachers and principals to access the use of curricular and instructional practices in classrooms. The research was conducted by the student while working as a Research Assistant in the Center for Applied Research and Educational Improvement (CAREI) at the University of Minnesota with her advisor, and Principal Investigator (PI), Dr. Frances Lawrenz, on a National Science Foundation State Systemic Initiatives (SSI) impact study during the first two years of graduate study.

Data for the study presented here were drawn from the larger quasi-experimental study looking at the impact of systemic reform efforts on student achievement (Lawrenz & Huffman, 2002). Prior to this study the student had no formal educational research experience. The student employed the existing SSI data set to answer the unique questions posed for this study. The central questions included, 1) *How does the level of teacher engagement in standards-based instructional practices vary between middle level mathematics classrooms in block and traditional schedule schools*, 2) *What is the pattern of use of whole class, individual and small group discussions in middle level mathematics classes between block and traditional schedule schools*, and 3) What is the level of engagement of middle level teachers in standards-based instructional practices? To answer these questions the student statistically analyzed survey data (SPSS, version 11) using a t-test and ANCOVA to compare engagement between block and traditional schedule schools and to create descriptive statistics. Additionally the student interpreted the data in light of the existing research literature and wrote up the results for publication.

Results of the study indicated there were few differences in curriculum and instruction practices based on type of school schedule. The findings of this study were significant because only a limited body of research existed at the time of publication on the impact of block scheduling on curriculum and instructional practices. Researchers in the field advocated for inclusion of more studies because results to date were limited, highly context specific, and somewhat inconclusive (Canady & Rettig, 2001; Queen, 2002; Evans, Tokarczyk, Rice & McCray, 2002). The majority of prior studies were comparisons between two schools, one with block scheduling and one without, or pre- and post-assessment data prior to and after a school implemented block scheduling. This study looked at a large number of mathematics teachers engagement with students in curriculum and instruction practices across several states and multiple classroom settings. The results presented here added to the growing body of knowledge of the impact of scheduling reform initiatives on teacher and student engagement in standards-based curricular and instructional methods (NCTM, 1989, 2000; NSF, 1993, 1996; Newman, 1997).

Throughout the study the student relied on the PI for direction and she also sought assistance from Mathew Shultz, a PhD student, who managed the complete SSI data set. The research led to two presentations by the student at national conferences (AERA, 2003; NARST, 2004) and a first author, peer-reviewed publication in the National Association of Secondary School Principals journal, *NAASP Bulletin* (Flynn, Lawrenz & Schultz, 2005).

Study 2, Building a Successful Middle School Outreach Effort: Microscopy Camp. Journal of Chemical Education, Vol. 84, No. 6., June, 2007. Penn, R.L., Flynn, L., & Johnson, P.

The second study, *Building a Successful Middle School Outreach Effort: Microscopy Camp,* focused on the development and delivery of standards-based curriculum and instruction designed to assist ten middle school science learners in their understanding of the atomic structure of solid matter and the development of an assessment tool to uncover their developing notions of the particulate nature of matter. Students are first formally introduced to notions of atomic structure in middle school (NRC, 1996; AAAS, 2001) and studies indicate students struggle with conceptually understanding the topic (Harrison & Treagust, 2002; Nakhleh, 1992). Students have limited opportunity to directly engage in activities or be exposed to technologies addressing the atomic structure of solid matter. With recent advances in the achievable resolution of electron microscopes, a direct method for demonstrating the atomic structure of solid crystals using High Resolution Transmission Electron Microscopes (HRTEM) and Scanning Electron Microscopes (SEM) is available. This study looks at the impact on students understanding of the atomic structure of solid particles by providing students direct experiences with the atomic structure of solid matter through activities and emerging technologies which may be directly implemented in the secondary science classroom. This study is unique as it is the first published study of students engaging with high transmission and scanning electron microscopy, a tool used commonly in research to characterize and visualize atomic structure but not utilized in the school curriculum. Visualizing atomic structure is conceptually difficult for children and this study hypothesized direct exposure to images and activities which were relevant to the student's lives would increase their understanding of the topic.

Microscopy Camp was designed to introduce current, scientifically acceptable concepts of the atomic structure of solid crystals and to develop activities which could be implemented into Minneapolis Public Schools middle school curriculum in alignment with national science, mathematics, and technology standards (NRC, 1996; NCTM, 2000; NETS, 2000). The student was contacted by the Minneapolis Public Schools science curriculum director after a curriculum scope and sequence analysis revealed students were not being provided effective opportunities to learn about atomic structure and the particulate nature of matter. The district was aware of the research on the conceptual difficulties students encounter and they reached out to University of Minnesota for some effective and creative curriculum. The research team created a two and a half week unit on the particulate nature of matter and delivered it to two pilot classes each receiving 12 hours of instruction at the University of Minnesota. In Microscopy Camp, the students' synthesized magnetite (Fe_3O_4) nanoparticles (which can be naturally found in playground sand), characterized the particles by visual inspection and light microscopy, and participated in the characterization of their particles using SEM and HRTEM microscopy. A pre-camp and post-camp qualitative open-ended assessment tool was developed by the Ph.D. student to gain insight into middle school students' developing concepts of the atomic structure of solid crystals.

Qualitative results indicate improved post-camp understanding of the atomic structure of solid matter. Students demonstrated an increased understanding of the macroscopic and microscopic properties of atomic structure of a solid crystal through a series of drawings and written and verbal descriptive explanations. The results indicate that, at this stage, students' concepts of the atomic structure of solid matter appear amenable to change from their pre-camp, personal theories. In other words, they seemed to accept, over the short, twelve hours of instruction during Microscopy Camp, a change in their view of atoms.

The success of Microscopy Camp depended upon the combined expertise of the chemist, science educator, and secondary science teachers and insights regarding establishing such a partnership and the design of the program are discussed. This study aligns with the current STEM focused standards-based reform initiatives where multidisciplinary partners drawn from multiple departments and institutions work together to solve complex problems. This study illustrates how one such partnership was formed and successfully proposed curriculum, instruction and an assessment tool for secondary science teachers to implement in their classrooms.

Microscopy Camp (http://www.chem.umn.edu/microscopycamp/), was co-created and directed by the student for implementation with two cohorts of twelve year old middle school students during the summer of 2005 and 2006. The interpretive, qualitative research was funded through two grants. For the first grant, the student acted as co-PI for the outreach component of a National Science Foundation grant, *From Particles to Atoms*, with Associate Professor, Dr. R. Lee Penn, in the Department of Chemistry at the University of Minnesota. The student served as the PI for the second grant, *Investigating* *the Particulate Nature of Matter and Atomic Structure*, offered through the MN Office of Higher Education. Professor Penn served as co-PI for this grant.

By the time Study 2 was being developed the student had completed all Ph.D. coursework, including multiple classes in both qualitative and quantitative research design and methodology. This coursework, along with the positive research experience from Study 1, provided the skills and confidence to undertake a leadership role in Study 2.

After conducting an extensive literature review of previous research on middle school students' notions of the particulate nature of matter and an analysis of the Minneapolis Public Schools middle school curriculum, a plan was developed for the implementation of Microscopy Camp and the research design. The student successfully: identified and recruited subjects; wrote the approved University of Minnesota and Minneapolis Public Schools IRB (Appendix A); developed research methodology; designed, pilot tested, and administered the assessment tool (Appendix B); coded and analyzed assessment data; developed and instructed activities aligned to national and state science, mathematics, and technology standards to match content area specialists presentations, and co-wrote findings for publication. In addition, the student trained the Co-PI and two graduate students in science education how to code the assessment in order to assess inter-rater reliability (Fleiss, 1971). Dr. Lee Penn's (Co-PI) responsibilities included recruiting additional STEM faculty to present, securing laboratory space, providing content instruction, directing chemistry graduate students in lab synthesis, and managing funds.

Study 2 was presented by the student at two peer-reviewed national conferences (ACS, 2007; NSTA, 2007) and the Gordon Chemical Education Research Conference (2011) where she was an invited, featured speaker. The research led to a second author peer-reviewed publication in the American Chemical Society's *Journal of Chemical Education* (Penn, Flynn & Johnson, 2007), and the curriculum is currently being implemented in Minneapolis middle school classrooms.

The student used this study as a framework for four successfully funded Minnesota Teacher Quality grants offered by the MN Office of Higher Education which provided approximately eighty Minneapolis and St. Paul teachers an opportunity to engage in Microscopy Camp across four years. As Principal Investigator, the student collaboratively worked with 16 professors across twelve interdisciplinary STEM departments at the University of Minnesota. The collaboration with STEM faculty was additionally expanded by collaborating with Hormel Foundation and Austin, MN Public Schools to offer a yearlong Microscopy Camp experience where teachers implemented the curriculum and research from this study into their classroom instruction and assessment practices.

Study 3, Integrating Technology into a Secondary Science Licensure Program: Modeling Student Teachers' Competencies to Use and Teach with Technology over the Course of the Program, Flynn, L. (2012).

The third study models thirty M.Ed. Science Initial Licensure student teachers developing competencies to use and teach with scientific and teaching technologies over nine months of a twelve month licensure program. The study was conducted concurrently as the UM Science Initial licensure program implemented recommendations from national technology educational standards (NETS, 2000) into their licensure program. This longitudinal study uses a Likert-type item survey and open-ended questions developed by the student to model developmental changes in student teachers ability to use and teach with technology. Central questions in this study include: *How do University of Minnesota M.Ed. secondary science initial licensure students self-reported competencies to use technology and preparedness to teach with technology change over the course of the licensure program?*, and *What barriers do University of Minnesota secondary science initial licensure students say they encounter as they attempt to incorporate technology into their student teaching experience*? Three waves of longitudinal data were collected over 9 months and were analyzed using growth curve models to assess student teachers technology competency for 22 technologies ranging from teaching (PowerPoint, concept map, efolio, Excel, etc.) to scientific (lab probes, computer simulations, computer adapted microscopes, etc.) technologies. Growth curve analysis using linear mixed models (LMM) showed significant increases in composite scores for both participants' self-reported skill to use ($p<.001$) and preparedness to teach ($P<.05$) with technology over the course of the program. In addition, technology implementation barriers decreased as skill to use and preparedness to teach with technology increased. Initial deficiencies and competencies reported at the start of the licensure program can help inform licensure programs which technologies to focus on throughout the program while deficiencies reported at the end of the program provide areas of needed curricular or instructional improvement in subsequent years.

The research was conducted by the student while serving as Co-PI with Science Education faculty Dr. Gillian Roehrig and Dr. Bhaskar Dahal on a Technology Enhanced Learning (TEL) grant (Flynn, Roehrig, Dahal, 2006) provided by the University of Minnesota Office of the Vice President. The student co-wrote the grant proposal and managed the equipment ordering and funds with Dr. Roehrig and Dr. Dahal. She was individually responsible for survey development (Appendix F), data collection, data entry, data analysis, instruction on use and implementation of technology and all writing presented here in Study 3. She expanded her quantitative analytic skills in this study by employing Linear Mixed Models; previous to this analysis longitudinal data was treated with repeated measures ANOVA (RMANOVA) when presenting preliminary data at an Association for Science Teacher Education conference in 2007. The student also developed her qualitative research skills by coding and analyzing student open-ended responses.

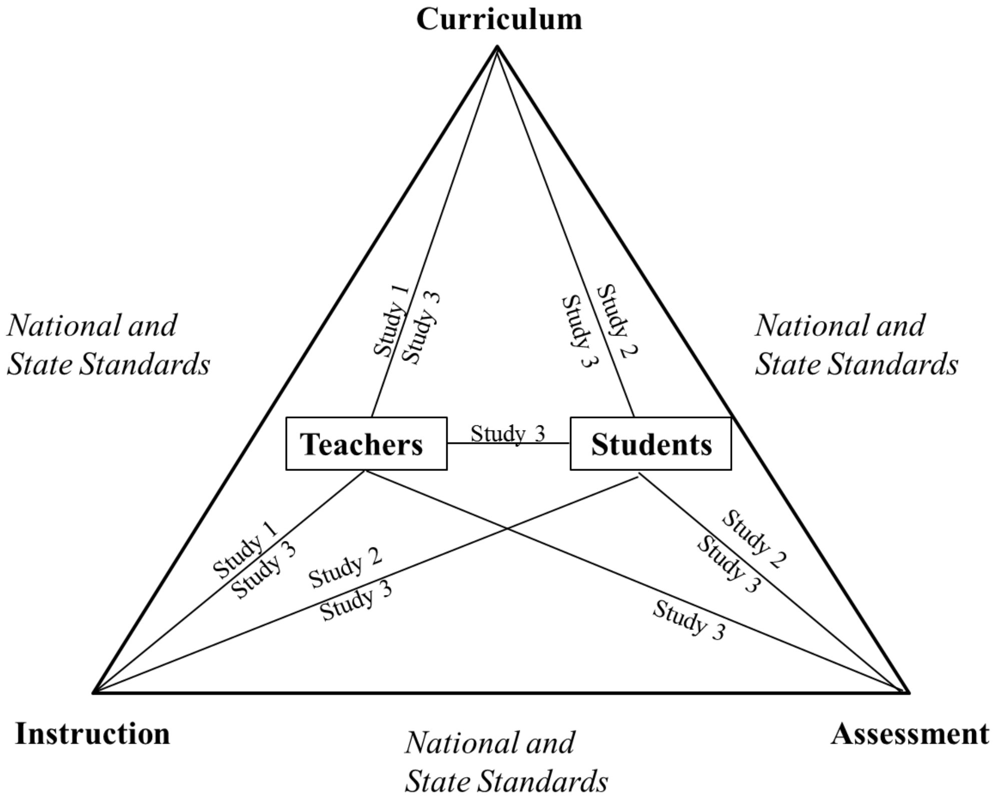
Study 3 was presented by the student at one international science education conference (ASTE, 2007), two University-wide technology presentations (DMC, 2006 & 2007), and the new technology, designed curriculum, and instructional practices were implemented into the M.Ed. science licensure courses at the University of Minnesota.

STEM standards as framework of three studies

The student is building a research and teaching agenda in Science, Technology, Engineering & Mathematics (STEM) education by researching and examining curricular, instructional and assessment design and implementation grounded in national and state education standards. The studies investigate reform initiative implementation and impact through teacher classroom-based instructional and curricular practice and the impact on student learning across disciplines. All three studies were developed under the framework of using national and state science, technology, and mathematics standards as a roadmap for reform.

Figure 1 illustrates the focus of and relationship between the three studies. All three studies are grounded in national and state STEM standards and investigate interactions with curriculum, instruction, and assessment of teachers and students. For example, Study 1 and Study 3 both examine teachers’ implementation of standards-based instruction. Study 1 looks at middle school mathematics teachers’ engagement in block vs. traditional schedule schools and Study 3 assesses pre-service teachers’ technology use and implementation in middle and high school classrooms. Studies 2 & 3 look at the impact of implementing standards-based curricular design on student learning. Study 2 accomplishes this by engaging middle school students in a summer science experience entitled Microscopy Camp and examining their development of the concept of atomic structure. Study 3 examines how engagement with technology-enhanced curriculum in a science licensure program impacts the student teachers ability to use and teach with technology in the secondary science classroom. Participants in this study are transitioning between a role as a student and teacher. In one sense they act as a student reporting on their skill to use a particular technology across the course of the program. In another sense, they are acting as a student teacher reporting how prepared they are, and what barriers they faced, while teaching with technology in their student teaching experiences.

Figure 1: Relationship of three studies to curricular, instructional and assessment reform engaging teachers and students.



The three studies selected here were chosen because they highlight research conducted on three separate standards-based reform initiatives and illustrate how the researchers translated STEM standards into curricular, instructional and assessment practices. As the research community becomes encouraged to solve complex problem in education by collaboratively working across disciplines researchers are looking to standards and studies addressing standards implementation for guidance. The presented reform-based initiatives used the standards as a framework for reform and their impact on student and teacher outcomes across the three areas of mathematics, science, and technology are presented.

The three studies also highlight the variety of research projects the student was engaged in across the course of the Ph.D. program, demonstrate her increasing competencies in both quantitative and qualitative methodologies, showcase strengths at curricular design and implementation, highlight her grant writing skill, and illustrate her developing interest in interdisciplinary collaborations with STEM colleagues across several University of Minnesota departments and within the broader education community. For a complete list of research colleagues involved with the student across the course of the three studies please refer to Appendix C. For information on the peer-reviewed journals where Study 1 and Study 2 were published refer to Appendix D. Copyright permissions to include published work in this dissertation are presented in Appendix E.

The dissertation consists of five chapters. Chapter one provided an introduction to the three studies, the student's role in each study, major research findings, and a framework for how the three studies tie together by exploring the impact and engagement of teachers and students in standards-based STEM curriculum, instruction, and assessment practices. Chapter two presents Study 1, *Block Scheduling and Mathematics: Enhancing Standards-Based Instruction?* Chapter three consists of Study 2, *Building a Successful Middle School Outreach Effort: Microscopy Camp*. Chapter Four presents study three, *Integrating Technology into a Secondary Science Licensure Program: Modeling Students' Competencies to Use and Teach with Technology over the Course of the Program.* Chapter Five synthesizes the three studies, illustrates methodological strengths and weaknesses in each study with suggestions for future research, and examines how the student's skill in research emerged across the course of study. Finally, implications for teaching, learning, and future research based on the three studies are discussed.

CHAPTER TWO

STUDY A

Block Scheduling and Mathematics: Enhancing Standards-based Instruction?
Published in the *National Association of School Principals (NASSP Bulletin)*, Vol. 89, No. 642, March 2005. Flynn, L., Lawrenz, F., & Schultz, M.

Abstract

This study investigates differences in eighth-grade mathematics students' engagement in standards-based curriculum and instruction practices between block- and traditional-schedule schools. Survey data were gathered from 156 middle level mathematics teachers to access the use of standards-based curriculum and instruction practices in their classrooms. Results indicate there are few differences in curriculum and instruction based on the type of school schedule.

Introduction

Educational reform is an ongoing process with many ideas being offered to improve our school systems. In the late 1980s, block scheduling emerged as an alternative to the traditional 6- or 7-period day schedules. Block scheduling, with its typical 85-100 minute periods, was promoted as a way to free the classroom from time constraints that encouraged the common direct/lecture method (Canady & Rettig, 1995; National Commission on Time and Learning [NCTL], 1994). The implication was that, with the consolidation of class time, teachers would be able to engage students in a greater variety of active learning methods (cooperative groups, in-depth investigations, inquiry), which address how students learn best (Canady & Rettig, 1995; Marshak, 1997; Queen, 2000).

Coinciding with the push toward block scheduling was the emergence of national standards in mathematics. Implementing the types of active learning methods advocated in block scheduling is consistent with the original and more recent recommendations of the national mathematics standards. Standards for mathematics were first published in 1989 by the National Council of Teachers of Mathematics (NCTM) and revised in 2000. These standards promote engaging students in extended investigations, involving students in discourse about mathematical ideas, and solving real-world problems. The introduction of standards is meant to serve as a vision of how mathematics should be taught in schools. According to NCTM, how well these standards are implemented within schools may have repercussion for the achievement of students in mathematics.

The importance of implementing standards in schools was reaffirmed on January 8, 2002, when President Bush signed into law the *No Child Left Behind Act* (NCLB) as his administration's answer for how to help our schools. One of the key principles of NCLB is educational accountability. As part of this accountability, all schools in districts that accept Title I funds must have adopted standards in reading/language arts and mathematics by 2002. In addition, examinations must be developed that align with the standards in order to measure students' progress in math annually in grades 3–8 beginning in 2005. Because a majority of the nation's schools accept Title I funding compliance in adopting standards is high. Requiring states to adopt standards is the administration's solution for ensuring schools use scientifically based methods with long-term records of success. The standards created must encourage higher-order thinking skills and problem solving in all students. The recommended state standards for content and instructional practices in mathematics will likely be closely aligned with the national mathematics standards. States across the nation cite the national mathematics standards as a framework for the development of their own standards in mathematics.

Because many standards-based instructional practices call for in-depth investigations, discussions, and reflections, extended periods associated with block scheduling may act as a catalyst for standards-based teaching techniques that have been neglected in the traditional school schedule. For example, students can more fully participate in extended investigations to explore their mathematical ideas and share these ideas with peers and teachers. Although a small body of research exists on the effect of block scheduling on curriculum and instructional practices (e.g., Canady & Rettig, 1996;O'Neil, 1995; Staunton, 1997), researchers in the field have advocated for inclusion of more research because results to date have been context specific and somewhat inconclusive (Canady & Rettig, 2001; Queen, 2002). In addition, little research has been conducted on specific differences in standards-based instructional practices.

Existing research on block scheduling has highlighted many perceived advantages. Teachers in a block schedule are reported to lecture less and gradually engage students in more active learning structures, resulting in students becoming less passive in their learning (Banbury, 1998; Canady & Rettig, 1996; Staunton, 1997). Teachers in block schedules reported increased use of a variety of instructional activities (Khazzaka, 1997-1998; Queen & Isenhour, 1998; Staunton, 1997) and specifically in student-centered learning (Banbury, 1998), hands-on projects/labs (Banbury, 1998; Hartzell, 1999) and small learning groups (Staunton, 1997). Another research study showed students in longer block-scheduled classes had a higher engagement rate than did students in the shorter, traditional schedule (Center for Applied Research and Educational Improvement, 1995). Studies in mathematics show that although some block schedule teachers may cover less material, they report the material they do cover is taught better and in greater depth (Kramer, 1996).

In contrast to these positive findings, research by Queen (2002) showed no instructional differences between traditional- and block-schedule teachers' use of lecture/direct instruction, small group/structured pairs, cooperative learning, discovery learning, and integrated/thematic teaching. Additional studies (Bexell, 1998; Bush & Johnstone, 2000; Hart, 2000) reported that teacher-centered instruction (i.e., lecture) predominated block-schedule classrooms and teachers had not changed their instruction to match longer periods of time.

The present study provides additional data for school administrators to use in making decisions about school scheduling options. This is particularly relevant in light of the current administration's emphasis on school accountability and use of standards. The study uses teacher survey data to compare eighth-grade middle level mathematics student engagement in standards-based instruction in block- and traditional-schedule schools.

Engagement is defined as students involved in “minds-on” activities.[1] The research provides additional evidence on school scheduling options’ effectiveness in increasing standards-based instructional practices.

Method

The data used in this study were originally collected as part of a large NSF Statewide Systemic Initiative (SSI) impact study (Lawrenz & Huffman, 2002), which can be accessed at http://www.education.umn.edu/CAREI/. The study was complex and included a variety of types of data from different states. Schools from different states were selected to be representative of those having high and low amounts of contact with an SSI. Several data collection devices-surveys, interviews, and observations- were developed and used in the larger study. Data from only two of the instruments will be reported on here: the surveys for middle level principals and mathematics teachers. The principal survey asked about school enrollment, grade levels, percent of students eligible for free or reduced-price meals, and the percent of Caucasians at the school. The teacher survey assessed the degree of standards-based mathematics instruction by asking teachers to indicate how often their eighth-grade students engaged in 17 types of instructional activities. A 5-point scale was used, where 1 = rarely or never, 2 = once a month, 3 = once a week, 4 = 2-3 times a week, and 5 = daily. Teachers were also asked what percentage of the class time was spent on instructing the class as a whole, students working in small groups, and students working individually. A 6-point scale was used for this item: 1 = 0%, 2 = 1-10%, 3 = 11-30%, 4 = 31-50%, 5 = 51-70%, and 6 = 71-100%. In addition, demographic information about teaching experience, professional development, and certification were collected.

Sample Characteristics

The data used here came from schools in three different states: Louisiana, Illinois, and Colorado. The sample includes 64 middle level schools (39 traditional, 25 block), 156 middle school teachers (85 traditional, 71 block), and 60 middle school principals (37 traditional, 23 block). Although the sample was not drawn randomly and, therefore, is not necessarily representative of all schools across the three states, it contains a broad range of teachers', principals', and school characteristics.

Characteristics of the block- and traditional- schedule middle level schools are presented in Table 1. Traditional schools appear to be smaller and perhaps have lower socio-economic status than block schedule schools. Forty-six percent of the traditional schools reported enrollments below 500 while only 24% of the block schedule schools reported enrollments under 500. Also 44% of the traditional schools reported that over 50% of their students are eligible for free or reduced-price meals compared with 20% of the block schedule schools.

Table 1. *Middle School Characteristics of Block versus Traditional Schedule Schools.*

School Characteristic		*Block Schedule N= 23 %*	*Traditional Schedule N= 37 %*
School Enrollment	100-499	24.0	46.2
	500-800	52.0	35.9
	above 800	24.0	12.8
	Missing	0.0	5.1
Grade Levels	5-8	0.0	23.1
	6-8	56.0	35.9
	6-12	4.0	0.0
	7-8	8.0	23.1
	7-9	12.0	2.6
	K-8	4.0	0.0
	PK-8	0.0	7.7
	Other	12.0	7.7
	Missing	4.0	0.0
Percent eligible for free or reduced priced meals	0-25	36.0	20.5
	26-50	36.0	33.3
	51-75	16.0	25.6
	76-100	4.0	17.9
	Missing	8.0	2.6
Percent Caucasian	0-25	0.0	10.3
	26-50	16.0	12.8
	51-75	16.0	23.1
	76-100	48.0	46.2
	Missing	20.0	7.7

Teacher characteristics between the groups were similar. Of the 156 teachers surveyed, no differences were indicated in mathematics teaching experience (block: *M* = 5.59 [6-10 years], *SD*= 1.97; traditional: *M* = 5.76 [6-10 years], *SD* = 2.26); highest level of formal education completed (block: *M* = 2.8 [master's], *SD* = 1.04; traditional: *M* =2.68 [master's], *SD* = .95) or professional development for curriculum or instruction implementation over the past two years (block: *M* = 2.86 [2 weeks], SD = 1.28;

traditional: *M* = 2.59 [2 weeks], *SD* = 1.39). A significant difference does exist (*t*= 3.02, *df*= 144, *p*= .00) between the number of teachers in traditional (51%) and block (75%) schedule schools that hold a mathematics degree.

Table 2. *Student Classroom Activities*

Student Activity	Schedule	N	Mean	SD	p
Use calculators or computers to solve mathematical problems	Block	69	4.07	.90	.04*
	Traditional	79	3.70	1.30	
Work on solving real-world problems	Block	70	3.84	1.10	.91
	Traditional	79	3.82	.97	
Participate in discussions to deepen mathematics understanding	Block	69	3.59	1.02	.07
	Traditional	79	3.24	1.35	
Share ideas or solve problems with each other in small groups	Block	69	3.45	1.08	.49
	Traditional	79	3.32	1.24	
Document and evaluate their **own** mathematics work	Block	69	3.19	1.35	.34
	Traditional	79	2.96	1.52	
Read from a mathematics textbook in class	Block	70	3.11	1.52	.61
	Traditional	79	3.24	1.48	
Describe what they know about a topic before it is taught	Block	70	2.84	1.19	.32
	Traditional	79	2.65	1.23	
Participate in student-led discussions	Block	69	2.81	1.48	.22
	Traditional	77	2.51	1.48	
Engage in hands-on mathematics activities	Block	70	2.69	.93	.54
	Traditional	79	2.58	1.12	
Record, represent, and/or analyze data	Block	70	2.64	.96	.93
	Traditional	79	2.66	1.15	
Complete worksheets that emphasize mastery of essential skills	Block	70	2.50	1.03	.48
	Traditional	78	2.62	.93	
Write reflections in a notebook or journal	Block	70	2.19	1.38	.00*
	Traditional	79	1.59	1.01	
Model or work on simulations	Block	70	2.07	1.07	.98
	Traditional	79	2.08	1.20	
Read other (non-textbook) mathematics-related materials in class	Block	69	1.91	1.09	.96
	Traditional	79	1.92	1.30	
Make formal presentations to the class	Block	69	1.48	.82	.98
	Traditional	79	1.48	.89	
Use community resources in the classroom (museums, business people)	Block	69	1.35	.64	.76
	Traditional	79	1.32	.63	
Prepare written mathematics reports of at least three pages in length	Block	70	1.07	.26	.92
	Traditional	79	1.08	.31	

Note: Means based on 5 point scale: 1(rarely or never), 2 (once a month), 3 (once a week), 4 (2-3 times a week), and 5 (daily).

Results

The mean and standard deviation data presented in Table 2 are arranged in descending order of mean frequency of use of the particular teaching strategy in the block schedule schools. In other words, the most commonly used teaching techniques are at the top of the list while the least commonly used techniques are at the bottom of the list. Table 3 shows the percent of classroom time spent in individual, small group, or full class work.

Table 3. *Use of Time in Classroom*

Activity	Schedule	N	Mean	SD	p
Teacher instructs the class as a whole	Block	70	3.96	.98	.91
	Traditional	81	3.98	1.02	
Students work individually	Block	68	3.22	.86	.12
	Traditional	81	3.47	1.05	
Students work in small groups	Block	69	3.14	.88	.16
	Traditional	78	2.91	1.08	

Means = percentage of class time based on a 6 point scale: 1(0%), 2(1-10%), 3 (11-30%), 4 (31-50%), 5 (51-70%), and 6 (71-100%)

Although there are some differences, the data show that teachers in both block and traditional schedule schools tend to follow the same patterns of whole class, small group, and individual student work. Teachers in both settings use whole-class instruction a third to half of their class time. They have students working individually about one-third of the time and have students working in small groups slightly less than one-third of the time. The data also show that teachers in both types of settings rarely use community resources or have students prepare written reports. In contrast teachers in both settings consistently (one to three times a week) have students use calculators or computers, work on solving real world problems, participate in discussions to deepen mathematics understanding, share problems in small groups, and evaluate their own work. Overall there are only moderate amounts of engagement in these recommended instructional practices.

Despite the similarities, as can be seen from the Table 2, several items showed differences in mean scores between the block and traditional settings. Although some of these differences were very small, 10 of the 17 items favored the teachers from the block-schedule schools. *T*-tests were conducted to determine if any of these differences were statistically significant. Analyses were run twice, first using no covariate (as presented in Table 2) and, second, controlling for the school's socioeconomic status (SES) by using free and reduced-price meals as a covariate in an ANCOVA. Analyses run without SES control showed that differences on two items, "use of calculators/computers to solve mathematics problems" (t = 2.0, df = 146, p = .04) and "writes reflections in notebook or journal" (t = 3.0, df = 147, p = .00), were statistically significant. When SES was controlled, only the difference for one item, "writes reflections in notebook or journal" was significant (t = 2.695, df = 136, p = .01). The "use of calculators/computers to solve mathematics problems" item was insignificant when SES was controlled (t = 1.75, df = 135, p = .08). This finding may indicate that the use of calculators and computers may be more related to SES than type of school scheduling.

Discussion

The results found here support Queen's (2002) findings of no differences between traditional and block schedule teachers' use of whole class and small group instruction. The results also suggest that despite the reported increases in the use of a variety of instructional activities in teachers with block schedules (Khazzaka, 1997-1998; Queen & Isenhour, 1998; Staunton, 1997), these increases may not produce significant differences between the instructional practices of teachers in block- and traditional- schedule settings. The lack of significant differences between the teachers in the two settings may be due to heightened emphasis throughout the country on the implementation of standards-based mathematics instruction. In other words, all teachers are trying to teach mathematics in the same ways. If this is true, however, it reveals another issue, the overall low level of engagement in standards-based instructional practices in both settings. Even the most frequently used technique (use of calculators/computers) was not a daily occurrence. Many of the techniques were used once a week or less. These less frequently used techniques include some that may be appropriately used such as long written reports or formal presentations. However, given the emphasis in the mathematics standards on communication of mathematics understanding, this pattern is troubling. Additionally, it appears that in contrast to the standards recommendations for real world, hands-on mathematics, these teachers are somewhat below where they should be in terms of use of simulations, data gathering, hands-on activities and community resources.

The results also support research showing that, although teachers in block-schedule schools are provided with more time per class period for instruction, it does not appear that they are using this time to vary instructional practices compared to traditional-schedule teachers. Simply changing the structure of the school schedule cannot act as the sole catalyst for instructional change. Teachers in block schedule schools may need to be provided with ongoing professional development to optimize the benefits of the extended period schedule. Teachers in this study reported receiving the same type and duration of professional development regardless of their school schedule. Previous research has emphasized the link between staff development and incorporation of varied instructional strategies (Adams & Salvaterra, 1997; Queen & Isenhour, 1998).

Because there were so few differences between the block and traditional schedule teachers, it is difficult to determine if an SES effect exists. Of the two items that showed differences the use of computers and calculators appeared to be more related to SES than to block scheduling; indicating that schools with higher SES engage students in using, or have more access to, calculators and computers. On the other hand the use of reflective writing seems to be a clear difference between the two types of scheduling. This is promising in that it is an example of the type of changes in instruction hoped for by the proponents of block scheduling.

The current reemphasis on school accountability and standards-based instruction brought about NCLB means we must look critically at the advantages and disadvantages of our current school structure. Schools adopting block schedules provide teachers an invitation to pursue varied instructional practices by providing them time to engage students in higher-order problem solving activities, discursive practice, and inquiry. Although there is more use of journaling in schools with block scheduling, other behaviors and activities associated with standards-based instruction are not used significantly more than in traditional-schedule schools. In order to really capitalize on the potential advantages, teachers may need more instruction on how to properly implement the standards into their classroom.

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CHAPTER THREE

STUDY B

Building a Successful Middle School Outreach Effort: Microscopy Camp. Published in the *Journal of Chemical Education*, Vol. 84, No. 6, June 2007. Penn, R.L, Flynn, L., & Johnson, P.

Introduction

Microscopy Camp is a program designed to introduce acceptable representations of crystalline particles and their atomic structure to twelve year old middle school students at a developmental/educational stage when they are forming notions of atomicity (Piaget & Inhelder, 1974). The initial goals of the Microscopy Camp were two-fold: introduce or reinforce concepts of atomic structure through the use of high-resolution transmission electron microscope (HRTEM) and provide experience to graduate students interested in careers in science education. As a part of many proposals for research grants, principal investigators are asked to develop a substantial educational and/or outreach program, often targeting K-12 students. The initial idea for Microscopy Camp was developed several years prior to the submission of a research proposal for the grant that ultimately funded the program (National Science Foundation CAREER award #0346385). A visit to the appropriate program officer provided the crucial piece of advice: partner with an expert in science education. Many scientific researchers struggle to design and implement an educational or outreach program that is effective and content-appropriate for the target audience. A member of the Curriculum and Instruction department at the University of Minnesota joined the effort and assisted in writing the program description for the grant proposal, which was funded. The collaboration between the chemist and the expert in science education molded the initial idea into a useful and effective program.

With recent advances in the achievable resolution of electron microscopes, a direct method for demonstrating the atomic structure of solid crystals is available. Ten middle school age students (7 males, 3 females), from one urban school located in the Minneapolis metropolitan area, attended Microscopy Camp 2005, which was held in August of 2005 at the University of Minnesota. Our program was a two-day, twelve-hour non-residential camp. The students engaged in a range of activities including synthesizing magnetite nanoparticles; building sodium chloride crystal models using gumdrops; making macroscopic, microscopic and symbolic predictions; comparing predictions to observations; and examining a range of items (like bugs, common household chemicals, sand, shells, and their nanoparticles) across a wide range of magnifications by using their own eyes, hand-held magnifiers, light microscopy, and scanning electron microscopy. Finally, campers examined their nanoparticles using a high-resolution transmission electron microscope (HRTEM) capable of producing atomic-structure images. This experience provided the students with their first opportunity to directly observe the atomic structure of solid crystalline materials. The students had no formal school instruction on the particulate nature of matter prior to attending camp. Our Microscopy Camp description is a recipe for building an appropriate team to work with middle school students and successfully address the atomic structure of matter.

The Particulate Nature of Matter Concept for Middle School Students

Students beginning middle school have been introduced to properties of and changes in solid materials through formal instruction in school. Instruction focuses on observation and description of macroscopic features of substances and of physical and chemical reactions. At the end of middle school, students are formally instructed on the idea of atomic and molecular particles (American Association for the Advancement of Science [AAAS], 1993; Minnesota Department of Education [MDE], 2005; National Research Council [NRC], 1996). Students bring prior conceptions of vocabulary and elementary notions of atomicity to the class; many of these ideas can vary widely from those recognized as acceptable by scientists (Brooks & Briggs, 1984; Gabel, 1993). Early ideas focus on particles having the same properties as the parent material; that is, they are solid, tiny pieces of the substance. These small bits of solid are seen as static and non-uniform in structure (Nakhleh, 1992). Middle school students appear to think these bits vary in size and shape, have no space between them, and possess similar properties to the parent material. A common inaccurate conception is the idea that larger objects have larger atoms than do smaller objects of the same material, which is contrary to the acceptable conception that the larger objects simply contain more atoms (Ben-Zvi, Eylon & Silberstein, 1986; Pfundt, 1981).

Pupils are expected, eventually, to abandon a continuous (non-particulate) view of chemical substances in favor of the particulate view of chemical substances, in which matter consists of component units that are uniform in both size and shape. Extensive research has shown that once these alternative conceptions are formed, they are difficult to change and persist into adulthood, making understanding more complex concepts about atomicity difficult (Driver, Squires, Rushworth & Wood-Robinson, 1994; Nicoll, 2003, Nussbaum & Novak, 1976).

Recently, Margel, Eylon, and Scherz (2004) designed and implemented a program to use a scanning tunneling microscope (STM) to show junior high school students the particulate nature of solid materials. These students had been formally introduced to the particulate nature of matter in school prior to the program. They demonstrated the effectiveness of using an advanced and state-of-the-art materials characterization method – an STM in this case – as a teaching tool for students in this age group. The ninety minute program involved a preliminary questionnaire, four activities involving the STM, and a post-STM questionnaire. Also, their program included a component geared towards junior high school teachers, which used the same four activities involving the STM in addition to reading and instruction on STM technology.

Microscopy Camp differs from the previous study in three major respects. First, our students had received no formal instruction on the particulate nature of matter in their school curriculum prior to attending the program. Second, students were engaged in a two-day, twelve-hour program in which multiple modes of characterization (visual, light, STM, HRTEM, and symbolic computer visualization/models) of varied, real world/familiar materials were used. Third, our assessment asked students to give macroscopic, microscopic, and symbolic representations of everyday substances (salt and sugar) present in small and large crystal form.

Our Recipe for Success

The Campers

Microscopy Camp 2005 campers were 12 year old students who attended sixth grade at a local, urban middle school (located in Minneapolis, Minnesota) during the 2004-2005 academic year and who all had the same science teacher. None of the students had received formal instruction regarding the particulate nature of matter prior to Microscopy Camp 2005. Recruitment occurred in May of 2005 and included a 30-minute presentation of chemistry demonstrations to potential campers. The classroom teacher distributed registration and parental consent forms to students who had voluntarily expressed interest in the program; the teacher also sent out memos to the parents via a monthly science newsletter distributed by the school. Microscopy Camp was entirely funded through the NSF CAREER award (# 0346385), there was no cost to the camper's families; this helped ensure financial concerns did not impact recruitment. Finally, the classroom teacher collected completed registration forms from twelve students, ten of whom actually attended Microscopy Camp 2005.

The Camp Counselors

Camp counselors consisted of the chemist, the science educator, and two student-teachers (both enrolled in the Department of Curriculum and Instruction's Teacher Licensure Program at the University of Minnesota). Camp counselors performed demonstrations, lead discussions, guided students through interactive demonstrations and activities, answered questions, and supervised all activities. In addition, the student teachers assisted the science educator with the pre- and post-camp assessments of the students' knowledge of the atomic structure of solid matter.

The Schedule.

Table 1. *Ideal Microscopy Camp Schedule.*

		Day One
9:00	am	Drop-off
9:15	am	Introductions accompanied by chemical demonstrations
9:30	am	Interactive chemical demonstration
9:50	am	Pre-camp assessment
10:20	am	Synthesis of iron oxide nanoparticles
10:45	am	Light microscopy (natural objects and synthetics)
11:15	am	Introduction to the atomic structure of solids
11:30	am	SEM I: Introduction to Scanning Electron Microscopy
12:00	pm	Lunch
12:20	pm	Recess outside with Dept. of Chemistry graduate students
1:00	pm	Light microscopy (nanoparticles, natural sands and sediments)
1:30	pm	Paint mural using paints and nanoparticles
2:00	pm	Continued discussion of atomic structure of solid materials

2:15	pm	Interactive chemical demonstrations
2:30	pm	Social time
3:00	pm	Pick-up

Day Two		
9:00	am	Drop-off
9:15	am	Tour of the Institute of Technology Characterization Facility
9:30	am	SEM II: Examine students' nanoparticles in the SEM
10:00	am	Examine nanoparticles using HRTEM (30 min; switch)
	am	Magnification Matching Game (30 min; switch)
11:00	am	Light microscopy (compare to images from EM)
11:30	am	Discussion on the atomic structure of solid materials
12:00	pm	Lunch
12:20	pm	Recess outside with Dept. of Chemistry graduate students
1:00	pm	Rap/skit/song/cheer development and rehearsal time
1:30	pm	Perform Rap/skit/song/cheers
1:45	pm	Group selection of images for website
2:00	pm	Post-camp assessment
2:30	pm	Interactive chemical demonstrations
2:45	pm	Social time
3:00	pm	Pick-up

Note: The University of Minnesota's Institute of Technology Characterization Facility houses electron microscopes and other advanced research equipment.

Our schedule is shown in Table 1. Priority in scheduling was given to hands-on activities and demonstrations, characterization of solids using state-of-the-art technologies, interactive learning activities, walks to various parts of campus, recess-time, snacks, and discussions with faculty and graduate students throughout each six-hour day in order to maximize student engagement. Table 1 can provide a framework for the design of a similar program.

Day One

Introductions.

By way of introduction, each team member lead an interactive chemistry demonstration (e.g., igniting a trail of peroxyacetone, the "Genie in a Bottle," or burning methanol in water cooler bottles, Fortman, Rush, & Stamper, 1999) by asking students to make predictions about what they expected would happen, guiding one or more students in the execution of the demonstration, and asking students to describe their observations and give their own explanations for why it happened.

Pre-camp assessment.

Each student's macroscopic, microscopic, and symbolic conceptions of particles were characterized through an open-ended assessment tool (designed by two of the science education researchers) followed by probing questions by the three science education researchers to gain clarity about students' drawings and written descriptions. The assessment focused on salt and sugar crystals, two commonly encountered crystalline materials, and the concept of how those objects would appear at a variety of magnifications, the similarities and differences between the two types of crystals, and what the students believed these crystals “were made of”. Finally, one key question asked students to draw a picture of what they would expect to see if they could examine a small and large salt crystal using a hypothetical microscope called the “world’s most powerful microscope.” Students were asked probing questions, such as “You say salt is made of rock. What do you think rock is made of?” and “You say ‘salt is a sketchy shape.’ What does the word, ‘sketchy’ mean to you?” The probing questions helped lessen the occurrence of items being coded as “unclear” in the analysis of the data.

Preparation of Magnetite (Fe_3O_4) Nanoparticles.

Magnetite was selected as the material of choice for students to synthesize and view at varying magnifications because most of the precursors are relatively easy and safe for young students to use and magnetite is stable under the electron beam. Magnetite is nontoxic, black in color, and strongly magnetic. In addition, iron oxides are environmentally relevant; for example, the magnetic minerals in many sands and soils are often magnetite or other black or nearly black magnetic minerals. To prepare approximately two grams of magnetite per student group, chemicals and their quantities required are 1.49 g of NaOH, 0.43 g of $NaNO_3$, 0.99 g of $FeCl_2$, and 4.04 g of $Fe(NO_3)_3$. In order to keep potential exposure to chemical hazards to a minimum, a 75 mL of 0.5 M sodium hydroxide solution per student group was prepared and bottled in a 250 mL bottle by the camp counselors. In addition, each solid was pre-weighed into glass vials for distribution to each group. Additional supplies include 250 mL bottles (two per group), 10 mL graduated cylinder, disposable plastic pipettes or eyedroppers, strong magnets (hard drive magnets are ideal), notebook for recording observations, writing utensil, plastic weigh boats, distilled and/or deionized water, non-latex lab gloves, lab safety glasses, and “lab coats”. Helpful but unessential equipment includes a centrifuge, a vortexer, and a mortar and pestle.

Students and counselors wore safety glasses at all times, and during the synthesis procedure students wore non-latex lab gloves. Campers wore “lab coats” selected from a stock of laundered, large, long-sleeved, button-down shirts purchased from a local thrift store. Students were required to wear the lab coats during the preparation of the magnetite nanoparticles and invited to wear them during other messy activities.

The steps for preparing the magnetite nanoparticles are described in Table 2, with the fourth step performed by the camp counselors.

Table 2. *Detailed procedure for magnetite synthesis*

Step	Procedure
1	• Pour each solid into the empty 250 mL Nalgene bottle. • Measure 10 mL of deionized water using the graduated cylinder. This volume need not be exact. • Pour the de-ionized water into the 250 mL Nalgene bottle containing the solids.
2	• Transfer the sodium hydroxide solution to the 250 mL Nalgene bottle containing the solids using the disposable, plastic pipettes. • Periodically screw the cap onto the reaction bottle and swirl the contents.
3	• When NaOH solution transfer is complete, demonstrate that the black particles are magnetic by holding a magnet next to the reaction bottle. • Allow the black particles to settle for approximately one hour. Place reaction bottles onto magnets to speed settling. • Use disposable, plastic pipettes, to remove as much supernatant as possible while leaving the particles at the bottom undisturbed. While not essential, this step proved challenging and fun for the campers.
4	• Rinse the particles 2-3 times by repeatedly centrifuging the suspension and discarding the supernatant. • Place the wet particles into weigh boats and allow to air-dry overnight. • The next morning, grind the black product with a mortar and pestle and distribute into labeled vials for each student.

The procedure was written on the board, as seen in Figure 1, which is the typical method of introducing a laboratory procedure in general chemistry at the University of Minnesota. Campers seemed to appreciate the idea they were performing a laboratory experiment similar to those performed in university laboratory classes. Each group of two students received glass vials containing pre-weighed quantities of sodium nitrate, ferric chloride, and ferric nitrate; an empty 250 mL Nalgene bottle; one 250 mL Nalgene bottle containing the 75 mL of 0.5 M sodium hydroxide; a magnet; non-latex gloves; and plastic pipettes. Deionized water was readily accessible via building supply. Students were instructed to record observations at each step throughout this procedure.

Figure 1. Lab Procedure for Magnetite Preparation

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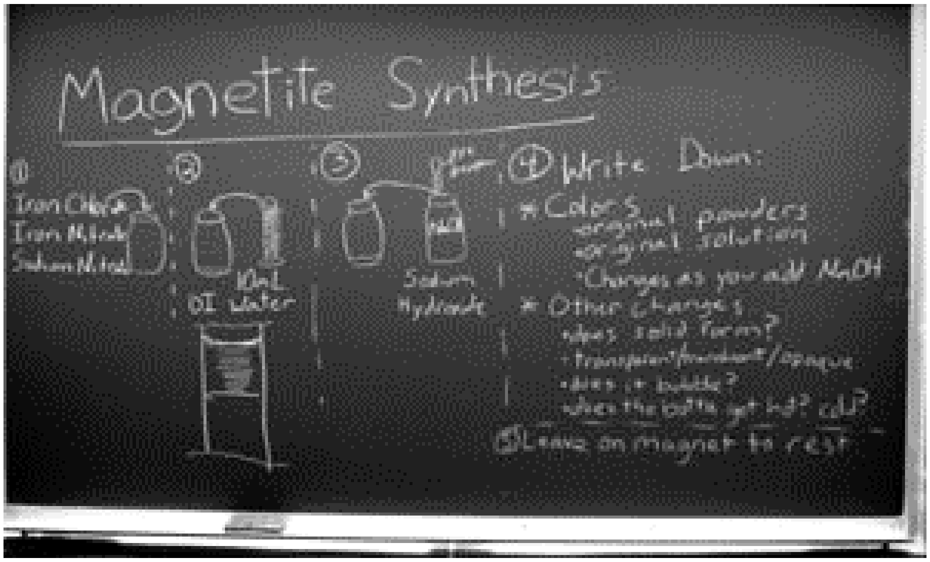


Light Microscopy

Students were asked to bring dead bugs to Microscopy Camp. The bugs ranged from a beautiful monarch butterfly to a cicada to a many legged bug from one student's basement. Students examined their bugs in addition to sand; pebbles; shells; and crystals of salt, sugar, monosodium glutamate, and baking soda using their own eyes, hand-held magnifiers, and student light microscopes (15x), which were loaned to us by Project Micro (funded and run by the Minnesota Microscopy Society; http://resolution.umn.edu/MMS/ProjectMICRO/Welcome.html). There were ten microscopes distributed between two stations: the sands station, which included natural sands, pebbles, and large hand samples of minerals, and the edible powders station, which included sugar, salt, and monosodium glutamate, among other edible chemicals. After approximately fifteen minutes, students were instructed to switch stations so that each student could examine materials from both stations.

Scanning Electron Microscopy (SEM) I

Students attended a 30-minute demonstration of SEM at the UMN Institute of Technology Characterization Facility. Samples examined included a circuit board, monarch butterfly wing, hair lice, a mosquito, and a spider. The goal was to introduce the concept of increasing magnification. After this section of Microscopy Camp, students had examined bugs using their eyes, hand-held magnifiers, light microscopes, and the SEM.

Day Two

Scanning Electron Microscopy (SEM) II

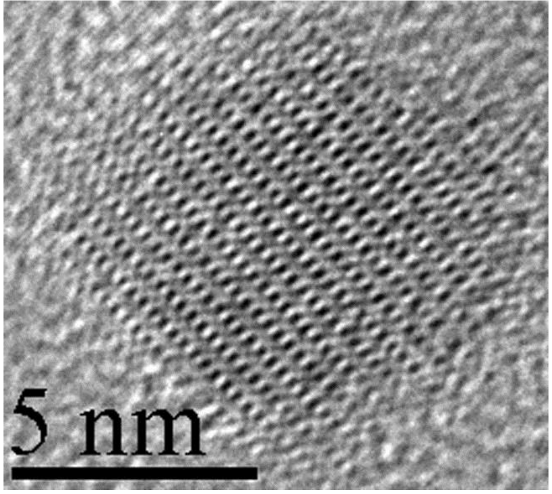
On Day Two, a second, short SEM demonstration focused on a sample of magnetite nanoparticles and salt crystals. This was in preparation for the demonstration on the transmission electron microscope.

High Resolution Transmission Electron Microscopy (HRTEM)

Students attended a demonstration of the FEI F30 TEM at UMN Institute of Technology Characterization Facility, which is capable of producing atomic-structure images of crystalline materials. The sample examined was magnetite nanoparticles synthesized using the procedure described above. Students were asked to compare the physical appearance of the light microscopes, the SEM, and the TEM. A major difference between these microscopes is one of size. Then, students were asked to predict what they might see in the images produced using the HRTEM.

Students were shown the image on the phosphor screen, which glows green upon irradiation by the electron beam. The sample was moved so they could see how the sample stage works. After demonstrating the use of the phosphor screen, the CCD (charge coupled device) camera was exclusively used so all students in the room could see the image simultaneously. Then, the magnification was incrementally increased. Lastly, a nicely oriented nanocrystal was imaged at multiple magnifications, and a high quality, atomic-structure image was collected (Figure 2). After a few high-resolution images were obtained, a brief discussion of what was observed ensued. Challenges during this section of Microscopy Camp mainly involved an unexpected but temporary instrument failure, which resulted in modifying the schedule so that all campers attended this demonstration simultaneously. A word of caution: Campers who had their magnets were required to leave them on the doorframe prior to entering the room in order to prevent anyone from placing their magnet near the microscope.

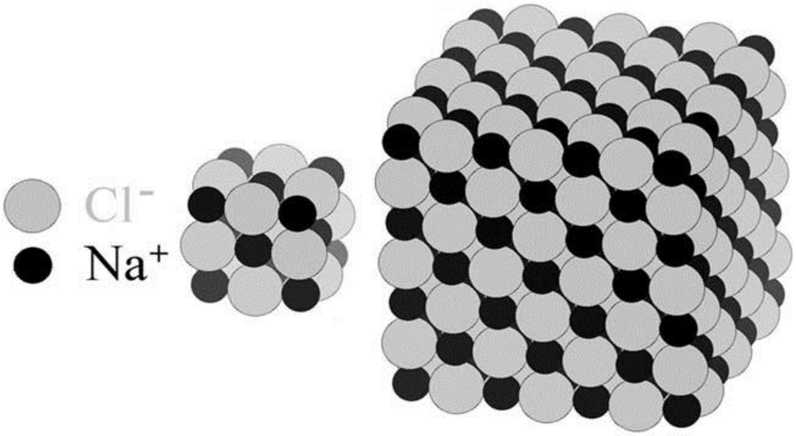
Figure 2. HRTEM image of a magnetite nanoparticle



Discussion: What is Solid Matter Made of?

On day two, Microscopy Camp moved to a large college classroom. A brief discussion of the atomic structure of solid crystals was facilitated by the chemist. The discussion began with the question "What is Solid Matter Made of?" Two pairs of atomic-structure images obtained using the HRTEM were shown at identical magnifications and with matching scale bars. Each pair consisted of one small nanoparticle and one larger nanoparticle, and campers were asked to compare these images. Then, a movie showing a rotating, atomic representation of a nanocrystal was shown. This symbolic representation of a nanocrystal was produced using CrystalMaker®, a program that enables the user to rotate crystal structures, set and change scales (i.e., magnification), change colors of atoms, import crystal structures (or use those provided with the Crystalmaker® library), display crystal structures using a range of options including space-filling and ball-and-stick models, and make movies. Students were asked to compare what they saw in the movie to the HRTEM images shown. Then, the discussion moved to the comparison of a salt crystal and a sugar crystal, focusing on the fact that each is made from different atoms (sodium and chlorine in the former case and carbon, oxygen, and hydrogen in the latter case) and each has distinct physical and chemical properties, such as appearance and taste. Atomic representations of nanocrystals were created and displayed using Crystalmaker®, with identical scales (e.g., 15 pixels per 0.1 nm) and the space-filling option selected. Students chose colors for each type of atom. Students were then asked to compare the crystal structures of salt and sugar, and two example images of salt nanocrystals are shown in Figure 3. The discussion centered on the idea that these materials are composed of different types of atoms and that the atoms are arranged in different ways. Then, campers were asked the question, “How could I make each of these crystals larger?” The overwhelming response was that additional atoms were required in order to grow larger crystals. Using Crystalmaker®, additional atoms were added to each crystal displayed, keeping the scale constant, and the crystal structures rotated. Finally, students were asked to go to the board in pairs and draw two-dimensional representations of the atomic structure of salt crystals within boxes of various sizes using small and large circle patterns for the sodium and chlorine atoms, respectively.

Figure 3. Symbolic representations of NaCl nanocrystals prepared using CrystalMaker®.



Website Development

At the end of Microscopy Camp 2005, Campers were shown pictures taken during the first day and asked to choose a subset for the website (http://www.chem.umn.edu/microscopycamp/). In addition, a selection of day two photos were chosen by the camp counselors and uploaded onto the website. This website has proven immensely useful in providing easy access to images (some were used in classroom instruction and one was used in the campers' school newsletter). Furthermore, it has served as a useful recruitment tool in preparation for Microscopy Camp 2006, which will include both student and teacher campers.

Post-camp assessment

At the end of day two, each student's macroscopic, microscopic and symbolic conceptions of particles were re-assessed through a subset of questions from the same open-ended assessment tool used on the first day of camp. Students drew pictures of salt and sugar crystals as they would appear at varied magnifications and provided written descriptions of what they had drawn. A key question asked the students to draw a picture of what they would expect to see if they could examine a small and large salt and sugar crystal using the "world's most powerful microscope." During this period, the education researchers circulated among the students to ask clarifying questions regarding answers to the assessment tool. Student's were asked probing questions, such as "What do you mean by the word 'fuzzy'?" and "What does, 'It looks clear' mean to you?" The probing questions helped lessen the occurrence of items being coded as "unclear" in the analysis of the data.

Analysis of Assessment Responses

Two key items from both the pre-camp and post-camp assessments are addressed in this paper: Item 2a asked campers to "Draw what you would see for the small piece of salt if you could zoom in and look at it using the World’s Most Powerful Microscope.” Item 3d asked campers to “Draw what you would see for the large piece of salt if you could zoom in and look at it using the World’s Most Powerful Microscope.” All four camp counselors independently coded these two items from the assessments. Responses were coded as “acceptable”, “unacceptable”, and “unclear”. An item 2a response was coded as “acceptable” when a clear presentation of atomic structure was given in which atoms had consistent sizes and shapes, as “unacceptable” when no evidence for atomic structure was presented, and “unclear” when the drawing included some indication of atomic structure but lacked consistent size and/or shape of symbolic atoms. Examples are presented in Figure 4. Item 3d responses were coded using the same criteria as for item 2a. Then, these results from item 2a and 3d were compared in order to assess students’ understanding of the difference, at the atomic level, between large and small crystals of the same material. Comparisons were coded as acceptable when a clear atomic structure with consistent sizes and shapes in both drawings was presented. Comparisons were coded as unclear when the drawings included some indication of atomic structure without consistency in size and shape. Comparisons were coded as unacceptable when drawings showed a clear lack of atomic structure or inconsistent sizes and/or shapes. An example of an “acceptable” comparison is shown in Figure 5.

Figure 4. Coding examples of student-drawn responses to the question: “Draw what you would see for the small piece of salt if you could zoom in and look at the salt using the World’s Most Powerful Microscope.” (item 2a).

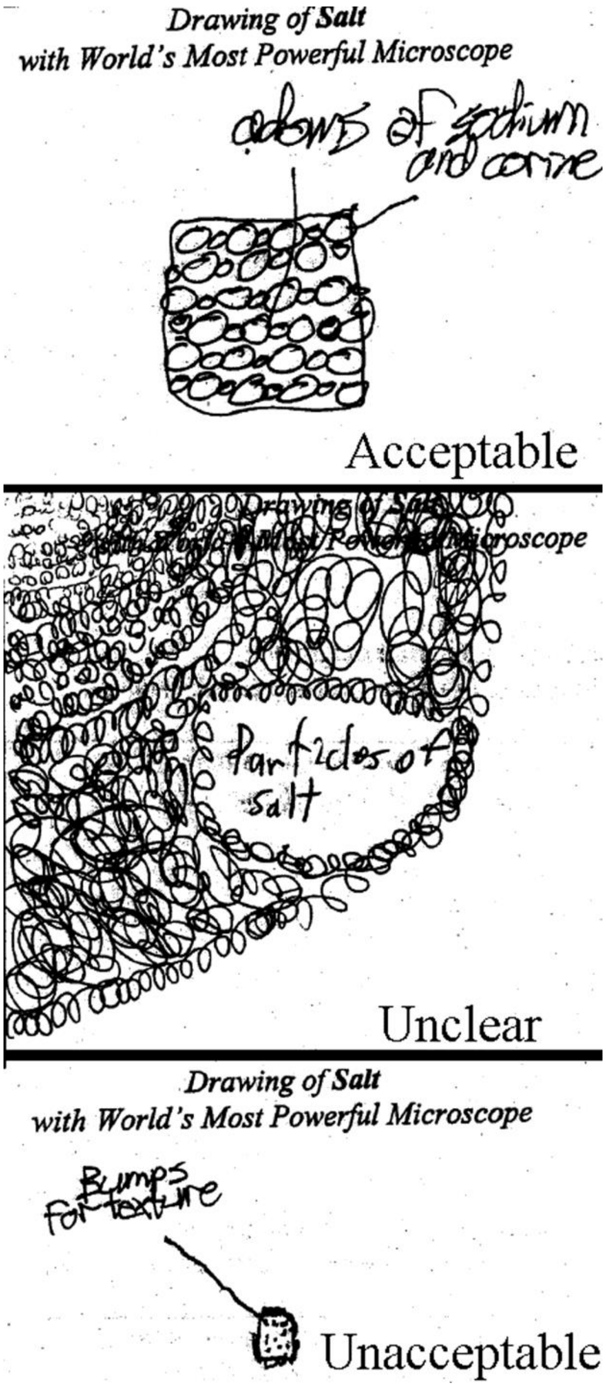
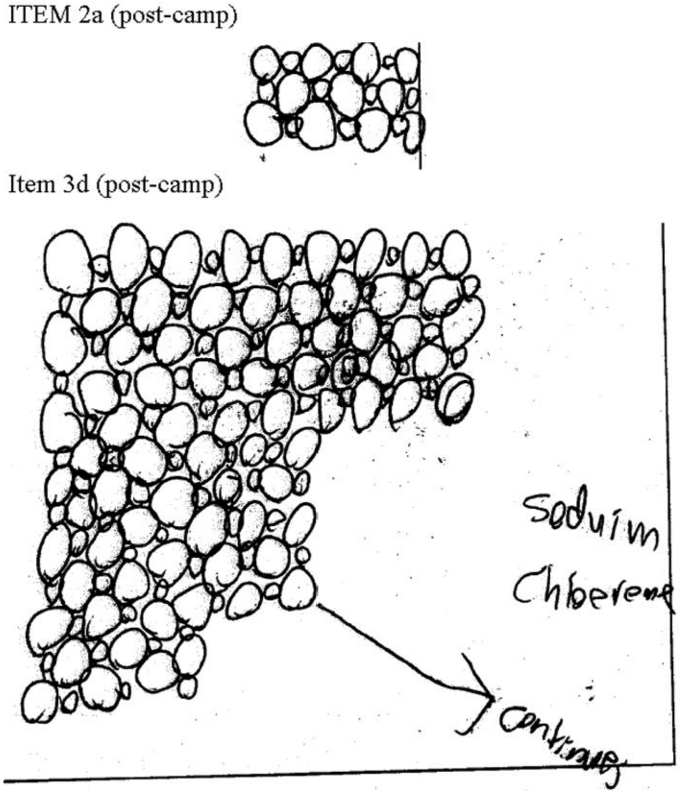


Figure 5. Example of student-drawn responses to items 2a (upper) and 3d (lower) that were coded as acceptable in the comparison between the small and large salt crystal drawings.



Results and Discussion

Assessments

Results comparing responses in the pre-camp and post-camp assessments for item 2a and the comparison between items 2a and 3d are reported in Table 3. For Item 2a, pre-camp assessments yielded no acceptable responses, one unclear response, and nine unacceptable responses while post-camp assessments yielded eight acceptable responses, one unacceptable response, and one unclear response. For the comparison between items

2a and 3d, pre-camp assessments yielded no acceptable responses while post-camp assessments yielded eight acceptable responses, two unacceptable responses, and zero unclear responses (see example, Figure 5). These results demonstrate students developed an improved understanding that the size of an object's atoms is independent of the size of the object. Furthermore, students demonstrated appropriate concepts of the atomic structure of a solid crystal through their drawings. The results indicate that, at this stage, students' concepts of the atomic structure of solid matter appear amenable to change from their pre-camp, personal theories. In other words, they seemed to accept, over the short, two days of Microscopy Camp, a change in their view of atoms. A longitudinal study (Flynn & Penn, 2007) is being conducted to capture the student's notions of atomicity 6 months after Camp and their feelings regarding their overall camp experience.

Table 3. *Distribution of Pre- and Post-Assessment Data*

	Pre-Assessment			Post-Assessment		
Item	Acceptable	Unacceptable	Unclear	Acceptable	Unacceptable	Unclear
2a*	0	9	1	8	1	1
3d**	0	10	0	8	2	0

* Draw what you would see for the small piece of salt if you could zoom in and look at the using the World's Most Powerful Microscope. ** Draw what you would see for the large piece of salt if you could zoom in and look at it using the World's Most Microscope.

Students, teacher, parents, and counselors impressions of Microscopy Camp 2005: The students and parents were very enthusiastic about their experience. One parent commented, “My son never talks to us about science and we are so excited to have him come home and talk about atoms, electrons and doing experiments- thank you! thank you! for this great idea”. One student queried, “Can we come again next year and sleep over and spend a whole week?” Three students wrote this cheer to describe their experience:

Microscopy Camp Cheer

We exploded things and made some goo,
We had fun, how 'bout you?
We had pizza and subs for lunch,
Chips, drinks, and yummy things to munch!
We mixed and boiled and bubbled and brewed,
We made fire, and it turned blue!
We looked at bugs under a microscope,
We learned new things and made stuff too!
We looked at a microscope that magnifies a million,
We had fun, TIMES A ZILLION!

The counselors at the camp were very impressed with the students' enthusiasm and ability to use the information they were learning to ask high level questions. One counselor commented, "It was great to have so much time one-on-one with students talking about their ideas about science and especially the atom. I wouldn't normally get that much time with individual students." Twelve weeks after Microscopy Camp 2005, the classroom teacher from the students' school wrote, "They are still talking about how much fun they had at camp and all the cool things they did and saw. Can I come next year and bring my two kids?"

Conclusions

Through active, visualization-based learning, our program successfully led to improved concepts of the atomic structure of crystalline materials. Particular strengths of our program include the examination of objects over a wide range of magnification, ranging from zero magnification with the use of unaided eyes to magnification exceeding one million times with the use of the HRTEM; incorporation of interactive demonstrations of chemical concepts; inclusion of the hands-on synthesis of magnetite nanocrystals; discussion of the atomic structure of crystalline solids using symbolic representations, images obtained from the HRTEM, and crystal building activities; and the incorporation of social, creative, and recess activities. While there is no doubt that using advanced research instrumentation, such as an HRTEM, can be high risk due to the relatively frequent downtimes, our inclusion of a range of technology, including the scanning electron and light microscopes and the computer-based symbolic representations ensured the success of the program. Qualitative pre-camp and post-camp assessments demonstrate improved concepts of the atomic structure of crystalline solids. Finally, through written and verbal impressions from a wide range of direct and indirect participants, it is clear student engagement and both parent and teacher support was strong for a program of this nature.

Supplemental Information for Building a Successful Middle School Outreach Effort: Microscopy Camp MS 2006_0012 provided online

Preparation of Magnetite: A detailed procedure for the synthesis.

To prepare approximately two grams of magnetite per student group, chemicals and their quantities required are 1.49 g of NaOH, 0.43 g of $NaNO_3$, 0.99 g of $FeCl_2$, and 4.04 g of $Fe(NO_3)_3$. In order to keep potential exposure to chemical hazards to a minimum, a 75 mL of 0.5 M sodium hydroxide solution per student group was prepared and bottled in a 250 mL bottle by the camp counselors. In addition, each solid was pre-weighed into glass vials for distribution to each group. Additional supplies include 250 mL bottles (two per group), 10 mL graduated cylinder, disposable plastic pipettes or eyedroppers, strong magnets (hard drive magnets are ideal), notebook for recording observations, writing utensil, plastic weigh boats, distilled and/or deionized water, non-latex lab gloves, lab safety glasses, and “lab coats”. Helpful but unessential equipment includes a centrifuge, a vortexer, and a mortar and pestle.

For each group of two students prepare vials containing pre-weighed quantities of sodium nitrate, ferric chloride, and ferric nitrate and provide an empty 250 mL Nalgene bottle, one 250 mL Nalgene bottle containing the 75 mL of 0.5 M sodium hydroxide, a strong magnet, non-latex gloves, plastic pipettes, and deionized water.

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CHAPTER FOUR

STUDY C

Integrating Technology into a Secondary Science Licensure Program: Modeling Students' Competencies to Use and Teach with Technology over the Course of the Program. Flynn, L. (2012)

Introduction

Technology is increasingly becoming a routine part of everyday life. From accessing news online to socially connecting with friends and family with Skype, Facebook, or Twitter the way we gather and share information has changed dramatically in the last ten years. Concurrently, the global business and scientific community has employed numerous communication and scientific technologies to increase efficiency and compete in a global economy. Today's children will grow up in a society strongly impacted by technology. In order to provide students with the skills to learn and utilize technology K-12 schools have begun integrating technologies such as computer simulations, presentation software, laboratory probes, internet, and digital microscopes, cameras and video into the classroom. Although the number of technology resources in schools has increased dramatically over the last ten years teachers are challenged to learn and develop effective technology enhanced lessons; for many teachers this new teaching tool is a challenge to effectively implement. Novice and pre-service teachers already struggle to develop effective lessons and the added complexity of learning and preparing to teach with a new technology may be particularly challenging.

Pre-service teachers enrolled in science licensure programs are asked to learn and teach with scientific (lab probes, computer simulations, digital microscopes) and teaching technologies (PowerPoint, concept map software, efolio, Excel) during their teaching methods classes and student teaching experiences. Faculty instructing pre-service teachers are challenged with choosing from many technology choices, making it difficult to select ones with the greatest potential impact to assist their students in creating effective learning activities. Often a minimal amount of teaching and scientific technologies are employed in pre-service teacher training programs due to a lack of equipment and training of faculty and teaching assistants. Integrating new technologies involves an initial expenditure for equipment and software, faculty and teaching assistants' time to learn and integrate the technology into lessons, and a dedication of class time in an already crowded curriculum.

The development of *National Educational Technology Standards* [NETS] (International Society for Technology in Education, 2000) provided a benchmark for teacher licensure programs to assess how well their current technology curriculum aligned with the new standards and acted as a catalyst for curriculum changes. This study presents a Technology Enhanced Learning Model (TELM) the University of Minnesota's science licensure program developed and implemented as a result of assessing current alignment with NETS technology standards and investigates how pre-service teachers reported competencies changed in a) skill to use technology, b) preparedness to teach with technology, and 3) barriers to technology implementation across the course of the program. This study informs future practice for the University of Minnesota program and others looking for a model on how to enhance their technology integration in pre-service licensure programs.

Technology in Pre-service Teacher Education

Education leaders agree that all new teachers must graduate from teacher education programs with the knowledge and skills that will allow them to integrate technology easily and effectively into their daily teaching. Today's pre-service teachers are expected to demonstrate competencies in skill to use and the effective use of technology for teaching and learning as they progress through their student teaching experience. Several researchers (Stobaugh & Tassell, 2011; Pope, Hare, & Howard, 2002; Sang et al, 2010; Fulton, Glenn, & Valdez, 2004; U.S. Department of Education, 2010; Tearle & Golder, 2008; Levine, 2006; Ottenbreit-Leftwich et al., 2010) found teacher education programs do not adequately prepare future teachers to teach with technology; far too many teacher candidates graduate without adequate exposure to, or experience with, effective teaching with technology.

Calls for reform stress the need for programs to ensure pre-service teachers not only understand how to use technology but also how to design high quality technology-enhanced lessons (Lawless & Pellegrino, 2007; Brush et al., 2003; Judge & O'Bannon, 2007; Polly, Mims, Shepherd, & Inan, 2010; Thompson, Schmidt, & Davis, 2003;

Watson, 2001; Wilson, 2003). Programs should provide specific models of how the program infused technology and provide evidence of the models effectiveness.

National Technology Education Standards

A first step to technology reform in teacher licensure programs is to identify a set of standards against which programs can align their current practice. The development of National Technology Education Standards in 2000 provided benchmarks teachers in a licensure program should obtain during the licensure program coursework and practicum and student teaching experiences. All licensure programs should align their curricular scope and sequence to provide opportunities for teachers to meet all of the NETS standards found in Table 1. Programs should provide opportunities a) for teachers to continually increase their skill to use current and emerging technologies, b) to design technology-infused, student-centered learning experiences, c) to use teaching methods and strategies for applying technology to maximize student learning. d) to evaluate student learning, e) to enhance teacher's productivity, professional practice, and communication, and f) to address the social, ethical, and legal issues surrounding technology use.

Table 1. National Educational Technology Standards for Teachers (ISTE, 2000).

Standard	Description
I. Technology Skills and Concepts	*Teachers:* A. demonstrate introductory knowledge, skills, and understanding of concepts related to technology B. demonstrate continual growth in technology knowledge and skills to stay abreast of current and emerging technologies.
II. Planning and Designing Learning Environments and Experiences	*Teachers:* A. design and plan developmentally appropriate and effective learning environments supported by technology.
III. Teaching, Learning and Curriculum	*Teachers:* A. facilitate technology-enhanced experiences that address content standards and includes methods and strategies to maximize student learning.
IV. Assessment and Evaluation	*Teachers:* A. apply technology in assessing student learning of subject matter using a variety of assessment techniques. B. use technology resources to collect and analyze data, interpret results, and communicate findings to improve instructional practice and maximize student learning.
V. Productivity and Professional Practice	*Teachers:* A. use technology to enhance their productivity and professional practice. B. use technology to communicate and collaborate with peers, parents, and the larger community in order to nurture student learning.
VI. Social, Ethical, Legal, and Human Issues	*Teachers:* A. model and teach legal and ethical practice related to technology use.

The NETS define the fundamental concepts, knowledge, skills, and attitudes for applying technology in educational settings which are essential elements to attend to in a technology reform initiative. The NETS recommendations align with those of researchers (Settlage, J., Odom, A.,& Pederson, J., 2004; Doering, Hughes, & Huffman, 2003; Flick & Bell, 2000; NSTA, 2003) suggesting teacher candidates should continually observe and participate in the effective modeling of technology use for both their own learning and the teaching of their students. Technology should be a part of the teaching and learning process in every setting supporting the preparation of teachers, and not merely included in teacher preparation programs in isolation for its own sake.

Technology Integration in Science Methods Courses

Standards are a first step in reform; however, teaching programs need specific guidance to effectively and efficiently restructure their method courses. A preferred approach for restructuring teacher education courses with technology has been to integrate technology in method courses because method courses provide a meaningful context within which the integration of technology can be situated in the teaching of subject matter (Angeli, 2004; Peck, Augustine, and Popp, 2003; Davis & Falba, 2002; Guy, Li & Simanton, 2002). Ertmer (2003) also argues we need to become more specific and explicit about the types of technology-supported lessons teacher educators design, and, in particular, which technology is being infused or integrated to support learning and implementation into classroom practice.

Incorporation of technology into science methods classes is particularly important because many science concepts require the use of science-specific software, instrumentation, and simulations. Appropriate educational technologies have the potential to make scientific concepts more accessible to students through visualization, modeling, and multiple representations. Science methods courses have the task of providing experiences with technologies whose purpose is to provide representations of concepts difficult to represent in everyday experience. For example, kinetic molecular theory, an abstract set of concepts central to the disciplines of physics and chemistry, may be easier for students to understand if they can see and manipulate representations of molecules operating under a variety of conditions by using simulations (Scalise, et al., 2011; Williamson & Abraham, 1995; Smetana & Bell, 2012).

One of the most powerful uses of technology in science teaching is to have students use probeware as a laboratory tool to collect and analyze data. Examples of probes used to collect laboratory data include temperature, motion, force, pH, sound, light and pressure. This technology offers a fundamentally new way of aiding students' construction of science concepts (Trowbridge, Bybee, & Powell, 2008; Linn, Songer, Lewis & Sterm, 199; Zucker, et al., 2008) as well as allowing students to experience what it is like to do science (Vonderwell, Sparrow, & Zachariah,.2005; Tinker & Papert, 1989;). The teacher plays a pivotal role in creating a classroom atmosphere that allows students to investigate using this technology. The overall effectiveness of probeware technology depends upon the teachers' understanding of how to use the new technology, their personal knowledge of the concepts involved, and their knowledge of how to create lessons to help students link their laboratory experiences with the concepts under investigation (Guzey & Roehrig, 2009; Krajcik, Layman, Starr & Magnusson, 1991). To apply these various technologies effectively in their teaching, pre-service teachers must see technology modeled effectively in their teacher preparation training.

Barriers to Technology Integration in Schools

As several researchers have noted, possessing the skill to use a technology does not translate into the ability to effectively teach students (Swan, K., Lin, L., & van't Hooft, M., 2008; Cuban, 2001; McClintock, 1999) One roadblock to technology integration are the real and perceived barriers teachers face as they attempt implementation. The National Center for Educational Statistics (NCES) 2000 survey of public school in-service teachers reported that two-thirds of public school teachers report inadequate teacher training as a barrier to effective technology use. Teachers noted a lack time for training (82 percent), lack of scheduled time for students to use computers (80 percent), insufficient number of computers (78 percent), lack of good instructional software (71 percent), and lack of adequate equipment (66 percent). Additionally, a lack of technical support or advice (64 percent), and support regarding ways to integrate technology into the curriculum (68 percent) were noted. Fifty-nine percent also reported a concern about student access to inappropriate materials as a barrier (Smerdon, et.al., 2000).

A literature review by Hew and Brush (2007) found 128 published articles on in-service teachers reported barriers to technology integration. Barriers include a lack of computers and software (Karagiorgi, 2005; O'Mahony, 2003; Sandholtz, Ringstaff,& Dwyer, 1997; Pelgrum, 2001), limited types of technology in locations where teachers and students can use them (Fabry & Higgs, 1997), and questioning importance of teaching technology because it is not assessed on national examinations (Hennessy et al, 2005).

Although several studies have been conducted on barriers to technology integration for in-service teachers only a handful of studies have been reported on barriers pre-service teachers face as they attempt technology integration. Barriers reported include a lack of training (Goktas, 2009), lack of appropriate software, hardware and materials and difficulty gaining access to technology (Doering, Hughes & Huffman, 2003; Goktas, 2009). When pre-service students have difficulty gaining access to technology they are less likely to see the benefits it could bring in the classroom and therefore perceive learning the technology as a waste of time; many use this excuse not learn technology in the first place (Teo, 2009; Laffey & Musser, 1998). Several researchers found that even if pre-service teachers do increase their skill to use various technologies they have little guidance on how to implement these into the classroom (Polly, Mims, Shepherd, Inan, 2010; Andersson, 2006; Wang, 2002). Ertmer and Ottenbreit-Leftwich (2010) argue that for pre-service teachers to become effective users of technology, teachers need practical strategies for dealing with the different types of barriers from use of specific technologies to creating pedagogical models. Multiple reports claim a common problem is colleges of education that train pre-service teachers possess limited technology compared to most schools where graduates will work and therefore are ill-equipped to model technology integration into teaching practice (Polly, Mims, Shepherd, Inan, 2010; Duhaney, 2001).

Infusing Technology into the University of Minnesota Pre-service Licensure Program

With the development of technology standards for teachers (ISTE, 2000) and calls supporting the notion that technology should be reinforced in the context of meaningful science in science education courses (Davis & Falba, 2002; Guy, Li, & Simanton, 2002) the University of Minnesota science education faculty modified existing curriculum, instruction and assessment practices to keep pace with emerging best practices for teacher education programs. Science methods faculty collaborated with learning technology faculty, university supervisors and cooperating teachers to prepare pre-service teachers to use and create effective technology-enhanced lessons in their teaching practice. At the time of this study, a minimal number of teaching technologies (Powerpoint, word processing, email) and scientific technologies (wet lab techniques, light microscopes) were employed in the science teacher training program due to lack of equipment, training of faculty and teaching assistants, and limited time to collaborate with learning technology faculty and cooperating teachers on effective strategies to implement technology into practice.

The context for this study was the University of Minnesota's M.Ed. Initial Licensure Program (2006-2007) which is a 13 month post-baccalaureate path to licensure in the state of Minnesota. General education foundation coursework (Learning, Cognition & Assessment; Teaching Students with Special Needs in Inclusive Settings; School & Society; Human Relations; Developmental and Individual Differences in Educational

Contexts) begins in June. Student's first engagement with science education faculty and courses begins in September. Students' seeking a secondary science licensure take two science methods courses. In the fall students enroll in a 4 semester hour middle school methods course accompanied by a 4 semester hour middle school practicum experience in the schools. During the spring semester students take a 4 semester hour high school methods course while they complete their 8 semester hour high school student teaching experience.

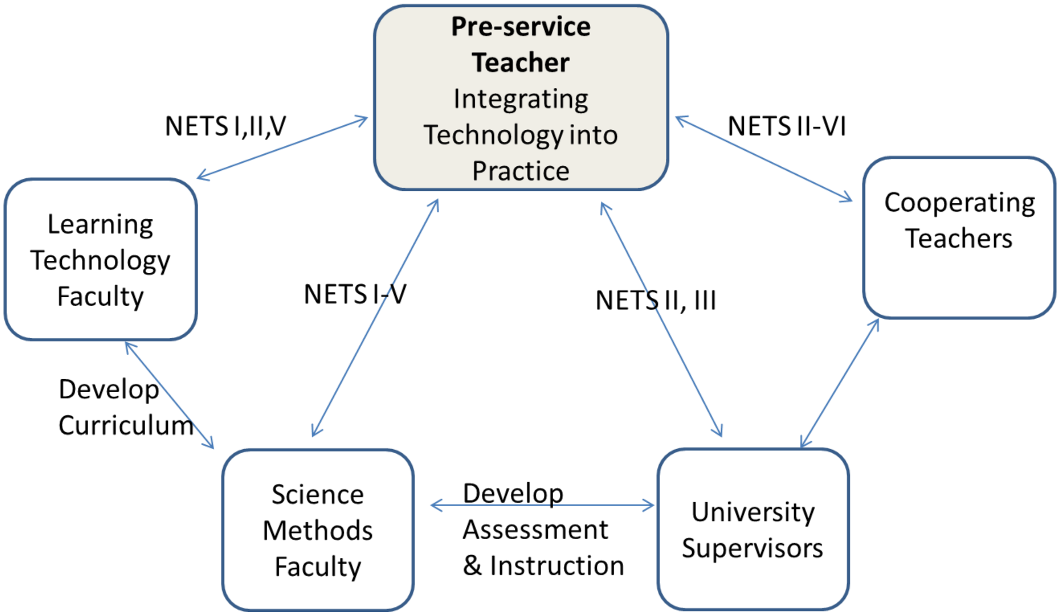
The program secured $8,000 in funding (TEL, 2006) to purchase additional scientific and teaching technologies to integrate into the licensure program. Purchases included 10 sets of Vernier LabPro interfaces, 30 probes (temperature, motion detector, pH), ten TI-92 graphing calculators, a Logger Pro site license and software, and 5 handheld Proscope digital microscopes. In addition, the following software (GIS, PowerPoint, Excel, Inspiration) and website links (Cells Alive, PhET) were installed on the existing classroom set of laptop Macintosh computers.

Technologies were chosen and curricular, instructional, and assessment modifications to the program were partially made based on a pilot survey administered to the previous year science cohort members at the conclusion of their program. This was done to identify technologies pre-service teachers were expected to use that were not represented on the proposed survey. The pilot survey also identified potential barriers our students may face in the coming year. Pre-service teachers were asked a) How did you incorporate technology into your student teaching activities?, b) What barriers did you face when trying to incorporate technology into your student teaching experience?, and C) What technologies would you have liked to learn during your licensure courses so you could implement them in your teaching. In addition, cohort members were asked to rate their skill to use and preparedness to teach with an initial list of technologies faculty members considered implementing based on the 2003 *Technology Use* instrument developed by Klecker, et al. administered at the end of a licensure program. The pilot survey responses for this study informed programmatic partners (science methods and learning technology faculty, supervisors, and cooperating teachers) to potential technology integration barriers which may be reported during the study. Pre-service teachers identified Concept Map software, GIS, electronic gradebook, and VISTA as technologies they used which were not included on the technology list; these were added to the survey. Additionally, the pilot survey was edited by correcting spelling and grammar errors and clarifying the wording of specific technologies to produce the *Technology Use and Preparation* survey used in the current study (Appendix F).

Technology Enhanced Learning Model

This study responds to the call by researchers for programs to detail changes and outcomes produced when infusing technology into methods courses in order to inform the practice of others (Songer, 2007; Ertmer & Ottenbreit-Leftwich, 2010). Figure 1 presents the Technology Enhanced Learning Model (TELM) illustrating a framework for how the secondary science licensure program integrated technology into the existing program.

Figure 1. Technology Enhanced Learning Model (TELM).



The overall goal of the model was to provide pre-service teachers an opportunity to continually observe and participate in the effective modeling of technology use for both their own learning and the teaching of their students and to make technology part of the teaching and learning process in every setting they encounter throughout the program. This was accomplished by collaboratively working across several groups encountering pre-service teachers: science methods faculty, learning technology faculty, university supervisors, and cooperating teachers.

Science methods and learning technology faculty met at the beginning of the fall semester to determine what NETS standards the current 1.5 credit stand-alone *Technology Tools for Educators* course was meeting. By comparing the standards in Table 1 to the course syllabus faculty determined the technology course was partially meeting Standard I: Technology Skills, Standard II: Design Learning Environments Integrating Technology and Standard V: Productivity and Professional Practice using Technology. From the technologies listed on the pilot survey, learning technology faculty identified the specific technologies they would employ using technology enhanced instruction and assessment practices as outlined in the standards; these are outlined in Table 2.

Science methods faculty also met with the pre-service teacher's university supervisors to work on revising curriculum, instruction, and assessment in the fall Middle School Science Teaching (4cr) and Practicum experience (4cr) and in the spring High School Science Teaching course (4cr) and Student Teaching (8cr) to meet NETS I-V. University supervisors then met with the fall and spring cooperating teachers on integrating the technology into the authentic, field-based placements and shared lesson plan formats which explicitly addressed how pre-service teachers planned to incorporate technology. Supervisors reinforced NETS II and III while the cooperating teachers reinforced and modeled NETS II-VI.

Instructional strategies used across the partners to assist pre-service teachers in using and effectively implementing technology into practice included: laboratory activities, computer simulations, demonstrations, authentic assessment, small and whole group discussions, reading, reflection, and direct instruction. Indicators of how each partner attended to the standards are outlined below in Table 2. Collectively the four partners introduced, reinforced, modeled and assessed all six of the NETS standards across the course of the pre-service teachers program.

Table 2. NETS Standard, Partner, and Technology Enhanced Activities Employed Indicating How Standard was Addressed with Pre-service Science Teachers.

Partner	**Technology Enhanced Instruction and Assessment**
Standard I. Technology Skills	
Science Meth[a]	Laboratory (Vernier Probeware, PhET, Cell's Alive, laboratory simulations), Direct Instruction (Inspiration, Excel, gradebook), Demonstrations (Science Websites, VISTA); Small and Whole Group Discussions (e-folio), Authentic Assessment (e-folio, Inspiration, presentation software)
LearnTech[b]	Demonstrations (GIS, computer adapted microscope); Direct Instruction (Powerpoint, e-folio, Moodle), Authentic Assessment (e-folio, Inspiration, Moodle)
Standard II. Design Learning Environments Integrating Technology	
Science Meth	Direct Instruction (Lesson Planning), Demonstrations (discrepant events), Authentic Assessment (lesson planning, discrepant event, Inspiration)
LearnTech	Direct Instruction (Webpage, GIS)
Supervisor[c]	Direct Instruction (lesson planning), Authentic Assessment (lesson plan, classroom observation)
CoopTeacher[d]	Direct Instruction (lesson planning) Model (instruction and assessment with technology)
Standard III. Teaching while Integrating Technology	
Science Meth	Laboratory (Vernier probeware, PhET, Cell's Alive, digital microscope), Demonstrations (science websites, VISTA); Small and Whole Group Discussions (Inspiration), Authentic Assessment (laboratory simulation, Vernier probeware, presentation software)
Supervisor[c]	Direct Instruction (lesson planning), Observation (classroom teaching)
CoopTeacher	Observation (classroom teaching)
Standard IV. Assessment and Evaluation with Technology	
Science Meth	Whole and small group discussions (gradebook); Laboratory Activity (Excel, gradebook, video, digital camera)
CoopTeacher	Authentic Assessment (gradebook, clickers)
Standard V. Productivity and Professional Practice using Technology	
Science Meth	Direct Instruction (NSTA website, Moodle)
LearnTech	Demonstration (Moodle)
CoopTeacher	Demonstration (course webpage, email)
Standard VI. Social, Ethical, and Legal Issues with Technology	
CoopTeacher	Direct Instruction (District technology use guides)

Note: a) SciMeth=Science Methods Faculty, b) LearnTech=Learning Technology Faculty,
c) Supervisor= University Supervisor, d) CoopTeach=Cooperating Teacher

Importance of Study

This study informs research and practice by providing a specific technology implementation model (TELM) to assist in interpreting the outcomes of an attempt to infuse current technology into our science methods courses. There is little research examining the actual technology topics addressed across teacher education institutions to prepare future teachers to use technology and the empirical basis for the inclusion of these topics within the teacher education curriculum (Hew & Brush, 2007; Lawless & Pellegrino, 2007). Specifically this study investigates the following research questions:

1) How do University of Minnesota M.Ed. secondary science initial licensure students reported competencies to use technology and preparedness to teach with technology change over the course of the licensure program?

2) What barriers do University of Minnesota M.Ed. secondary science initial licensure students report as they attempt to incorporate technology into their practicum and student teaching experience over the course of the licensure program?

Incoming student's current technology competencies are reported which may assist programs in narrowing the choices of technologies to address in their programs, allowing resource allocation to other program area priorities. Modeling students' growth in skill to use and ability to teach with technology highlights the impact of technology integration into the methods curriculum across the course of the program and this informs future curricular modifications. Examining students reported barriers faced during technology integration into the secondary science classroom helps inform the link between the focus and impact of technologies currently employed in pre-service teaching methods courses and those barriers encountered in the student teaching setting.

Participants

Participants include 30 University of Minnesota M.Ed. Secondary Science Licensure students (10 males and 20 females) with an average age of 27 years old (range= 22-45, mode=23, median 24.5). All students enter the program holding an undergraduate science degree and were seeking licensure in middle school science and in a high school specialty: Life Science (N=18), Physics (N=4), Chemistry (N=7), and Earth Science (N=1). Students were all Caucasian and drawn from undergraduate schools primarily from the upper Midwest.

Instrument

The survey, *Technology Use and Preparation,* consisted of four parts: A) Demographic information (gender, age, licensure area, ethnicity); B) Open-ended written descriptions and examples of how student's incorporated technology, barriers they faced, and what technologies they would like to learn; C) A 4 point Likert-type scale (0=novice,1= somewhat, 2=proficient, 3= leader) asking students *How skilled they are using the* *following technologies*?; and, D) A 4 point Likert-type scale (0=not at all, 1=somewhat, 2=moderately, 3=extremely) asking students to report *How prepared they are to teach using the following technologies?* Parts C and D of the survey include 22 technologies; fifteen of which were coded teaching technologies (web page development, PowerPoint, concept map software, efolio, electronic gradebook, Excel:data entry, Excel:creating charts/graphs, word processing, Email, TV/VCR, desktop publishing, VISTA, digital camera, digital video, online chat) and seven coded science specific technologies (probeware, computer adapted microscopes, lab simulation software, science websites as resource, graphing calculators, GIS, science websites as research tool). The total possible composite score for section C (skill to use technology) is 66 points. The total possible composite score for section D (prepared to teach with technology) is 66 points.

The same survey was used across all three data collection points. The survey used for this study is a modification of an instrument developed by Klecker, etal. in 2003 to evaluate the effectiveness of a Preparing Tomorrow's Teachers for Technology (PT3) grant at a Mid-Atlantic state university. The population for the study was undergraduate students completing their student teaching. Modifications included removing one technology considered irrelevant to this study as it is no longer widely employed in schools, audiotapes or radio, and replacing it with Concept Map software, GIS, electronic gradebook, and VISTA. The added technologies were identified in the pilot study to be ones our students reported using in local schools or during teacher preparation courses.

For each technology teachers ranked *Skill to Use* the technology and *Preparedness to Teach* with the technology. The survey also included an open-ended free-response question asking pre-service teachers to describe all barriers they faced while integrating technology in their teaching setting. The research team agreed the wording of the open-ended question to assess barriers teachers faced was appropriate.

A standard protocol was used to administer the instrument across the three time points. Pre-service teachers were informed of the purpose of the survey and that their names would be stripped from the coding and assigned a number by one of the researchers. In each administration of the instrument teachers were give unlimited time to complete the survey. Surveys were administered the last 30 minutes of practicum and student teaching seminar. In all three administrations, no survey completion took longer than 20 minutes. Teachers were instructed to answer all questions.

Cronbach's alpha was computed for the *Skill to Use* composite at the first time point, $\alpha_c = .92$ and values at the other time points were similar. To test for scale homogeneity, corrected item total correlations for the items were calculated. The item-total correlations ranged from $r = 0.28$ to $r = 0.84$, and all items but one had $r > 0.30$, Concept Maps ($r = 0.28$). For the *Preparedness to Teach* composite, $\alpha_c = .86$ at the first time point and values were slightly higher for the other times. The item-total correlations ranged from $r = 0.25$ to $r = 0.79$, and two items had $r < 0.30$, digital microscope ($r = 0.28$), and probeware (r = 0.25). Corrected item-total correlations exceeding 0.30 indicate each item is related to the overall scale (Nunnally & Bernstein, 1994). For this study, all items were retained for the longitudinal analysis.

This study reports the results of part B: *What barriers did you face when trying to incorporate technology into your student teaching experience*? part C: *How skilled are you using the following technologies*? and part D: *How prepared are you to teach using the following technologies?* across three time points which span the time students were enrolled in the science methods courses and engaged in student teaching experiences. The means for each technology item are presented and growth curve analysis is presented to note statistically reliable changes in competencies across time. Students were asked to list all barriers they faced while implementing technology across the three time points. Part B of the survey reporting what technologies student teachers would like to learn are not reported here.

Research Design

Quantitative

A repeated measures design was utilized to report on the technology competencies of 30 M.Ed. Secondary Science Initial Licensure students' enrolled at the University of Minnesota over a nine month course of the science licensure program from September to May. Data was collected over three time points at the beginning (Sept.), middle (Jan), and end (May) of the licensure program. Students were surveyed three times with the

Technology Use and Preparation survey to assess their skill to use and preparedness to teach with the 22 (15 teaching and 7 scientific) technologies. In addition, barriers pre-service teachers reported were coded and tallied across the three time points. There was some non-response by participants for technology competency scores at time one (3.3%), time two (10%), and time three (6.7%) of data collection. The data was considered missing at random.

Qualitative

Inductive qualitative content analysis was employed to explore and identify themes and patterns by systematically coding open-ended response data to the question *What barriers did you face when trying to incorporate technology into your student teaching experience?* The constant comparative method (Lincoln & Guba, 1985) was utilized to derive categories for barriers to technology integration for pre-service teachers. Student teachers reported barriers integrating technology on the open -ended section of the survey question, These barriers were then subsequently grouped into a number of tentative categories. Every subsequent new barrier identified was compared to the existing categories, with specific barriers recoded as the definitions and properties of each category became better developed. Analysis continued until the categories were saturated; the additional data began to confirm the existing categories rather than identifying new categories.

To support the trustworthiness of the open coding method the data was coded by several researchers: a faculty member and a graduate student who was previously trained in standardized coding procedures through coursework and as a research assistant on NSF grants. The same coders analyzed the data for all three time points. The data were coded and the coding scheme refined until an acceptable inter-coder agreement of 90% was reached. Three peer debriefing sessions were conducted after the first data collection point, one after time two, and three after the final data collection to establish acceptable inter-coder reliability. Each coder kept detailed field notes while coding to help establish categories which were mutually exclusive and internally consistent. A codebook was created to document coding procedures and defines word meanings. Descriptions of the codes with raw data are presented.

***Data Analysis*.**

Technology competency composite scores for student teachers skill to use and preparedness to teach were collected over three waves and analyzed with growth curves using linear mixed models (LMM). Estimation was performed using SAS PROC MIXED, Version 9.1. LMM was used because it accommodates missing data (there was some non-response, see above), and allows the fitting of relatively parsimonious growth models (Fitzmaurice, Laird, & Ware, 2004). For each variable (skill to use technology and prepared to teach with technology), a linear model and a $\log_e$(time) model was fit. The latter provides a means of modeling non-linear trends with a single slope parameter. Models with time or $\log_e$(time) were compared using the corrected Akaike information criterion (AIC_c) which provides a small sample size bias correction(Anderson, Link, Johnson,& Burnham, 2001; Hurvick & Tsai, 1991). The model with the smallest AIC_c is the best fitting and thus, preferred.

For the LMM, let Y_{ij} be the response variable score (e.g., skill to use technology) for the ith person ($i = 1, \dots, N$) at the jth time point ($j = 1, \dots, n_i$). The LMM is

$$Y_{ij} = (\beta_0 + b_{0i}) + (\beta_1 + b_{1i})t_{ij} + e_{ij}$$

where β_0 is the mean intercept, b_{0i} is the ith person's deviation from the mean intercept, β_1 is the mean slope, b_{1i} is the ith person's deviation from β_1, e_{ij} is random measurement error, and t_{ij} = time or $\log_e$(time) the latter being for a non-linear trend. Because of missing data, $n_i = 1$ or $n_i = 2$ or $n_i = 3$. Thus, n_i is the number of time points unique to ith individual. For example, if the first subject had two time points, then $n_1 = 2$ and $j = 1, 2$. If the second subject had one time point, then $n_2 = 1$ and $j = 1$, etc. Dependency due to repeated measures and individual differences in slope and intercept is accounted for through the random effects covariance structure, $Cov(\mathbf{Y}) = \mathbf{Z}'\mathbf{G}\mathbf{Z} + \sigma^2\mathbf{I}$, where $\mathbf{Z}$ is the the design matrix, $(b_{0i}, b_{1i}) \sim N(\mathbf{0}, \mathbf{G})$, and $e_{ij} \sim N(0, \sigma^2)$.

Results

Results of the linear mixed model analysis are presented in Table 3.

Table 3: Linear Mixed Model Analysis for Student Teachers Ratings of Skill to Use and Preparedness to Teach with Technology.

Variable	Intercept	*Intercept SE*	Slope	*Slope SE*
Skill to Use Composite Score[a]	33.91***	2.04	8.01***	1.30
Preparedness to Teach Composite Score	33.35***	1.79	1.95*	0.95

Note.[a]Slope of Log_e(Time), **p* < .05, **, *p* < .01, ****p* < .001

Composite Score Interpretation

Figure 2 illustrates the change in composite score technology use for *skill to use* technology across the three time points. Time 1 was collected at the beginning of the program (September), Time 2 halfway through the program (January), and Time 3 at the end of the program (May). The predicted intercept for *skill to use technology* of 33.91 is the average initial technology competency score of the group when the study began. The total possible composite score is 66 for the 22 items. The predicted slope of 8.01 (p<.001) for *skill to use technology* indicates an overall statistically reliable increase over time.

Figure 3 illustrates a predicted intercept of 33.35 for *preparedness to teach with technology*. The total possible composite score is 66 for the 22 items. The predicted slope of 1.95 (p<.05) for *preparedness to teach with technology* indicates an overall statistically reliable increase over time.

Figure 2: Skill to Use Technology Composite Competencies Scores.

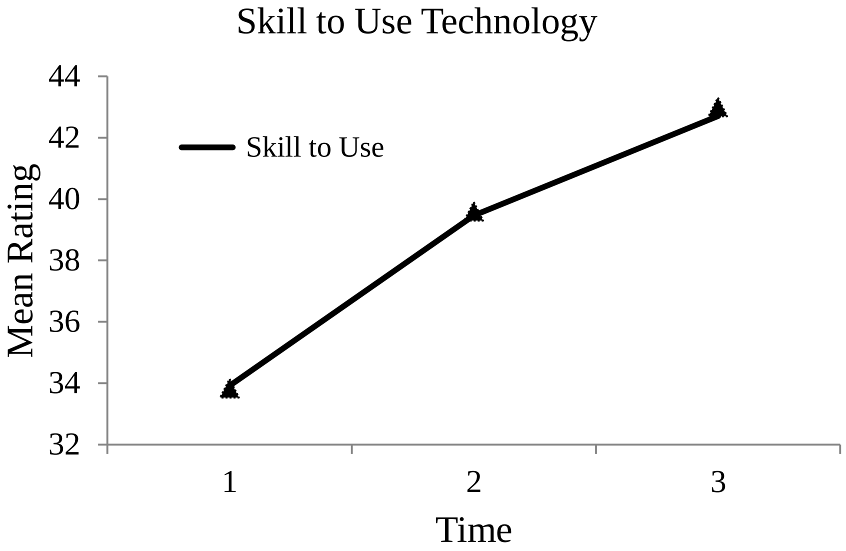
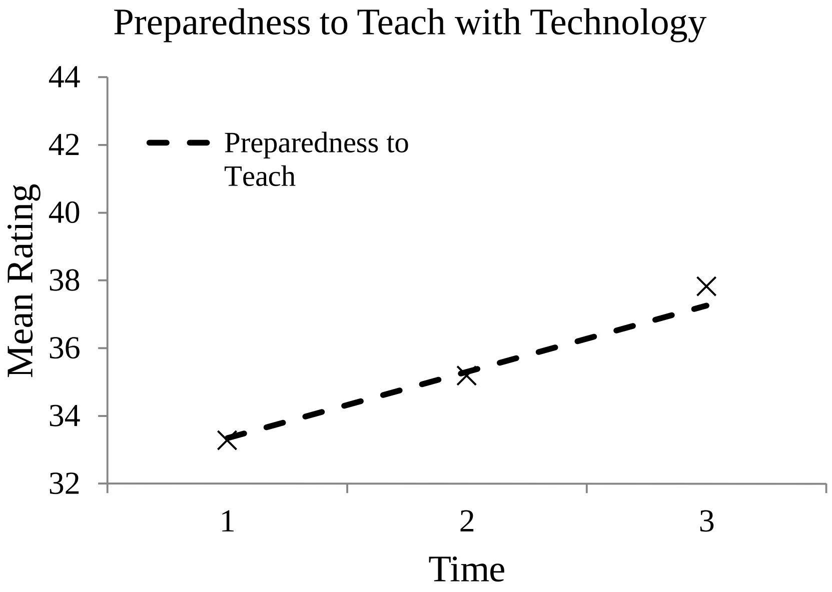


Figure 3: Preparedness to Teach with Technology Composite Competencies Scores.



Individual Technology Score Interpretation

To illustrate specific technology competencies the mean of each of the individual survey items across the three time points is presented in Table 4 arranged in ascending order of mean frequency from the pre-test data. In other words, the competencies students report being most familiar with prior to entering the program (*skill to use technology*) and ready to use in their teaching (*preparedness to teach*) are at the bottom of the table. A 4 point, ordinal Likert-type scale (0-3) was used (Likert, 1932). For skill to use technology 0=novice, 1=somewhat, 2=proficient, 3=leader, and for preparedness to teach 0= not at all, 1= somewhat, 2=moderately, 3=extremely. Item responses for specific technologies are reported to illustrate competencies in technologies at the onset and end of the study which may inform the choice of technologies to focus on across the course of the pre-service program. For example, those technologies rated as between novice or somewhat skilled to use (0-1) and not at all or somewhat prepared to teach (0-1) may require the most attention while those rated as proficient or leader in skill (2-3) and moderately to extremely prepared to teach (2-3) may need less emphasis during the program.

Table 4. Pre-service Science Teachers Reported Mean Frequencies and Effect Size for Skill to Use and Preparedness to Teach with Technology.

Technology	Competency	**T1** Mean[a]	**T3** Mean[b]	**T3-T1** $\overline{X}_{\text{diff}}$	**Cohen's d**
GIS: Geographic Information System	Skill[c]	.08	.25	.17	.30
	Preparedness[d]	.19	.11	-.08	.00
e-folio/digital portfolio	Skill	.44	1.78	1.34	1.09
	Preparedness	.70	1.37	.67	.55
Computer adapted microscope	Skill	.48	0.93	.45	.43
	Preparedness	.56	1.00	.41	.40
Webpage development	Skill	.50	1.07	.61	.78
	Preparedness	.48	.71	.23	.09
Desktop publishing (Page Maker, Microsoft pub)	Skill[b]	.67	1.15	.48	.50
	Preparedness	.85	.96	.11	.09
Grade Book	Skill	.70	1.96	1.26	1.49
	Preparedness	.89	1.56	.67	.61
Probeware to collect data in lab	Skill	.78	1.63	.85	1.31
	Preparedness	.74	1.26	.52	.62
Computer laboratory simulations	Skill	.96	1.70	.74	.93
	Preparedness	.69	1.54	.93	.81
Digital video	Skill	1.44	1.70	.26	.27
	Preparedness	1.56	1.44	-.12	.00
Graphing calculators	Skill	1.59	1.56	-.03	.00
	Preparedness	1.29	1.22	-.07	.00
Concept Map software:	Skill	1.65	2.12	.47	.62
	Preparedness	1.78	2.15	.37	.51
Online discussions: chat rooms	Skill	1.93	1.96	.03	.05
	Preparedness	1.69	1.58	-.11	.00
Digital camera	Skill	1.96	2.04	.08	.11
	Preparedness	1.89	1.59	-.30	.00
Excel Charts/graphs	Skill	2.04	2.41	.37	.55
	Preparedness	2.00	2.07	.07	.09
Science/Science Ed websites: as research tool	Skill	2.07	2.31	.24	.31
	Preparedness	1.89	2.22	.33	.16
Excel spreadsheets: data entry	Skill	2.18	2.44	.26	.50
	Preparedness	2.11	2.18	.07	.12
Presentation software: ie Powerpoint	Skill	2.19	2.63	.44	.65
	Preparedness	2.29	2.26	-.03	.00
Science Websites: as resource	Skill	2.23	2.35	.12	.17
	Preparedness	2.11	2.19	.08	.08
VISTA	Skill	2.37	2.63	.26	.38
	Preparedness	2.19	2.33	.08	.14
Television/VCR	Skill	2.67	2.74	.07	.16
	Preparedness	2.59	2.63	.05	.04
E-mail communication	Skill	2.67	2.89	.22	.53
	Preparedness	2.48	2.74	.27	.31
Computer word processing	Skill	2.74	2.81	.07	.28
	Preparedness	2.70	2.67	-.03	.00

Note: a) N=29, B) N=28 C) Skill= 4 point Likert-type scale used 0=novice, 1=somewhat, 2=proficient, 3=leader d) Preparedness =4 point Likert-type scale 0= not at all, 1= somewhat, 2=moderately, 3=extremely

Initial Competencies

The results of the pre-test survey mean scores for individual technologies indicate students on average report their *skill to use* (M_S) and *preparedness to teach* (M_T) with computer word processing ($M_S=2.74$; $M_T=2.70$), television/VCR ($M_S=2.67$; $M_T=2.59$), email communication ($M_s=2.67$; $M_T=2.48$), VISTA ($M_s=2.37$; $M_T=2.19$), science websites as resources ($M_s =2.23$; $M_T=2.11$), presentation software ($M_s=2.19$; $M_T=2.29$), Excel spreadsheets ($M_S=2.18$; $M_T=2.11$), and Excel graphs/charts ($M_S=2.04$; $M_T=2.00$) in the highest categories of *proficient* and *leader* ($M_S \geq 2.0$) for skill to use and between *moderately* to *extremely* ($M_T \geq 2.0$) in their preparedness to teach with these eight technologies.

On the other end of the spectrum, students report on average feeling between *novice* and *somewhat* prepared ($M_S \leq 1.0$) at their skill to use and *not at all* to *somewhat* prepared ($M_T \leq 1.0$) to teach with computer laboratory simulations ($M_s=0.96$; $M_p=0.69$), probe ware ($M_s=0.78$; $M_p=0.74$), electronic gradebook ($M_s=0.70$; $M_p=0.89$), desktop publishing ($M_s=0.67$;$M_p=0.85$), webpage development ($M_s=0.50$; $M_p=0.48$), efolio ($M_s=0.44$; $M_p=0.70$), computer adapted microscope ($M_s=0.48$; $M_p=0.56$) and GIS ($M_s=0.08$; $M_p=0.19$). Results indicate the eight latter technologies are ones pre-service teachers feel least prepared in their skill to use and preparedness to teach with; therefore, programs may want to focus on these in teacher preparation. In contrast, the former eight appear to be competencies the average student believes they have acquired prior to entering the program and programs may want to deemphasize these technologies to emphasize ones with the greatest need.

Growth in Skill and Teaching Preparedness of Individual Technologies over Time

The greatest gains in *skill to use* technology between pre and delayed post assessment occurred with these seven technologies: grade book ($\overline{X}_{\text{diff}}$ =1.26; d=1.49), probe ware ($\overline{X}_{\text{diff}}$ =0.85; d=1.31), e-folio ($\overline{X}_{\text{diff}}$ =1.34; d=1.09), computer lab simulations ($\overline{X}_{\text{diff}}$ =.74; d=.93), webpage development ($\overline{X}_{\text{diff}}$ =.61; d=.78), presentation software ($\overline{X}_{\text{diff}}$ =.44; d=.65), and concept map ($\overline{X}_{\text{diff}}$ =.47; d=.62). All seven of these technologies were addressed across the program and with multiple instructional and assessment strategies (Table 2) indicating some level of program effectiveness at least with these specific technologies.

By the end of the program 12 of the 22 technologies were rated by students in the proficient to leader category ($M_s \geq 2.0$) for *skill to use*, an increase of 2 from the initial 10. Technologies added to the proficient to leader category include e-folio and concept maps. Science methods faculty and learning technology faculty both emphasized how to use these technologies in their curriculum on multiple occasions through varied instructional strategies (direct instruction, small and whole group discussions) and authentic assessment (creation of individual e-folio, creation of concept map). Two technologies (GIS and computer adapted microscope) remained in the novice category.

Demonstrations by Learning Technology faculty (GIS) and Science Methods faculty (computer adapted microscope) were utilized to teach these technologies which may have not been effective in increasing pre-service teacher's skill to use. Additionally, skill to use graphing calculators ($\bar{X}_{\text{diff}}$ =-.03; d=.00) and online discussions: chat rooms ($\bar{X}_{\text{diff}}$ =.03; d=.05) both rated as between somewhat and proficient in skill to use remained stagnant indicating more direct experiences with these technologies need to be provided across the program.

The greatest gains in *preparedness to teach* using technology between pre and delayed post assessment occurred with these seven technologies: computer lab simulations ($\bar{X}_{\text{diff}}$ =.93; d=.81), grade book ($\bar{X}_{\text{diff}}$ =.67; .61), e-folio ($\bar{X}_{\text{diff}}$ =.67; d=.55), probe ware ($\bar{X}_{\text{diff}}$ =0.52; d=.62), computer adapted microscope ($\bar{X}_{\text{diff}}$ =.41; d=.40), and concept map ($\bar{X}_{\text{diff}}$ =.37; d=.51), and E-mail communication ($\bar{X}_{\text{diff}}$ =.27; d=.31).

In *preparedness to teach*, 10 technologies were rated in the proficient to leader category, an increase of 2 technologies (concept maps and science education websites) from the beginning of the program. Again, for efolio science methods faculty and learning technology faculty directly addressed how to plan and deliver effective lessons with these two technologies. Of note is the fact that while webpage development and concept map technologies were in the top seven in growth in skill to use they were not in preparedness to teach indicating more emphasis may need to be placed on how to effectively teach with these technologies.

Additionally, for preparedness to teach several technologies remained stagnant or decreased slightly across time: GIS ($\overline{X}_{\text{diff}}$ =-.08; d=.00), digital video ($\overline{X}_{\text{diff}}$ =-.12; d=.00), graphing calculators ($\overline{X}_{\text{diff}}$ =-.07; d=.00), online discussions: chat rooms ($\overline{X}_{\text{diff}}$ =-.11; d=.00), digital camera ($\overline{X}_{\text{diff}}$ =-.30; d=.00), presentation software ($\overline{X}_{\text{diff}}$ =-.03; d=.00), television/VCR ($\overline{X}_{\text{diff}}$ =-.05; d=.04), computer word processing ($\overline{X}_{\text{diff}}$ =-.03; d=.00), indicating more attention on how to teach with these technologies needs to be provided across the program.

Barriers to Technology Integration

Student reported technology integration barriers were grouped and classified into three main categories: (a) physical resources, (b) knowledge and skills, and (c) school support. Categories were developed from the complete set of student open-ended responses to the question, *What barriers did you face when trying to incorporate technology into your student teaching experience?* Table 5 presents the category labels and descriptions for pre-service teachers reported barriers across the three data collection periods.

Table 5: Technology Integration Barrier Categories Student Teachers Report while Incorporating Technology into Practice.

Barrier Categories
1) Physical Resources Lack of equipment for classroom, compatibility of new equipment with old, concern over computer access for students at home, lack of funding for new hardware and software, limited number of computer labs, access for only certain classes, theft and damage of technology
2) Knowledge and Skills How to teach for learning, not using technology for technology sake, knowing how to teach with technology, not knowing what is available and how to use, fear of looking stupid in front of tech savy students, how to create lessons that are not too long/boring, how to technology skills improve skills
3) School Support Lack of support staff to help with technical difficulties: virus, crashed network, getting technology hooked up, locating cables, cords, outlets; cooperating teacher resistance to new technology, time allotted in day for set-up and time to learn, technology not part of curriculum

Physical Resources

Example student responses coded into the *Physical Resources* category include:

- *My classroom & school did not have any technology available for use except one computer that was for teacher use;*
- *Having to book the schools data projector and borrow a lab(sic) top whenever I wanted to show something from the web or have typed notes available;*
- *Funding is the largest barrier, technology is expensive to buy and fix. Not all schools will have the funding to provide computers, smartboards, and ceiling projectors for computers;*
- *No access to LCD projectors to show PowerPoint. It was unavailable or a pain to get a hold of;*
- *One projector for the whole school;*
- *The school did not have any probe ware or other technology in the classroom.*

In general student teachers feel there is an inadequate amount of technology available for them to access in the schools. The technology available is in limited supply and lacks updated software or connection cables necessary to use the technology. Availability of computers in the classroom is scarce and most schools only have a few computer labs which are scheduled months ahead of time and mostly used for word processing. Most student teachers resort to using overheads in their classrooms due to the lack of LCD projectors or a screen large enough for students to view. With the limited supply of technology student teachers cite concerns over the possibility that technology may be damaged or stolen. A real or perceived notion that students may not have access to a computer at home limits assignments utilizing computers outside of the classroom.

Knowledge and Skills

Sample responses coded into the *Knowledge and Skills* category include:

- *Worried class became more about technology and not about science;*
- *Trying to learn (or relearn) how to use it;*
- *I had to practice using the smart board before my lessons so I would know how to pull up my screens when I needed them;*
- *How to put together an effective PowerPoint presentation in a timely fashion;*
- *Getting all the technologies set-up was usually the hardest part;*
- *I hope technology is not taking away from their education. Sitting in front of a computer is quite different than the real world.*

When a technology failure occurs pre-service teachers fear looking incompetent or disorganized in front of students. They are unclear of how to gain additional skills of how to use technology and how to best teach with technology. Student teachers are concerned about the value adding technology brings to their lessons. Technology is cited as interfering with the flow of a lesson because it frequently fails and the student teacher is unable to proceed with the lesson as planned.

School Support

In the *School Support* category responses ranged from:

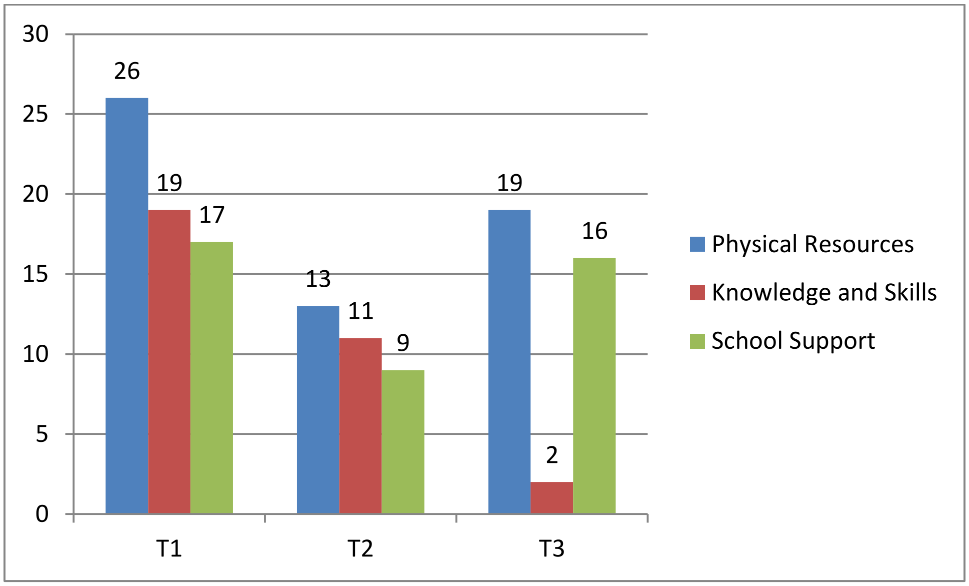
- *My cooperating teacher kept reminding me that she doesn't use any "fancy computer stuff". She told me students learn better from copying notes off the overhead;*
- *"old school" teachers who are against using lots of technology;*
- *Help to hook everything up with cords everywhere- it seemed to be a constant challenge;*
- *A coop teacher that wasn't very gun-hoe for it;*
- *Activities were already planned- I was able to do notes, but other tech. was not used for classes.*

In general students felt there was a lack of technology support staff to assist with the installation, set-up, and support of technology to enhance their lessons. Technology became perceived as more trouble than it was worth. Technology was not explicitly defined as being part of the curriculum and therefore its value was questioned in a crowded curriculum. This paired with a lack of enthusiasm from cooperating teachers left student teachers ambivalent about the importance of integrating technology into their lessons.

Reported Barriers across Time

Figure 5 presents the barrier categories reported by the pre-service teachers across the three time points. Participants were asked to list all barriers they faced while integrating technology. The counts for the barrier categories assist in visualizing a pattern across the the three times points which can assist the program in making adjustments to the TELM model. For *Knowledge and Skills* category the number of total reported barriers steadily decreased (19, 11, 2) indicating the program may have had a positive impact on increasing technology knowledge and skills across time. This may have occurred because the implemented TELM model provided continuous opportunities for pre service teachers to acquire and implement new technology skills into practice and reflect on implementation with multiple sources of support (cooperating teacher, supervisor, science methods and learning technology faculty). This opportunity to engage in and increase their skill with multiple new technologies may have lessened their real or perceived notion of *Knowledge and Skills* as a barrier across time.

Figure 4. Reported Barriers to Technology Integration



A different pattern emerged for the *Physical Resources* (26, 13, 19) and *School Support* (17, 9, 16*)* categories. Initially the reported barriers decreased following the fall practicum experience but then increased following the spring student teaching experience. This pattern may be partially explained by the level of classroom teaching engagement pre-service teachers had during their practicum and spring experiences. The typical pre-service teacher's role in the fall is limited to approximately one class period in the middle school with 4-8 days of instruction with the remainder of their time observing and assisting the cooperating teacher. These short teaching opportunities allow pre-service teachers ample time to plan, discuss, gather materials and practice lessons with their cooperating teacher, science and learning technology faculty, supervisor, and peers. There is enough time to acquire the physical resources (projectors, digital microscopes, computers) and school support (assistance with technical difficulties, reserving computer labs)   to implement the technology enhanced lessons. However, in the spring pre-service teachers are instructing between 3-4 high school classes daily across a 10-12 week experience; providing little time for extensive planning and opportunity to seek assistance. This lack of time may decrease the ability of teachers to acquire the physical resources or support they need to implement technology; therefore increasing their awareness of this as a barrier.

Another possible explanation for the difference in trend patterns may be in how much individual control a pre-service teacher has in reducing the barrier. *Knowledge and Skill* barriers can be reduced by a teacher based on their individual effort put forward such as gaining additional skills with technologies outside of the program requirements and researching and practicing effective technology-enhanced lessons prior to instruction. For *Physical Resources* and *School Support* the pre-service teacher is highly dependent on other faculty, support staff, or school policies to address the issue. This lack of control paired with limited time may have increased the real or perceived barriers from those reported in the fall.

These findings suggest the collaborative TELM model may assist pre-service teachers in decreasing their reported technology barriers in *Knowledge and Skills*; however the model shows little impact on the reported *Physical Resources* and *School Support* barriers across time. Based on these findings, a modification suggested to the TELM model includes sharing the barriers with cooperating teachers and asking them to discuss specific school-based strategies with pre-service teachers on how to solve specific technology issues.

Discussion

The Technology Enhanced Learning Model (TELM) was developed to address curricular changes necessary to meet National Education Technology Standards (NETS). The integration of the TELM collaborative model and introduction of technologies into the program at least initially, over the nine months of engagement, appear to show overall improvement in student's skill to use and preparedness to teach with technology as indicated by the total score on the *Technology Use and Preparation* survey. Across the course of the program, as teachers' skill and preparedness to teach with technology increased (Figure 2, Figure 3) their reported barriers in knowledge and skill decreased (Figure 5). The implementation of TELM showed how our program prepared pre-service science teachers to use and teach with technology in their practicum and student teaching experiences with multiple collaborative partners and varied instructional and assessment strategies. These multiple opportunities across the program increased their technology competencies.

The presentation of TELM model and empirical data responds to a national call for programs to document the curricular, instructional and assessment changes they make so teaching programs have specific guidance to restructure their courses. NETS and several researchers (Levine, 2006; Stobaugh & Tassell, 2011; Fulton, Glenn, & Valdez, 2004; Ottenbreit-Leftwich et al., 2010) point out that many teacher education programs do not plan for and therefore do not properly prepare future teachers in technology. Multiple researchers argue that technology should be infused in several settings and not isolated to one class. Additionally pre-service teachers must be provided experiences that not only help them understand how to use technology but also how to design and deliver quality lessons (Brush et al., 2003; Dawson, Pringle, & Adams, 2003; Ertmer, 2003; ISTE, 2002; Thompson, Schmidt, & Davis, 2003; Watson, 2001; Wilson, 2003). The model presented attends to these calls for change and adds to existing literature by detailing changes to our program and providing outcomes produced after implementation.

As a result of model implementation, science pre-service teacher’s illustrated a modest improvement in ability to both use and teach with technology. These findings are in contrast to those presented by others (Pope, Hare, & Howard, 2002; Selinger, 2001; Wang & Holthaus, 1999; Levine, 2006) showing that programs do not sufficiently plan for and train teachers in technology. The limited number of studies on pre-service teacher’s and technology implementation usage as a result of program curricular modifications is limited and therefore results are highly context specific. In this regard the study adds to the research in pre-service teacher technology preparation.

Barriers pre-service teachers face while attempting to integrate technology can discourage them from attempting or continuing technology usage. Barriers our teachers reported which align with previous findings include: lack of appropriate software, hardware and materials (Polly, Mims, Shepherd, & Inan, 2010; Doering, Hughes & Huffman, 2003; Goktas, 2009; Lawless & Pellegrino, 2007) no time to learn and set-up (NCES, 2000), limited computers in locations where students can use them (Karagiorgi, 2005; O'Mahoney, 2003), no technical support (Goktas, 2009, NCES, 2000), and concern on how to properly implement to create effective lessons (Polly, Mims, Shepherd, & Inan, 2010; Andersson, 2006; Wang, 2002). Additional barrier's our pre-service teachers reported include: resistance by cooperating teacher's to integrate and use technology, concern over student's damaging or stealing technology, lack of their student's access to computers at home; fears of looking incompetent in front of student's. Few studies have been conducted on pre-service teacher's barriers to technology implementation and our findings add to the research base in this area.

The results highlight several areas to be considered when programs consider revising their curriculum. First, programs should continuously evaluate technologies used to train teachers and select those with the highest impact to improve technology competencies for pre-service teachers. These include technologies teachers rate as being unprepared to use and teach with based on results from the *Technology Use* survey and also ones students identify which were not included on the survey, such as Smart boards. Second, programs should share the TELM model and data from of the *Technology Use* survey with new faculty, supervisors and cooperating teachers in order to illustrate each partner's responsibility in technology integration and highlight student teachers competencies. This is particularly important as there is a high turnover rate in supervisors and cooperating teachers. The TELM model should be revised to specifically address the real and perceived barriers to technology integration pre-service teachers report.

Members of the education community who currently work with, or make administrative decisions regarding curriculum, instruction, and assessment decisions in pre-service teacher training programs may find these results valuable as it showcases one university's *Technology Enhanced Learning Model* used to meet National Educational Technology Standards (ISTE, 2000) and presents the outcomes as a result of the models implementation. Pre-service teachers increased their overall skill to use and teach with technology while simultaneously decreasing the barriers they reported facing during implementation. Results of this study add to the limited research base on pre-service teacher's technology competencies and barriers to implementation.

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CHAPTER FIVE

The three studies presented inform research and practice in the area of STEM education standards-based reform initiatives by highlighting the impact of implementation efforts across multiple disciplines, settings and with a variety of participants. Standards in the areas of mathematics, science, and technology were within the last 20 years. Across all three disciplines the research community has called for empirical studies to investigate the impact the adoption and implementation of standards based reform has had on curriculum, instruction and assessment practices of teachers and their students learning. The standards in all three disciplines were created by reform documents, policies and research on best practices in curriculum, instruction and assessment practices.

Study 1, Block Scheduling and Mathematics: Enhancing Standards-Based Instruction, research was informed by several national reform documents. First, the *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989, 2000) provided direction for how teachers could improve classroom instruction. These standards placed more emphasis on conceptual understanding and problem solving and less emphasis on direct instruction of facts. The teacher survey employed assessed use of these practices through several items (work on solving real world problems, participate in discussions to deepen mathematics understanding, describe what you know about a topic before it is taught, etc).

In addition to the NCTM mathematics standards, the National Science Foundation's (NSF) Drivers for Systemic Reform (NSF, 1993, 1995) informed the direction of the research as they outlined a framework for successful components of systemic reform and accountability in mathematics and science education. These drivers included 1) standards-based curriculum aligned with instruction and assessment and providing laboratory experiences to every student, 2) coherent policies, 3) use of multiple resources, 4) inclusion of multiple stakeholders, 5) evaluation of effectiveness of programs on student achievement, and 6) improvement of achievement for all students, especially those historically underrepresented. Items such as *Use community resources in the classroom (museums, business people)*, *Read other (non-textbook) mathematics-related materials in class, Use of calculators or computers to solve problems, and Engage in hands-on mathematics activities, and Model or work on simulations* attended to several of the recommendations. The NSF drivers made joint recommendations for elements of both science and mathematics education reform which began a process of looking at best practices in reform across disciplines.

Other national reform documents informing the model for Study 1 include elements of authentic instruction (Newman, 1997) with a focus on higher order thinking, connections to the world beyond the classroom, substantive conversation, and deep knowledge. Several items on survey addressed these elements including, *participate in discussions to* *deepen mathematics understanding work on solving real world problems, participate in student-led discussions, and make formal presentations.*

Study 2, Building a Successful Middle School Outreach Effort: Microscopy Camp, was developed based on the curricular, instruction and assessment recommendations acquired from the reform documents in Study 1 (NCTM, 1989, 2000; NSF, 1993, 1996; Newman, 1997), along with those in the National Science Education Standards (NRC, 1996), MN Science Academic Standards (MDE, 2005), and Benchmarks for Science Literacy (AAAS, 1993). These documents emphasized students should be engaged in student-centered authentic tasks of importance to the student's lives. Students should be engaged in inquiry investigations to deepen their understanding of the content and practices of science. The study also employed prior research on student's conceptual understanding of atomicity to develop appropriate instruments and instruction. Collectively these recommendations were used to inform the curricular, instruction and assessment practices engaged in during the study.

Study 3, Integrating Technology into a Secondary Science Licensure Program: Modeling Students' Competencies to Use and Teach with Technology over the Course of the Program, built on the established reform documents employed in Studies 1 & 2 but focused on recommendations from the National Educational Technology Standards [NETS] (ISTE, 2000). Similar to the reform documents in Studies 1 and 2 the NETS standards stressed an emphasis on development of core concepts and skills, curricular, instructional and assessment methods to maximize student learning, and communication for collaboration. The NETS standards place a strong emphasis on the productivity and professional practice of teachers and the social, ethical, and legal issues associated with technology which are not emphasized in the science and mathematics based reform documents from Studies 1 and 2.

Researchers and practitioners may use the presented studies research design, curricular framework, instructional practices, assessment techniques, and results to advance their own research and practice. Study 1 illustrates how differences in school schedule impact curriculum decisions and the type of instructional strategies mathematics teachers engage; Study 2 presents an informal science education experience for middle school students and highlights changes in their conceptual understanding of atomic structure; Study 3 examines how implementation of a Technology Enhanced Learning Model into a teacher preparation program impacts pre-service teachers technology competencies and barriers to implementation.

To facilitate the use of this research the studies have been published in peer-reviewed journals (Studies 1 & 2) and presented at peer-reviewed national conferences (Studies 1, 2 & 3). Peer-review has highlighted several strengths and weaknesses in the studies which should be attended to in future research and practice. Presented here are the studies

1) methodological considerations with suggestions for future research, and 2) implications for teaching and learning.

Methodological Considerations and Suggestions for Future Research

Study 1, Block Scheduling and Mathematics: Enhancing Standards-Based Instruction

Study 1 illustrated several elements of effective research practice. First, the data was drawn from a large, multi-year NSF funded grant which allowed substantial resources to be devoted to the project across several years. Sustained engagement with the project allowed adequate time to revise and refine the research design prior to and during execution of the grant. A collaborative research team consisting of several experts in educational research informed all phases of the research design, implementation, analysis, scholarly presentations and publications. The strong leadership of senior personnel paired with their expertise in research design and methods enhanced the overall quality of this study significantly. The experts mentored the novice student researcher of this study on appropriate research questions, data entry, data mining, data analysis and interpretation of results which lessened the likelihood of errors.

Another strength of this study is the large sample size (156 teachers, 60 principals) drawn from multiple sites (62 middle schools across 3 states). Previous research in this area involved small sample sizes and was highly context specific. Although not a randomized control study, this quasi-experimental study did provide a sufficient matching of groups on several teacher characteristics shown to impact classroom teaching practice: teaching experience, level of formal education, and professional development.

An additional strength of the study included pilot testing and revision of the survey instrument. Two pilot tests were conducted and the survey was revised prior to collecting data. Psychometric properties were determined and items eliminated which were not performing well. Experts in school administration reviewed the survey to guarantee the items were concurrent with school issues and practices. Experts in education reviewed items to guarantee they were aligned with reform-based practices.

The article also advanced the type of analyses presented in the principal leadership journal where it was published, *National Association of Secondary School Principals*. Prior to this journal article, data presented had been mostly descriptive in nature with a handful of studies where inference testing was conducted and confounding variables were considered. In this study, data on teaching strategies between block and traditional school settings were presented with two analyses, with and without controlling for relevant demographic variables. When differences existed in demographic characteristics, such as socioeconomic status, the variable was controlled for by using ANCOVA analysis to illustrate if this variable accounts for some differences in the two school settings. Socioeconomic status did appear to account for one of the teaching strategies found to be statistically reliable, *use of calculators or computers to solve mathematical* *problems*. This allowed the researchers to hypothesize that socioeconomic status may be a barrier to the use of calculator and computer use in traditional setting schools (where SES was lower) and not because the students were in a block schedule setting.

Despite the positive methodological aspects of Study 1 several items should be considered in future studies including research instruments and data analysis. First, self-reports by teachers were used to measure the level of engagement in standards-based instructional practices. Survey self-reports may not accurately reflect the reality of classroom instruction. Observation and reporting of the teacher's classroom instructional practices by the research team using a teacher observation protocol would increase the validity of this measure across teachers. If this is impossible due to cost, a sample of teachers should be observed to compare their self-report assessment to the observation protocol to provide added validity evidence.

The second consideration is the interpretation and presentation of hypothesis testing when multiple comparisons are made on the same set of data, in this case teachers reported instructional practices. Two of the seventeen instructional practices presented in Table 2 (writing reflections and use of calculators or computers) were statistically significant between the two classroom settings assuming independent levels of $\alpha=0.05$. It may be preferable for the entire set of instructional practices to be tested at $\alpha=0.05$.

Adjusting the alpha level when multiple comparisons of teaching practices are made using the same data avoids an increase in type I error (false positive) that occurs when inference tests are used repeatedly on the same set of data. The Bonferroni correction method can be used to counteract the problem by adjusting the alpha level by testing each individual hypothesis at a statistical significance level of $1/n$ times (1/17 in this case) what it would be if only one hypothesis were tested. Then the Bonferroni correction $\beta = \alpha/n$ would test each of the individual tests at a significance level of $0.05/17 = .003$. Considering this new criteria, the two instructional practices (writing reflections and use of calculators or computers) are no longer statistically significant, indicating there is no statistical difference between block and traditional schedule schools on any of the standards-based instructional practices.

ANCOVA testing was performed on the items *Use of calculators and computers* (p = 0.04) and *Write reflections in a notebook or journal* (p= 0.00) which showed a significant difference between block- and traditional-schedule schools. This was done to tease out the possible confounding variable of socioeconomic status (SES). Results indicated calculator use may be more related to SES than type of school schedule. The ANCOVA should have also been performed on the one item that was close to reaching significance levels, *Participate in discussions to deepen mathematics understanding* (p= 0.07) to establish if controlling for SES would indicate a significant difference.

Descriptive statistics of means and standard deviations for block- and traditional classroom engagement with reform based classroom activities are presented in Table 2 along with inferential testing of significance between the two settings. Although the table provides the necessary information to calculate Cohen's effect size (means, standard deviations, p-value) it would be helpful to include this descriptive statistic in Table 2. Over a decade ago the American Psychological Association stated that the reporting of effect sizes is considered good practice when presenting empirical research findings (Wilkinson, 1999). The reporting of effect sizes facilitates the interpretation of the substantive and not just the statistical significance of findings. Effect size is a measure of the magnitude or strength of a relationship without making any statement about whether the relationship in the sample data reflects a true relationship in the population. For example, the effect size for the item*, Write reflections in a notebook or journal,* is d= 0.5 indicating a moderate effect while only a small effect of d= 0.3 exists for the item *Use calculators or computers* even though both showed statistical significance with the t-test (Cohen, 1988).

Block scheduling is purported to provide more instructional time to provide standards-based practices. Although teachers in this study noted how many days they engaged in particular practices there was no accounting for the actual time on task per day these students spent in these practices. For example, in both settings teachers report students spent an average of one day a week *evaluating their own mathematical work.* This provides no indication of whether this was for 10 or 80 minutes during the day. Across the course of a typical sixteen week semester the range of engagement in this practice could be between 160 to 1280 minutes. Future work should account for detailed times of student engagement possibly through observational studies.

Additional studies investigating varied instructional practice of teachers between block and traditional schedule schools should focus on the middle school setting as this study added to the very limited data drawn from this population; the majority of studies are from the high school setting where block scheduling was first initiated. In addition, regardless of school setting, few studies exist beyond the academic areas of mathematics and literacy. These have been areas of research interest as data is available in these subjects from annual state achievement tests. Research should be expanded to areas, like science, where standards-based teaching practices have been highly emphasized and therefore differences in school schedule may be observed.

Study 2, Building a Successful Middle School Outreach Effort: Microscopy

The researcher drew on the strengths and weaknesses from Study 1 to inform the design of Study 2. The strengths of this study included sustained collaborative engagement among researchers and stakeholders, pilot testing and revision of the qualitative assessment tool, detailed description of treatment, and use of qualitative methods for an emerging area of research. Design features which should be attended to include a richer description and more examples from student data, reporting of follow-up data, and anticipating loss of participants.

Study 2 was a collaborative multi-year project funded by the National Science Foundation which involved participation from both science education and science researchers. Teaming the two research traditions increased the overall project effectiveness by sharing multiple modes of research engagement which led to choosing the most effective procedures and practices to accomplish project goals. For example, because of the exploratory nature of the research the science education researcher suggested creating a qualitative assessment tool to answer the research questions; the science researcher suggested multiple choice items. There were no known standardized items for this age group which addressed the research questions therefore a new open-ended assessment tool was created. The scientist's content expertise allowed for suggestions of a variety of investigations which the science education researcher could choose from based on science standards, student's age, and interests.

Creating an assessment tool which closely aligned with the research questions and was tailored towards the age of the participants was a positive attribute of this study. The assessment tool (Appendix B) was developed, pilot tested, and revised several months before implementation. The researcher first interviewed four, 6th grade students and then returned a month later to interview four new students with the revised assessment. The 6th grade science teacher selected four students with variability in achievement based on 3rd quarter grades. One low achieving (bottom quartile), two middle achieving (second and third quartile), and one high achieving (top quartile) student was selected. This was done to provide a range of possible responses across all ability groups. The initial assessment was changed based on student responses and suggestions for wording and a list of new probing questions was developed. For example, the original wording of item 2a was, *Draw what you would see for the small piece of salt and sugar if you could zoom in as far as you can.* One student responded, *Do you mean with the best microscope ever or just with my eyes?* the second commented, *With the world's most powerful microscope?* Student's noted they had just used microscopes with different lens magnifications to look at plants. The classroom teacher confirmed all students had used microscopes to look at differences in plant and animal cells. Because of this language familiarity the researcher decided to change question 2a to, *Draw what you would see for the small piece of salt and sugar if you could zoom in and look at them using the World's most powerful microscope.* Prompting students that they were able to zoom in with tools other than their unaided eye made it more likely we could probe for microscopic views of particulate matter and not just macroscopic views which may have been reported if students believed they could only use their unaided eye.

Another revision involved breaking apart a question asking for multiple comparisons. The pilot question, *How are your two drawings of the salt and sugar* ***alike*** *and* ***different****?*

was broken into two questions, *How are your two drawings of the salt and sugar* ***alike****?* and, *How are your two drawings of the salt and sugar* ***different****?* This helped prompt the student to answer the questions in more detail. The researcher also increased the amount of space for student's to draw and label their structures because students did not want to draw outside of the boxes provided. These changes clarified the questions for students which gave more time for the researchers to ask probing questions when drawings or language was unclear which avoided having to code responses as "unclear". This was important in light of the small sample size of 10 students.

To assist other researchers in replicating and interpreting the results thorough details were provided on the types of activities students' engaged in across the course of the experience which are believed to have produced the change in conceptions. This is important because the treatment provided was novel compared to previous studies in that it provided multiple opportunities for students to develop notions of particulate matter and atomicity using a variety of scientific tools not utilized in previous research (electron microscopes) and at a variety of magnifications (eyes, hand lens, light microscope, electron microscope).

The coding of student responses by the science and education researchers was a strength of this study because it involved coming to a shared understanding of criteria for coding items as "correct", "unacceptable" or "unclear". These criteria would then be consistently used in publication and future research. To increase inter-rater reliability the four researchers first independently coded the pilot data then shared explanations for why they coded as they did. This allowed categories and descriptors to be created. For example, “Acceptable” responses would illustrate correct atomic structure in which atoms would maintain consistent size and shape. This also highlighted the importance of the probing questions which helped clarify drawings such as, *What is this circle? Are these circles the same or different sizes?* The inter-rater reliability of the coded pilot data was K=0.84 which increased to K=0.94 for the published study.

Although issues about inter-rater reliability were attended to in the research it was not included in the publication. This could have easily been added to *Table 3: Distribution of Pre- and Post-Assessment Data*. Also, because of page limit considerations, added examples of student drawings and how individual student drawings changed were not included. This would have added to the richness of the assessment analysis by providing the reader with details of student responses as opposed to just reporting the number correct over time. The researcher took field notes for each individual student when probing questions were asked; however, because of the poor quality of audio-recordings (due to fume hoods running) the researcher was unable to verify all of the student’s verbal responses to the recorded field notes in several circumstances. This may have increased the number of responses which were coded “unclear”.

The coded data in Table 3 needs to be more detailed regarding the change in individual student responses for item 2a, which assesses conceptions of what a small piece of salt would look like microscopically. On the pre-assessment, none of the ten students provided an acceptable representation, nine were coded unacceptable, and one was coded unclear. In the post-assessment, eight students were coded acceptable, one as unacceptable, and one as unclear. The chart does not illustrate if the student who had an unclear drawing on the pre-assessment retained an unclear drawing, or moved to an unacceptable or acceptable drawing on the post-assessment. This student's coding remained unclear across the study but the data presented does not reflect this finding.

Initially the study was to include a third time point six months after completion of the summer experience. Unfortunately, 5 of the 10 student's had left the school where they were recruited. The IRB obtained for this study did not allow for us to obtain student transfer data so we only interviewed 5 students for the follow-up assessment. The IRB the following year was changed to account for mobility of students in the Minneapolis School District and follow-up data was collected on 11 of the 12 participants (92% retention over 3 time points) . Because of these limitations, it is difficult to draw any substantial conclusions about the impact the experience had on students except to say it appears to at least initially improve students conceptions of the particulate nature of matter.

Study 3, Integrating Technology into a Secondary Science Licensure Program: Modeling Students' Competencies to Use and Teach with Technology over the Course of the Program

The longitudinal design, pilot study, and use of both quantitative and qualitative methods were strengths of Study 3's design while improvements in the survey design and collection of additional data are considerations for future study. Previous studies of teacher's technology skill involved one-shot surveys to categorize types and frequency of technology use or pre- and post- survey collection following brief interventions. For the pre- and post- designed studies the interventions typically involved a short (day or two) instruction followed by a post survey to assess teacher's competency following treatment. These studies shed no light on the teacher's competency over an extended time period which makes comments on the sustainability of treatment questionable. Several researchers have called for longer duration studies with details about teacher training programs curriculum and instruction in order to aide in the interpretation of the data.

This study spanned nine months and three data collection points across the course of the program which provides the ability to establish trends over time and not just at the conclusion when employing a specific technology. The study also outlines the TELM model used and specific instructional strategies and technologies employed to assist interpreting the results. The longer time horizon and assessing competencies across three time points in a naturalistic setting adds to the credibility of statements on sustained efficacy over time.

Based on the lack of prior research investigating barriers faced while pre-service teachers attempt to integrate technology the researcher chose an open ended survey response format for the question, *What barriers did you face when trying to incorporate technology into your student teaching experience*? This allowed all possible responses from pre-service teachers and did not constrain responses to those from the researcher's experience. The unique set of barrier categories created informs the research and practice for future studies on pre-service teachers.

Collection of pilot data from the previous year's science cohort helped refine the list of choices for specific technologies used for the Likert-type items. For the individual technologies listed, modifications included removing one technology considered irrelevant to this study as it is no longer used widely in the classroom, *audiotapes or radio*, and replacing it with *Concept Map software, GIS, electronic gradebook,* and *VISTA*. The added technologies were identified in the pilot study open ended response question, *What technologies would you like to learn during your licensure courses so you could implement them in your teaching?* as ones our pre-service teachers reported using in local schools or during teacher preparation courses.

Despite the positive design features of this study several features should be attended to in future studies. The 4-point Likert-type survey used to assess pre-service teachers skill to use and preparedness to teach with individual technologies should be revised considering the longitudinal nature of this design. Restricting responses to a 4-point scale can lead to low variability in scores due to a ceiling effect which can lower power for statistical inference testing. The ceiling effect is demonstrated on several items during the first data collection point. For example for the item *skill to use word processing* 22 of the 29 participants responded with a maximum score of 3(leader), and 20 of 29 participants ranked their preparedness to teach with *word processing* as 3(extremely), the highest value possible. Consideration should be given to increasing the scale choices to avoid participants beginning the study at the maximum score as the goal of the longitudinal design is to model trends which could increase, decrease or stay the same. For participants who begin the study at the maximum score their trend trajectory can only decrease or remain constant. Two items on the survey (digital microscope, r= 0.28; probeware, r=0.25) did not appear to perform well based on item-total correlations. The low number of participants (N=30) suggests more data should be collected so that an informed decision can be made about inclusion or exclusion of items in further studies.

Conducting individual interviews to discover the barriers to technology integration pre-service teachers' face would have added to the richness of the data and credibility of the coding categories constructed. At a minimum, a small subset of participants should have been interviewed to confirm that the barrier categories formed captured the essence of what the participant was expressing in their open ended response to the question, *What barriers did you face when trying to incorporate technology into your student teaching experience*?. For example, one pre-service teacher wrote, I *don't think my coop likes technology because he always says it is just a bunch of bells and whistles and kids can learn just as well without us having to set-up technology in our classrooms. This gave me the impression I shouldn't use technology in his room.* This response was coded under the category, *School Support.* However, with further probing it may have been revealed the cooperating teacher did not understand the value of technology to improve student learning or did not possess the skill to use the technology the pre-service teacher was suggesting. If this was the case the category would have been changed to *Knowledge and Skills*.

Another struggle with the design was the lack of resources devoted to the project. The project was funded over one academic year; however it only provided funds to purchase technology. Therefore, the amount of time researchers had to devote to the project was limited and this impacted the choice of research tools employed and subsequently the depth of analysis which could be undertaken. Future research should also follow-up with the pre-service teachers once they are fully licensed and engaged in their own classroom to capture the impact of the program longer term and also to provide teacher insights as to successes and areas for improvement with the TELM model.

Implications for Teaching & Learning

Study 1, Block Scheduling and Mathematics: Enhancing Standards-Based Instruction

Block scheduling, with a typical 85 minute period, has been proposed as an option which supports the use of standards-based teaching practices because it allows sufficient time to engage in extended investigations that cannot typically be completed during a 50 minute traditional school period. The opportunity for students to engage in these sustained activities supports increased student learning. Seventeen standards-based mathematical instructional and assessment practices were examined and only two practices were found to involve more engagement with the block schedule, *use of calculators or computers* and *writing reflections in a notebook or journal*; however when socioeconomic status is considered, only *writing reflections in a notebook or journal* was significantly different. This indicates teaching, and by extension student learning, may not be substantially impacted by just considering school schedule.

Due to the relatively recent trend of schools switching to block schedule, teachers in these school settings may still be instructing their students with the same methods they used when they were on a traditional schedule. If this is the case teachers would need support to incorporate standards-based instructional practices, possibly through professional development and peer coaching, in order to take advantage of the extended schedule. Regardless of schedule, teachers in both settings only engaged in standards-based instruction half of the time (2-3 times a week) for only 2 of the 17 strategies (use calculators or computers and work on solving real world problems). Although these are strategies encouraged in the mathematics standards they are also typical of a practice found in traditional settings.

In both settings, standards-based practices for the majority (65%) of the remaining practices were engaged in never, rarely, once a month, or less than once a week. These results are troubling and indicate more emphasis needs to be placed on transforming all teachers' classroom practice to improve student learning outcomes.

Study 2, Building a Successful Middle School Outreach Effort: Microscopy Camp

This study impacts teaching practice and student learning by providing examples of activities for classroom incorporation and data to illustrate areas where students' struggle which may need additional attention during instruction. Study 2 illustrates students in middle school can form acceptable notions of the particulate nature of matter if allowed the opportunity to investigate with multiple activities which address the microscopic and macroscopic nature of matter. National and state standards emphasize the importance of students gaining a scientifically acceptable notion of particulate matter in middle school in order to build more sophisticated notions of atomicity in high school (NRC, 1996; AAAS, 2001; MNDOE, 2009). In addition to increasing student's content knowledge, the goal of activities was to be, 1) reproducible in a home or school setting, 2) relevant to student’s everyday life and attend to their interests, and 3) age appropriate. By attending to these four goals the implication is that the activities would increase student learning and be more likely to be integrated into classroom practice.

Microscopy Camp served as a pilot study to test and assess the viability of activities to be used in the Minneapolis School District middle school curriculum. The data from this study informed future projects where all Minneapolis secondary science teachers were invited to Microscopy Camp for Teachers (2007-2011) to improve their content knowledge of and explore effective pedagogy when teaching the particulate nature of matter. At the teacher institutes activity kits were provided of all investigations conducted by students in Microscopy Camps 2005 & 2006. Teacher’s engaged in the same activities and assessments as the middle school students and then compared their responses to those of the students. Overall pre-assessment data showed teachers displayed incomplete conceptions prior to Microscopy Camp and these improved following the experience. Many teachers held the same incomplete conceptions as their middle school students.

Examining student responses provided teachers with a better idea of how students struggle with understanding the concepts and what they should focus on in instruction. To facilitate incorporation of the activities into classroom practice teachers were provided time to reflect individually and as a group on each activity. Teachers wrote reflections on how the activity applied to their curriculum, how it could be improved, and what new knowledge and skills they learned as a result of the activity. These activities increased the likelihood that the new content knowledge and effective pedagogy would be incorporated into the teacher's classroom practice.

Study 3, Integrating Technology into a Secondary Science Licensure Program: Modeling Students' Competencies to Use and Teach with Technology over the Course of the Program

Study 3 illustrates that implementing a collaborative technology learning model can positively impact the skill and preparedness to teach with technology of pre-service teachers while also decreasing the barriers these teachers report across the course of the program. To increase the skill of pre-service teachers, programs should provide multiple opportunities to engage with technologies, this could occur in open technology labs. At the beginning of practicum experiences pre-service teachers can inventory what technologies are typically used in the classroom so they may acquire the skill to use these well in advance of the days they teach. Finally, the list of technologies the science education and learning technology faculty utilize in their courses should be constantly revised to include emerging technologies (Smart boards, clickers, iPad) teachers will use in their practicum experience. Programs should also minimize the emphasis on increasing the skill of those technologies students report a high level of skill entering the program (word processing, e-mail communication).

Teachers report their skill to use technology consistently higher than their preparedness to teach with technology. This finding impacts the instruction teacher educators should engage in during licensure coursework and practicum experience. Courses should not only allow sufficient time for pre-service teachers to gain competency with a technology but also time to reflect and plan how the technology may be best implemented in a classroom setting. For example, pre-service teachers could design a lesson using technology and model it in peer groups to receive feedback on the effectiveness of instruction to increase student learning outcomes. Discussions should focus on why the technology is necessary and how it assists student's development of concepts. For example, differences in cell structure between plant and animal cells can be improved utilizing light microscopes. The microscopes allow students to image samples from their own environment (plant from yard, cheek swab) and construct their own drawing of each cell. Students can then label the similarities and differences using their own descriptions which can later be matched with academic language. The use of the microscope allows students to be active participants in the construction of new knowledge as opposed to passive participants where the teacher lectures by showing pictures of cell types and labels the parts. By explicitly stating how a technology can or cannot increase student learning pre-service teachers are able to make decisions about the appropriate use of technology in the classroom.

Providing opportunities for pre-service teachers to reflect and discuss technology use during the licensure program can help minimize several barriers addressing concerns over instructional choices and the impact on student learning. In the *Knowledge and Skills* category concerns over not knowing when and why using technology is important to improve student understanding of concepts is a concern. Sample responses include, *Sometimes technology takes so long to use, I wonder if it is helping them learn the idea any better than just telling them; I hope technology is not taking away from their education*; *Worried class became more about technology and not about science*. In our programs we should be explicit how technology can positively impact learning. The goal is to provide opportunities so pre-service teachers can link instructional decisions to student learning outcomes. Then, pre-service teachers can base decisions to integrate technology because it improves student learning and minimize technology use when no added value can be identified.

Conclusions

The standards movement emerged to focus greater attention on student learning, to ensure the success of all students, and to provide guidance for educational improvement.

Reform initiatives were launched and research conducted to illustrate the effect of standards-based reform implementation on a variety of student and teacher outcomes. The series of studies presented here adds to the research literature about the impact of standards-based practices on curricular, instructional and assessment practices of teachers and the impact these have on student learning across multiple settings. Study 1 suggests that school schedule alone may have little impact on facilitating changes in the instructional practices of teachers. Study 2 outlined a successful informal education experience to increase student understanding of atomicity and the particulate nature of matter. Study 3 presents a higher education curriculum model to increase the technology competencies of pre-service science licensure students. Systemic reform in STEM education involves evaluating research across multiple studies encompassing multiple disciplines and populations to advance those practices most effective in meeting reform goals. The results of these three studies inform future educational reform initiatives and research directions in STEM education.

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APPENDIX A

Figure 1. IRB Approval for Study 2: Building a Successful Middle School Outreach Effort: Microscopy Camp

Study Number: 0601E80048

Principal Investigator: Leslie Flynn

Title(s):
Assessing Student's Understanding of the Particulate Nature of Matter

The study number above is assigned to your research. That number and the title of your study must be used in all communication with the IRB office.

For research in schools: Any changes to this research must be approved by the IRB and school district involved before initiation.

If you requested a waiver of consent or documentation of consent and you received this email, approval for the waiver has been granted.

This exemption will last for three years from the date of this correspondence and will be filed inactive at that time. If this research will extend beyond three years, you must submit a new application to the IRB a month prior to the study_s expiration.

Upon receipt of this email, you may begin your research. If you have questions, please call the IRB office at (612) 626-5654.

You may go to the View Completed section of eResearch Central at http://eresearch.umn.edu/ to view further details on your study.

The IRB wishes you success with this research.

Figure 2. IRB Approval for Study 3: Integrating Technology into a Secondary Science Licensure Program: Modeling Students Competencies to Use and Teach with Technology over the Course of the Program.

The IRB: Human Subjects Committee determined that the referenced study is exempt from review under federal guidelines 45 CFR Part 46.101(b) category #2 SURVEYS/INTERVIEWS; STANDARDIZED EDUCATIONAL TESTS; OBSERVATION OF PUBLIC BEHAVIOR.

Study Number: 0509E74746

Principal Investigator: Bhaskar Upadhyay

Title(s):
Effectiveness of Integrating Technology Into The K-12 Science Initial Licensure Program

The study number above is assigned to your research. That number and the title of your study must be used in all communication with the IRB office.

Research that involves observation can be approved under this category without obtaining consent.

SURVEY OR INTERVIEW RESEARCH APPROVED AS EXEMPT UNDER THIS CATEGORY IS LIMITED TO ADULT SUBJECTS.

Upon receipt of this email, you may begin your research. If you have questions, please call the IRB office at (612) 626-5654.

You may go to the View Completed section of eResearch Central at http://eresearch.umn.edu/ to view further details on your study.

The IRB wishes you success with this research.

APPENDIX B

Microscopy Camp (PRE)

Name:________________________________

Item 1: Observe the small pieces of salt and sugar in front of you with the magnifying glass. A) **Draw** what you see for salt and sugar in the boxes below. ***Label your drawing.***

*Drawing of **Salt*** *with Magnifying Glass*	*Drawing of **Sugar*** *with Magnifying Glass*

B) How are the two drawings for salt and sugar **alike**?

C) How are the two drawings for salt and sugar **different**?

D) Next you will be asked to imagine zooming in to look at the salt and sugar with the World's Most Powerful Microscope, what does the phrase "World's most Powerful Microscope "mean to you?

Item 2: A) **Draw** what you would see for the small piece of salt and sugar if you could zoom in and look at them using the World's Most Powerful Microscope**. Label your drawing.**

*Drawing of **Salt** with World's Most Powerful Microscope*	*Drawing of **Sugar** with World's Most Powerful Microscope*

B) How are your two drawings of the salt and sugar using the World's Most Powerful Microscope **alike**?

C) How are the two drawings of the salt and sugar using the World's Most Powerful Microscope **different**?

D) What do you believe salt is made of?

E) What do you believe sugar is made of?

Item 3: Observe the large piece of salt in front of you with your eyes and with the magnifying glass. A) **Draw** what you see for the large piece of salt in the box below. **Label your drawing.**

Drawing of Large Piece of ***Salt***
With Magnifying Glass

B) How is your drawing of the large piece of **salt** the **same** as the small piece of salt you drew earlier?

C) How is your drawing of the large piece of **salt different** from the small piece of salt you drew earlier?

Item 4: A) **Draw** what you would see for the large piece of salt if you could zoom in and look at it using the World's Most Powerful Microscope**. Label your drawing.**

Drawing of Large Piece of ***Salt*** *With World's Most Powerful Microscope*

E) How are the two drawings of the small and large piece of **salt** using the World's Most Powerful Microscope **alike**?

F) How are the two drawings for the small and large piece of **salt** using the World's Most Powerful Microscope **different**?

G) What do you believe the large piece of **salt** is made of?

APPENDIX C

Table 1. Research Collaborators Name , Affiliation and Associated Study

Name	Affiliation*	Study
Dr. Frances Lawrenz	Educational Psychology, UM	1
Dr. Mathew Shultz	Kinesiology, UM	1
Dr. John Nelson	NanoCharacterization Facility, UM	2
Dr. Andreas Stein	Chemistry, UM	2
Dr. Christy Haynes	Chemistry, UM	2
Dr. Greg Haugstad	NanoCharacterization Facility, UM	2
Joe Franek	Chemistry, UM	2
Dr. R. Lee Penn	Chemistry, UM	2
Dr. Wei Zhang	Diagnostic & Biological Sciences, UM	2
Deb Newberry	Dakota County Technical College	2
Page Johnson	Edina High School	2
Dr. Jennifer Kuzma	Humphrey Institute of Public Policy, UM	2
Linda Palmquist	Minneapolis Public Schools	2
Dr. Brandy Toner	Soil, Water, and Climate, UM	2
Dr. Deena Wassenberg	College of Biological Sciences, UM	2
Dr. Christine Greenhow	Learning Technologies, UM	3

Dr. Bhaskar Dahal	Curriculum & Instruction, UM	3
Dr. Gillian Roehrig	Curriculum & Instruction, UM	3
*Note: Affiliation at time research conducted, UM= University of Minnesota, Twin Cities		

APPENDIX D

Journal and Publisher Information for Published Studies 1 and 2

Study 1: *Block Scheduling and Mathematics: Enhancing Standards-Based Instruction?* **NASSP Bulletin**, a peer-reviewed journal, is the award-winning official journal of the *National Association of Secondary School Principals* that contributes scholarly and research-based knowledge that informs practice, supports data-driven decisions, and advances the vision and performance of middle level and high school principals. **NASSP Bulletin** features a wide range of articles of enduring interest to educators to promote students learning and achievement, provide insight for strategic planning and decision making in schools, and provide research and contemporary perspectives on educational reform and policies. **NASSP Bulletin** is also used as a resource and a teaching text by professors of educational leadership who are involved in preparing new school administrators and by school district leaders at all levels and their professional staffs who are concerned about the professional development or new and veteran school leaders and teacher leaders. NASSP Bulletin is published by Sage Publications, Thousand Oaks, California.
http://www.principals.org/s_nassp/sec_inside.asp?CID=42&DID=42

Study 2: Building a Successful Middle School Outreach Effort: Microscopy Camp.
The Journal of Chemical Education is the journal of the Division of Chemical Education of the American Chemical Society. Published continuously since 1924, JCE is the world's premier chemical education journal. The mission of the journal is to help chemistry

teachers stay current with research advances as well as share new ideas in teaching methodologies and course organization. The Journal of Chemical Education is published by the American Chemical Society Division of Chemical Education, Bellmawr, NJ. http://www.jce.divched.org/

APPENDIX E

Figure 1. Letter to NASSP Bulletin Requesting Copyright Permission

UNIVERSITY OF MINNESOTA

Twin Cities Campus ***Department of Curriculum and Instruction*** *125 Peik Hall*
College of Education and Human Development
159 Pillsbury Drive S.E.
Minneapolis, MN 55455

Editor
NASSP Bulletin
Washington State University
College of Education
P.O. Box 642136
Pullman, WA 99164-2136

October 21, 2007

Dear Dr. Foster,

I am writing to request authorization to use my article entitled, **Block Scheduling and Mathematics: Enhancing Standards-Based Instruction?** by Leslie Flynn, Frances Lawrenz, and Matthew J. Schultz published in NASSP Bulletin, 2005 89: 14-23 for inclusion in my alternate dissertation. My dissertation will include three articles, including this one, which were published while pursing my PhD in Education at the University of Minnesota.

I will need a brief letter from you authorizing the use of this material. <u>The authorization letter must state that the copyright owner is aware that Proquest/UMI may supply single copies on demand.</u>

Thank you for your consideration in this matter. If you are willing to grant permission you may send the letter to my email leslie@umn.edu or by post to the address in the letterhead above. I look forward to publishing with NASSP Bulletin in the future as I begin my career.

Sincerely,
Leslie Flynn
Leslie Flynn
Teaching Specialist

Figure 2. Response from NASSP Bulletin

-----Original Message-----
From: Hutchinson, Adele [mailto:Adele.Hutchinson@sagepub.com]
Sent: Friday, October 26, 2007 11:59 AM
To: leslie@umn.edu
Subject: FW: Alt Dissertation permission NASSP

Dear Ms. Flynn,

Thank you for your request. Please consider this written permission to reuse your work detailed in your letter in your dissertation. Please include proper attribution to the original source. Please note that this permission does allow Proquest/UMI to allow your dissertation to be downloaded on demand. Please note that this permission does not include any 3rd party material found within the work. Good luck with your dissertation!

Best,
Adele

-----Original Message-----
From: Leslie Flynn [mailto:leslie@umn.edu]
Sent: Sunday, October 21, 2007 3:31 PM
To: Foster, Lenoar
Subject: Alt Dissertation permission NASSP

Dr. Foster-
Please see the attached letter for permission to use an article I published with NASSP Bulletin in my alternative dissertation. Thank you!
-leslie flynn

Leslie Flynn
Teaching Specialist
Science Education
University of Minnesota

374 Peik Hall
159 Pillsbury Dr
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Ph:(612)625-3267
Fax: (612)624-8277
leslie@umn.edu

Figure 3. Letter to Journal of Chemical Education Requesting Copyright Permission

UNIVERSITY OF MINNESOTA

Twin Cities Campus
Department of Curriculum and Instruction
College of Education and Human Development
125 Peik Hall
159 Pillsbury Drive S.E.
Minneapolis, MN 55455

John W. Moore, Editor
Journal of Chemical Education
University of Wisconsin-Madison
209 N. Brooks St.
Madison, WI 53715-1116

October 21, 2007

Dear Dr. Moore,

I am writing to request authorization to use the article entitled, **Building a Successful Middle School Outreach Effort: Microscopy Camp** by R. Lee Penn, Leslie Flynn, and Page Johnson published in the Journal of Chemical Education in June 2007, Vol. 84, No. 11 for inclusion in my alternate dissertation. My dissertation will include three articles, including this one, which were published while pursing my PhD in Education at the University of Minnesota.

I will need a brief letter from you authorizing the use of this material. The authorization letter must state that the copyright owner is aware that Proquest/UMI may supply single copies on demand.

Thank you for your consideration in this matter. If you are willing to grant permission you may send the letter to my email leslie@umn.edu or by post to the address in the letterhead above. I look forward to publishing with the Journal of Chemical Education in the future as I begin my career.

Sincerely,
Leslie Flynn
Leslie Flynn
Teaching Specialist
Figure 4. Response from Journal of Chemical Education

American Chemical Society's Policy on Theses and Dissertations

Thank you for your request for permission to include **your** paper(s) or portions of text from **your** paper(s) in your thesis. **Permission is now automatically granted**; please pay special attention to the implications paragraph below. The Copyright Subcommittee of the Joint Board/Council Committees on Publications approved the following:

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APPENDIX F

Technology Use Survey

2005/2006 Cohort POST

Thank you for taking the time to fill out this survey. Your responses will be used to assess educational technology needs in the UM Science Education Licensure Program.

Part A. Demographic Information

Name: ___________________
Gender:__________________ Licensure Area:_____________________
Age: __________________ Ethnicity: _______________________

Part B. Technology Use in Licensure Program

How did you incorporate technology into your student teaching activities/experience? Provide a specific example(s).

What barriers did you face when trying to incorporate technology into your student teaching experience? Provide a specific example(s).

What technologies would you like to learn during your licensure courses so you could implement them in your teaching?

Part C. Current Technology Competencies

How *skilled are you* using the following technologies? ***Mark one box only***	*Novice*	*Somewhat*	*Proficient*	*Leader*
Webpage development	○	○	○	○
Science Websites: as resource	○	○	○	○
Science/Science Ed websites: as research tool	○	○	○	○
Concept Map software: Inspiration, CMap tools	○	○	○	○
GIS	○	○	○	○
Presentation software: ie PowerPoint	○	○	○	○
Electronic grade book	○	○	○	○
Computer laboratory simulations	○	○	○	○
Computer adapted microscope	○	○	○	○
e-folio/digital portfolio	○	○	○	○
Excel spreadsheets: data entry	○	○	○	○
Excel spreadsheets: creating charts/graphs	○	○	○	○
Probeware to collect data in lab	○	○	○	○
Computer word processing	○	○	○	○
Television/VCR	○	○	○	○
E-mail communication	○	○	○	○
VISTA	○	○	○	○
Desktop publishing (Page Maker, Microsoft publishing)	○	○	○	○
Excel Charts/graphs	○	○	○	○
Graphing calculators	○	○	○	○
Digital camera	○	○	○	○
Digital video	○	○	○	○
Online discussions: chat rooms	○	○	○	○
Other:	○	○	○	○
Other:	○	○	○	○

Part D. Current Preparedness to teach Student's Technology

How *Prepared* are you to teach your students to use the following technologies? ***Mark one box only***	*Not at All*	*Somewhat*	*Moderately*	*Extremely*
Webpage development	○	○	○	○
Science Websites: as resource	○	○	○	○
Science/Science Ed websites: as research tool	○	○	○	○
Concept Map software: ie Inspiration, CMap tools	○	○	○	○
GIS	○	○	○	○
Presentation software: ie PowerPoint	○	○	○	○
Electronic grade book	○	○	○	○
Computer laboratory simulations	○	○	○	○
Computer adapted microscope	○	○	○	○
e-folio/digital portfolio	○	○	○	○
Excel spreadsheets: data entry	○	○	○	○
Excel spreadsheets: creating charts/graphs	○	○	○	○
Probeware to collect data in lab	○	○	○	○
Computer word processing	○	○	○	○
Television/VCR	○	○	○	○
E-mail communication	○	○	○	○
VISTA	○	○	○	○
Desktop publishing (Page Maker, Microsoft publishing)	○	○	○	○
Excel Charts/graphs	○	○	○	○
Graphing calculators	○	○	○	○
Digital camera	○	○	○	○
Digital video	○	○	○	○
Online discussions: chat rooms	○	○	○	○
Other:	○	○	○	○