

Strategies For Integrating STEM Content: A Pilot Case Study

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Abstract

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By Fred Figliano

The goal of this study was to identify strategies used by exemplar practitioners to develop integrated instruction. A pilot case study design was used and four sources of data were analyzed allowing for a convergence of data sets. These data sets included a questionnaire, an audio recording, lesson plans, and student artifacts. Data were analyzed through theme analysis producing 26 strategies. These strategies were then collapsed into a final list of 15 representing important areas of consideration for practitioners. A careful review of these 15 strategies identified three broad strategy categories: Planning, Implementation, and Evaluation. By grouping strategies in this way, each could be shown to relate to specific aspects of the overall integrative instructional process.

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Chapter I: Introduction

Science, technology, engineering, and mathematics (STEM) literacy is a critical component of 21st century education (AAAS, 1989, 1993; NCTM, 2000; ITEA, 2000).

America's current educational reform agenda is spurred by an urgent need for a more STEM literate population. The central tenet of STEM literacy is the preparation of people who are knowledgeable of the connections between the content and practices of the STEM fields. When conceived as an integrated curriculum model designed around teamwork and problem-solving environments, STEM education is the ideal pathway for achieving such literacy.

A goal of STEM education is developing interdisciplinary thinkers. Interdisciplinary instruction is the act of consciously applying methodology and language from more than one discipline to make connections in content that cuts across subject areas (Pring, 1973, Jacobs, 1989, Drake, S., & Burns, R. 2004). Pring (1973), in his analysis of the term 'integration' concluded that "the very notion of 'integration' incorporates the idea of unity between forms of knowledge and their respective disciplines." For developing interdisciplinary thinkers, integrative instruction is the requisite approach.

Integrative instruction can be a powerful way to present information to students. It has the potential to present seemingly abstract topics in a practical, application driven way. The National Council for Teachers of Mathematics (2000) recognizes this potential. The *Principles and Standards for School Mathematics* stresses the integration of math concepts and students' own interests so that they can "connect mathematical concepts to their daily lives, as well as to situations from science, the social sciences, medicine and commerce."

Helping students to make these connections is a topic that has been central to recent educational reform agendas. One limitation common to elementary school curriculum is that teachers often move from topic to topic without any logical connections between them (Wineburg & Grossman, 2000). The lack of logical connections could be one reason why students have difficulty applying knowledge to other subject areas. If we can better understand the processes surrounding the design and delivery of “integrative” instruction, we will be better informed to help other educators to teach using integrative instructional strategies.

The research presented in this document was designed to identify and describe successful teaching strategies revealed by studying an exemplar of integrative instruction. The results provide a clearer, deeper understanding of the instructional practices found effective in delivering integrative instruction and promoting more STEM literate students.

Need for the Study

Current literature reveals that we do not yet fully understand what integrative instruction is, from the practitioners prospective, how it is designed, or how it is integrated into classroom practice. The research in this case study therefore addresses the need to better understand integrated instructional strategies by attempting to identify them and understand how they are used. Doing so will give teachers a springboard for planning lessons and building units that utilize integrative instructional methodologies. Through this investigation, a set of strategies will surface that are “cross disciplinary” and can be used by practitioners to give lessons based on integrative instructional strategies.

Problem Statement

The problem of this study is to examine pedagogical practices associated with exemplar approaches to Integrative Instruction of STEM content at the high school level, inclusive of both

teacher and student perspectives. As a means of answering this problem, we must first begin to understand how to teach STEM content in an integrated way by identifying successful strategies for the delivery of integrative instruction.

Purpose of Study

The data gathered from this study gives Technology Education practitioners strategies to use when designing instruction to purposefully integrate STEM content. Ultimately, the purpose of this study was to identify strategies used by exemplar practitioners to deliver purposeful integrative instruction.

Research Questions

This study is guided by the following research question and sub-questions:

How are teaching/learning strategies, as reflected in exemplars of integrative instruction, used to promote the purposeful integration of STEM content?

The data needed to answer the question were gathered through the following set of sub-questions.

RQ-S1 What strategies are used in lesson plans to purposefully integrate STEM content?

RQ-S2 What instructional strategies do teachers use, based on self-reflection, to teach purposefully integrative STEM content?

RQ-S3 What collaborative teacher strategies are used in planning for purposeful integration of STEM content?

RQ-S4 What strategies are used to evaluate student recognition of multidisciplinary connections?

Delimitations

1. A convenience sample of a single high school was the focus of this study.

Limitations

1. Biases introduced by the methods used to select participations, design tools, and process results.
2. Time considerations related to population due to the school calendar

Definitions

Integrated Curriculum

An educational sequence organized in such a way that cuts across disciplines and teaches students to transfer knowledge to the real world. (NCTE, 1935, Pring, 1973, Shoemaker, 1989, Beane, 1997, Drake, S., & Burns, R. 2004)

Integrated Instruction

The purposeful selection and use of instructional strategies to intentionally transfer knowledge from one discipline into another. (Barton & Smith, 2000)

Multidisciplinary Instruction

The use of a common topic or theme to organize lessons or units that incorporate two or more subject areas. (Jackson & Davis, 2000, Drake, S., & Burns, R. 2004)

Interdisciplinary Instruction

Consciously applying methodology and language from more than one discipline to make connections in content that cuts across subject areas. (Pring, 1973, Jacobs, 1989, Drake, S., & Burns, R. 2004)

Integrative STEM Education

An integrative curriculum model that seeks to make connections among the Science, Technology, Engineering, and Mathematics (STEM) disciplines through the use of open-

ended and real world problems. (Drake, S., & Burns, R. 2004, VT Technology Education, 2006, Sanders, 2006)

Chapter II: Review of Literature

This chapter presents the exploration of literature relevant to this study. The goal of this exploration was to inform the investigator of the current state of relevant literature and to help the reader understand the topics found in this study. There are four areas covered in this section which were included based on the research question. The exploration begins with the need for integrative STEM education. This was chosen as the first area because integrative STEM education must be understood before any other topics. The next topic covered is integration. This was next because after an understanding of STEM education is achieved, integration is next because this research study seeks to look at STEM education in an integrative way. The third topic covered is pedagogy because after integrative STEM education is understood, it is important to understand it in the context of classroom practice. The exploration ends with a review of case study research methods. Case study is used as the design of this study and is included in this section as a segway to Chapter III.

STEM Literacy

A goal of K-12 education is to prepare a literate citizenry to enter college or the workforce. Since today's global market is vastly competitive and, in order for the U.S. to compete, it must focus on "its knowledge-based resources, particularly in science and technology..." (National Academy of Sciences, 2006). Therefore, increasing STEM literacy must be the focus of today's educational reform agenda. Today's youth are the future of this country. They are the ones that will make the decisions affecting this country's future. In order for the citizens of the United States to positively affect the future of their country, they will have to make informed decisions. For citizens to be properly informed, it is necessary that they are educated and have a functional level of STEM literacy. The National Academies (2006) report to

Congress states that, “Americans need a basic understanding of science and technology to lead productive lives in today's increasingly complex, high-tech society...” If this country’s future decision makers are not properly educated and provided with a functional level of STEM literacy, their uninformed decisions will have great consequences for the future successes of this country.

The United States ranked 16th out of 17 nations for 24-year-olds who earn engineering or natural science degrees as opposed to other majors (NAS, 2006). According to the 2003 Trends in International Mathematics and Science Study (TIMSS), U.S. eighth graders lag behind several other nations in science and mathematics. In order to bridge these gaps within the STEM fields, the United States educational system needs a plan to generate STEM literacy among its citizens.

As seen in the history of the United States, the educational system has responded with major reforms to a number of significant events. These reforms include an educational emphasis in mathematical problem solving and scientific inquiry, following the post WWII era (1960’s) when the Russians became the first nation to launch a manned space craft (Sputnik) into orbit. *A Nation at Risk*, compiled by the National Commission for Excellence in Education (NCEE) in April 1983, provided a response to the “widespread public perception that something is seriously remiss in our educational system” (NCEE, 1983). The report evaluated current problems with the educational system and provided recommendations for improvement and implementation. Most recently, *Rising above the Gathering Storm* (NAS, 2006), outlines the United States’ economic deficiencies compared to the rest of the world. The report describes actions that the government can take to increase the emphasis on science and technology so that the U.S. can compete and prosper within the global community (NAS, 2006).

In response to these calls for reform from both the public and the government, there have been various initiatives to promote the development of science, technology, engineering and math education in U.S. schools. These initiatives include *Science for All Americans* (SfAA) (American Association for the Advancement of Science [AAAS], 1989), which provided a framework for science education and how it relates to math and technology. The *Principles and Standards for School Mathematics* (National Council for Teachers of Mathematics [NCTM], 1989) provided a vision for mathematics reform. The *Benchmarks for Science Literacy* (AAAS, 1993) outlines targeted learning goals by grade level for how students should progress towards science literacy. The *Standards for Technological Literacy* (STL) (International Technology Education Association [ITEA], 2000) provides a structure for the implementation of Technology Education in grades K-12. *The Engineer of 2020: Visions of Engineering in the New Century* (National Academy of Engineering, 2004) outlines insights for the future of scientific and technological trends and suggests ways to improve the education of engineers in preparation for emerging technical, social and ethical issues, resulting from new technologies. The *Criteria for Accrediting Engineering Programs* (Engineering Accreditation Board [ABET], 2004) presents criteria for the accreditation of undergraduate engineering, technology, and computer science programs in the U.S.

According to the National Science Foundation (NSF), “raising academic achievement levels for all students is a top priority for education reform at all levels across the United States. Interdisciplinary education can increase learning gains among low achieving minority students while increasing engagement and problem solving skills for all levels of students (Mehalik, Doppelt & Schunn, 2005). Interdisciplinary education has the potential to increase STEM literacy levels among all students.

The Need for Interdisciplinary Education

The goal of integration is to help students make sense of interrelated subjects as they are all parts of a common problem. Kain (1993) suggests there are two purposes for integration: “either improving student learning and engagement in the present system or replacing the system altogether.” If an interdisciplinary curriculum is implemented to improve the current educational system, it should be accessible to all students and be beneficial for everyone.

The purpose and benefits of interdisciplinary education vary from study to study. Some claim that it increases students’ interest and curiosity (Brusic, 1991; Ingram, 1966), engagement and problem solving skills (Loepp, 1999); skills in certain subjects (Clayton, 1989; Cordogan, 2001; Dugger & Johnson, 1992; Fisher, 2001), or achievement among certain demographic groups of students (Mehalik et al., 2005; Scarborough & White, 1994). It also decreases behavioral problems (Cordogan, 2001). Kain (1993) claims that the true purpose and benefits of interdisciplinary education cannot be found in empirical discovery. He argues that a variety of tools, such as standardized tests and ethnographic portrayals, should be used to examine educated persons who are emerging from an integrated program. Interdisciplinary education has the potential to make the curriculum more relevant, while increasing the engagement and curiosity levels of all students. This is a step towards raising the STEM literacy levels among Americans.

Pedagogical Practices

Pedagogical Knowledge

Pedagogy refers to the techniques and strategies used by practitioners to develop instruction (Huber, 1999). Without pedagogy, teachers risk producing poorly developed lessons that may not be effective in stimulating student learning. Pedagogy represents a blue print that the instructor can follow in order to appropriately introduce students to new knowledge.

Student-centered instruction and teacher-centered instruction represent two pedagogical models (Freire, 1996). In the student-centered model the teacher acts as a facilitator rather than one who didactically imparts knowledge to students. This didactic method represents the teacher-centered model where students simply act as depositories of knowledge. The goal then of professional education should be to develop pedagogies to link ideas, practices, and values (Shulman, 2005). This goal can be met through the use of a professional teaching commons.

Teaching Commons

Educators must be willing to share their ideas with others both inside and outside of their own fields. “If you have only a hammer, then everything looks like a nail.”(Huber, 1999). If we shelter ourselves in our own box then we will never grow or move forward as a community of educators. We must break free of traditional paradigms and begin fostering dialogue between all disciplines. This will not only improve our field over the long term, it will also promote more dynamic educational experiences that will produce the leaders of the future. If we as a community of educators diversify our techniques more than a single “hammer” we will begin to see that there may be more effective ways of teaching than what we have been using (Huber, 1999).

Research Designs

The goal of this study was to identify strategies of integrative STEM education. To get a clear picture of strategies several data sources must be analyzed. These data sources may include lesson plans that each teacher creates as a guide for what should be taught each day. Data sources may also include collaborative planning meetings. These would be meetings attended by groups of teachers to discuss the planning of integrative units. It may also include student work to assess if students are making cross-disciplinary connections. To analyze these different data sources, a

research design must be chosen that can handle them all. Therefore the research design chosen was case study.

A case study approach can be useful for this research project because it can be used to better understand integrative instruction through its close examination. It can offer thick, rich descriptions of the experiences of teachers. A case study can also help to develop a better understanding of the links between the four STEM disciplines, as well as the link between curriculum standards and state content standards.

A case study involves studying a particular individual, program or event in depth for a defined period of time. It can be useful for learning more about how programs change over time, as a result of circumstances or interventions. Data collected can include observations, interviews, documents, photographs, videotapes and audiotapes (Yin, 2003, Miles, 1994).

Pilot Case Study

There are three general reasons to choose to do a pilot case study: convenience, access, and geographic proximity (Yin, 2003). This means that a case may be chosen due to its ease of access and proximity to the research institution. When designing a case study there are many decisions that must be made. These decisions are known as case study protocols which include all aspects of how data will be collected and analyzed (Yin, 2003). To make better protocol decisions, a pilot case study may be initiated. “The pilot case is more formative, assisting you to develop relevant lines of questions—possibly even providing some conceptual clarification for the research design as well” (Yin, 2003). In this way, the tools and methods of analysis were chosen to be sure that appropriate data could be collected to answer the research questions. “The inquiry of the pilot case can be much broader and less focused than the ultimate data collection plan” (Yin, 2003). This allowed for the exploration of data at a higher level to help refine the inquiry and ultimately allow insight into a more focused study.

The goal of this pilot case study is analytic generalization. As Yin (2003) describes, “the case study, like the experiment, does not represent a “sample,” and in doing a case study, your goal will be to expand and generalize theories (analytic generalization) and not to enumerate frequencies (statistical generalization)”.

Chapter III: Method

This chapter presents the method used to answer the research questions of the study. This chapter includes the following sections: research design, selection of subjects, description of the instrument, data collection and data analysis.

Research Design

A pilot case study design was used as the framework for conducting this research, and was guided by the following research question and sub-questions:

How are teaching/learning strategies, as reflected in exemplars of integrated instruction, used to promote the purposeful integration of STEM content?

The data needed to answer the question will be gathered through the following set of sub-questions.

RQ-S1 What strategies are used in lesson plans to purposefully integrate STEM content?

RQ-S2 What instructional strategies do teachers use, based on self-reflection, to teach purposefully integrative STEM content?

RQ-S3 What collaborative teacher strategies are used in planning for purposeful integration of STEM content?

RQ-S4 What strategies are used to evaluate student recognition of multidisciplinary connections?

In developing the research questions, data sources and methods of analysis had to be considered. Once the overarching question was developed, four sub-questions were identified that would help to answer the overarching question. As each sub-question was independently considered an appropriate data source was identified for each. Once data sources were identified,

methods of analysis had to be chosen that would produce appropriate data to answer the research questions. All of this needed to be determined at the beginning of the study to produce a framework for the research design. That conceptual framework is shown in Table 1.

Table 1
Data Design

Research Question	Data Source	Data Analysis
What strategies are used in lesson plans to purposefully integrate STEM content?	Lesson Plans	Theme Analysis
What instructional strategies do teachers use, based on self-reflection, to teach purposefully integrated STEM content?	Open-ended Questionnaire	Theme Analysis
What collaborative teacher strategies are used in planning for purposeful integration of STEM content?	Tape recorded planning meeting	Theme Analysis
What strategies are used to evaluate student recognition of multidisciplinary connections?	Student Artifacts	Theme Analysis

The design of this research calls for the analysis of exemplar programs featuring integrative instruction. To accomplish this analysis, a pilot case study design was implemented. The specific type of case study used was a “single case: embedded” design. The single case comes from the use of only one participating site. It is embedded because data were collected from three different instructor perspectives: Biology, History, and English. The four research sub-questions were individually applied to each of these perspectives, and then analyzed as a whole through a process of convergence discussed later in this section.

A case study has the unique ability to deal with multiple types of data in order to create an accurate picture of a phenomenon. The over arching question in this case study is a “how” question, an exploratory question that tries to understand how an event occurs. To answer the “how” question in this case study, four sub-questions have been developed. These questions addressed four different aspects of the phenomenon through four different sets of data that allow for a convergence of information. This convergence of data helped to create a clearer picture of integrated instruction. Data collection followed a logical flow from teacher to student, and was arranged around four phases.

These phases are organized around three themes, Integrated Teaching Practice, Teacher Knowledge, and Student Learning, as depicted in Figure 1. Data of integrated teaching practice were collected from both planning meetings and lesson plans. Teacher knowledge data were collected through the use of an open-ended questionnaire. Student learning data were collected from student artifacts. These three themes provided a mechanism for the convergence of data through triangulation.

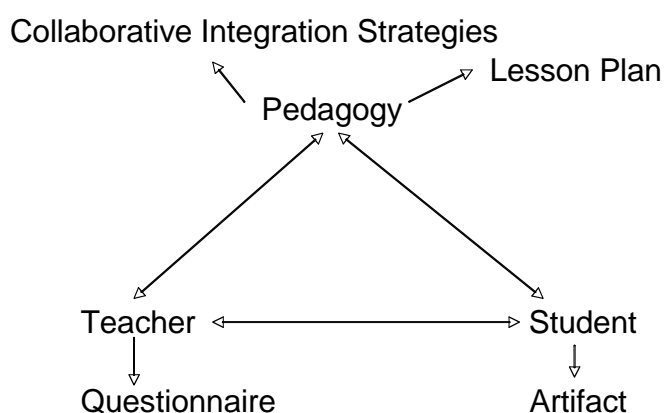


Figure 1 – Convergence of Evidence (Triangulation)

The sequence of data collection is outlined in the following four phases.

Phase One: Pre-Teaching Collaboration

Began during the planning for a six-week unit. This phase involved the collection of data at a planning meeting in order to identify strategies for the purposeful integration of STEM content.

Phase Two: Faculty Teaching Artifacts

Began with the collection of lesson plans. During this phase, participants produced lesson plans both electronically and in hard copy.

Phase Three: Teaching Practice

Began with the Biology, English, and History teachers filling out a 14 item open-ended questionnaire. The open-ended questionnaire was administered to identify strategies of purposeful integration of STEM content through reflecting on pedagogical practices.

Phase Four: Student Learning Artifacts

Began at the end of the six-week unit. Data was collected through student work and rubrics used to assess this work. The goal was to determine whether students were making the desired connections, as well as how teachers were assessing these connections.

Quality of Research

The quality of a research design can be judged according to certain logical tests. Concepts that have been offered for these tests include trustworthiness, credibility, confirmability, and data dependability (U.S. General Accounting Office, 1990)

Four tests, however, have been commonly used to establish the quality of any empirical social research (Yin, 2003). These four tests include; Construct Validity, Internal Validity,

External Validity, and Reliability. Because case studies are one form of such research, the four tests are equally relevant to this case study (Yin, 2003). This pilot case study adhered to the following rigor.

Construct Validity

Data triangulation helps to address the potential problem of construct validity because the multiple sources of evidence essentially provide multiple measures of the same phenomenon (Yin, 2003). This study uses triangulation (see Fig. 1) to collectively look at evidence and see if integrated instructional strategies occur across data sets.

Internal Validity

“Internal validity is only a concern for causal (or explanatory) case studies, in which an investigator is trying to determine whether event x led to event y” (Yin, 2003). Therefore, Internal Validity was not an issue of concern for this particular case study.

External Validity

In analytic generalization, the investigator is striving to generalize a particular set of results to some broader theory. Therefore, as explained by Yin (2003), “a theory must be tested by replicating the findings in a second or even third study, where the theory has specified that the same results should occur.” As a pilot case study, this research only looked at one case. However, with the presentation of data collected from this case study, others could conduct identical studies to determine whether the same findings are true of other cases.

Reliability

As Yin (2003) explains, “the goal in establishing [reliability] was to allow the data to be the subject of separate, secondary analysis, independent of any reports by the original investigator.” Reliability, in this study, was handled through the presentation of case study

protocols and the development of a case study database. Case study protocols were developed to make all steps as operational as possible and to conduct the research as if someone were always looking over the investigators shoulder. An electronic database was therefore created to house all the data collected during the study.

Indicators of quality research as discussed above help to minimize bias in this study. In this way many of the inherent problems in case study research have been addressed, improving on the accepted validity of this study.

Selection of Subjects

The types of participants needed for this study were those exemplar practitioners practicing integrative instructional strategies. The review of relevant literature provided many sites as being exemplar models of integrated instruction. *Meeting Standards Through Integrated Curriculum* (Drake and Burns, 2004) was the primary source used for these identifications. Once these sites had been identified, the list was narrowed down to only those in Virginia, this being done because the research institution was in Virginia. From that final list, a selection was made based on the relative proximity to the research institution.

Subjects were selected through the use of a convenience sample. “A convenience sample is a group of subjects selected because of availability, for example, a class of a university professor who is conducting a study on college students, the classrooms of teachers who are enrolled in graduate class, the schools of principles who are participating in a workshop, people who decide to go to the mall on Saturday, or people who respond to an advertisement of subjects” (McMillan, 2004). Convenience samples are often chosen because it is the only type of sampling possible, though it has its limitations. The nature of convenience samples may bias the results. There is also no precise way of generalizing from a convenience sample to a

population. However, a convenience sample is appropriate if the primary purpose of the research is not generalization, but rather to better understand theory that may exist within a phenomenon.

Data Collection and Analysis

Discussed in this section are the methods used for data collection and analysis, including a discussion of those instruments used in analyzing data from multiple sources. Instruments were chosen for their ability to reveal data appropriate to answer the research questions, as described below.

Research Questions 1

To address research question 1 (RQ-S1) “What strategies are used in lesson plans to purposefully integrate STEM content?” lesson plans were collected and analyzed from the three subject area teachers (Biology, History, and English). The method of analysis to determine if lesson plans indeed reflected integrated teaching/learning strategies for integration was a theme analysis.

Research Question 2

To address RQ-S2 “What instructional strategies do teachers use, based on self-reflection, to teach purposefully integrated STEM content?” data were collected through the use of a 14 item open-ended questionnaire (Figure 2). The questionnaire was designed to better understand what instructional strategies were used, by practitioners, to collaboratively create lessons using integrated instruction. The questionnaires were then used to identify instructional strategies used by practitioners based on their own self-reflection, on the purposeful integration of STEM content.

Research Question 3

To address RQ-S3 “What collaborative teacher strategies are used in planning for purposeful integration of STEM content?” data were collected through the recording of one planning session that occurs every six weeks. Dual tape recorders were used to insure the voices were properly recorded. The recording was then transcribed in preparation for coding. A theme analysis was conducted on the transcription to identify common threads across the three disciplines.

Research Question 4

To address RQ4, “What strategies are used to evaluate student recognition of multidisciplinary connections?” data were collected in the form of student artifacts. Students’ final interdisciplinary projects for several 6 week units were collected with help from the instructors. A theme analysis was conducted on this data source to determine whether students were making interdisciplinary connections.

Convergence of Data Sets

Following the analysis of the four sets of data, they were examined further to identify points of convergence. These points of convergence allowed for the creation of a three-dimensional picture of integrated instruction discussed further in Chapter 5 of this study.

Chapter IV: Results

The purpose of this study was to identify how teaching and learning strategies are used in a high school to promote the purposeful integration of STEM content. The method of analysis used was a single case embedded research design. Data were collected to address the following research question and sub-questions:

How are teaching/learning strategies, as reflected in exemplars of integrated instruction, used to promote the purposeful integration of STEM content?

The data needed to answer the question was gathered through the following set of sub-questions.

RQ-S1 What strategies are used in lesson plans to purposefully integrate STEM content?

RQ-S2 What instructional strategies do teachers use, based on self-reflection, to teach purposefully integrated STEM content?

RQ-S3 What collaborative teacher strategies are used in planning for purposeful integration of STEM content?

RQ-S4 What strategies are used to evaluate student recognition of multidisciplinary connections?

The design of this research calls for the analysis of exemplar programs featuring integrated instruction. To accomplish this analysis a pilot case study design was used and data were collected across four phases: Collaborative planning meeting, instructor questionnaire, lesson plans, and student artifacts. Results of data analyzed in each phase are presented following the chronological order in which the data were collected.

Phase 1: Collection and Analysis of Collaborative Planning Meeting Data

Data collection in Phase 1 began with the audio recording of a collaborative planning meeting attended by all three participants and the researcher. The purpose of attending this planning meeting was to inform the researcher of the collaborative strategies used by the participants to purposefully integrate content. The meeting began with the participants discussing what they were planning for the next six week unit. Throughout the meeting questioning by the researcher was encouraged. In the days following the meeting the audio recording was transcribed by the researcher.

The researcher analyzed the transcript by identifying and coding common themes throughout, as suggested by Yin (2003). Yin (2003) also suggests that coding should be done by referring to the research question and knowing what types of data are needed. The researcher is informed of the data needed to answer each research question by referring to the purpose of the research. The end goal of this study is to produce a set of strategies that practitioners can use when implementing integrated instruction into their own classrooms. This purpose has allowed the researcher to look for emerging themes that can be used as strategies when designing integrated instruction. Following this approach, the researcher looked for themes such as instructor collaboration, curricular issues, assessment, and support. Color coding, used for identifying themes was completed in three steps. The first step required an initial reading of the transcript, from which the researcher coded for broad themes. The researcher conducted a second read of the transcript and identified a list of emerging themes. A third and final read was conducted to determine the frequency of these emerging themes throughout the transcript. An example of this coding process is shown here:

Tom: So generally what we try to do is get together, the two of us with Mike every year and we will be in here at least now first semester, we will discuss what **units** we want to

do and then um for Mike, his participation is from the **science** perspective is in basically in the **projects** themselves. Um but for the two of us, this really gives us a framework on what we do on a day by day basis so that what we do in the **English** class Chris is either covering the same period or using the same terminology, the same concept and so the kids, were forcing them to make this **interdisciplinary connection** that they were not making on their own.

Chris: So while I am doing the Civil War, Tom will do Walt Wightmans poetry from that era, Wightman and Dickinson. And we try to plan that Tom chooses literature that goes along with when we do the war **unit**, Tom chooses literature that compliments what we're doing.

Analysis of coding frequencies resulted in 15 distinct themes that logically grouped into five categories. Table 2 displays the emerging themes as determined through coding and grouped by logical categories.

Table 2
Coding results of key themes by category

Theme Categories	Emerging Themes	<i>f</i>
Instructor Collaboration		
	Time	28
	Trust	8
	Planning	4
Curricular Issues		
	Interdisciplinary Connections	19
	History	19
	SOL	18
	Unit	9
Assessment		
	Presentation	9
	Rubric	7
	Alternative Assessment	3
Student Work		
	Project	11
	Groups / Cooperative	10
	Research	5
Adopters		
	Support	5
	Admin	4

Research Sub-Question 3 (RQ-S3) asks what collaborative strategies are used in planning integrative units of instruction. Further analysis of individual themes within each category, as determined through coding of transcript data, was conducted to develop theme explanations and reveal associated strategies. The results of this analysis are presented in Tables 3, 4, 5, 6, and 7 along with strategies reflective of the theme category.

Theme explanations were derived from how emergent themes were being used in the transcript data. As themes were used in the data, their usages were recorded for later synthesis. This produced a listing of varying usages that were broken down and consolidated based on similarities. The final list of consolidated usages produced single explanations of how emergent themes were used in the data.

Using the explanations of identified emergent themes, collaboration strategies were identified. These resultant collaboration strategies represent the synthesis of explanation data for emergent themes. Within an identified category, several emergent themes and explanations were identified and then grouped together by logical pairings. These pairings allowed for the identification of one or more strategies that define the particular category.

Table 3 shows data of the first theme category *instructor collaboration*. Within this theme category, three emergent themes were identified and logically grouped as *time and planning* (Group 1) and *trust* (Group 2). Next, explanations of emergent themes were synthesized for both groups. This was done by matching up commonalities between the explanations. The final analysis step was to take the synthesized explanations and identify collaborative strategies. This method of data analysis is presented in Table 3 and resulted in two main collaborative strategies.

Table 3
Instructor collaborative planning strategies

Emergent Themes	<i>f</i>	Explanation of Emergent Themes	Collaboration Strategies
Time	28	The time it takes to plan, implement, and assess an integrated unit.	<ul style="list-style-type: none"> • Instructors must find common time to meet and plan the integrated unit. • Instructors must trust each other enough to teach and assess content in an integrated way.
Trust	8	Being able to trust the other teachers in the group to teach and assess.	
Planning	4	Instructors meeting during common time to plan units	

Table 4 shows data of the second theme category, *curricular*. Within this theme category, four themes were logically grouped as History, SOL, and Unit (Group 1) and interdisciplinary connections (Group 2). Based on the explanation of emergent themes, two strategies were identified.

Table 4
Curricular planning strategies

Emergent Themes	<i>f</i>	Explanation of Emergent Themes	Curricular Strategies
Interdisciplinary Connections	19	Instruction that seeks to make connections among disciplines.	<ul style="list-style-type: none"> • Units are driven by SOL's and are designed around a central theme that comes from a single content area. • Connections are purposefully made across disciplines.
History	19	Real / Relevant unit topics based on History curriculum Broad topics	
SOL	18	Minimum proficiencies that all students must meet.	
Unit	9	A block of six weeks that is guided by a central theme.	

Following the approach used to present data in the previous tables, Table 5 shows data of the third category, *assessment*. The three emergent themes identified in this category were similar enough to be grouped together into a single collaborative strategy.

Table 5
Assessment planning strategies

Emergent Themes	<i>f</i>	Explanation of Emergent Themes	Assessment Strategies
Present	9	A method of alternative assessment	<ul style="list-style-type: none"> • Presentations are watched and graded by the entire instructor team and a single holistic score is awarded. This score will count in each participating course.
rubric	7	Grading criteria	
alternative assessments	3	Not a standard paper/pencil assessment. (ex. Presentation)	
		One holistic grade that is applied to all disciplines involved	
		Instructional team grades together	

Continuing the approach used to present data in previous tables, Table 6 shows data of the fourth category, *student work*. The three emergent themes identified in this group were similarly discussed by participants enough to be grouped together into a single collaborative strategy.

Table 6
Student work planning strategies

Emergent Themes	<i>f</i>	Explanation of Emergent Themes	Student Work Strategies
Project	11	A final interdisciplinary project that occurs at the end of a unit.	<ul style="list-style-type: none"> • Lessons are set up to allow students to work in cooperative groups where they complete a project and conduct research on a topic.
Groups / cooperatively	10	Students work together as a group on projects	
Research	5	Students conduct research in groups about a topic.	

The final category was *adopters*. Themes in this category were similarly discussed by participants and therefore logically grouped into a single strategy.

Table 7
Adopters planning strategies

Emergent Themes	<i>f</i>	Explanation of Emergent Themes	Adopters Strategies
Support	5	Having the support of administration to conduct the integrated units.	<ul style="list-style-type: none"> • During the planning of an integrated unit, it is helpful, though not necessary, to have the support of your schools administration.
Admin	4	The administrative body of the school of which support is critical.	

A cumulative analysis of collaborative planning data (Tables 3-7) exposes seven main collaborative strategies that are essential for the successful planning of integrative instruction.

Phase 2: Collection and Analysis of Instructor Questionnaire Data

Phase 2 data collection began with the distribution of a 14 item open-ended questionnaire (Figure 2). The questionnaire was designed with select items targeting specific research questions. The questionnaire was unique because it allowed the researcher to collect data relating to all the research questions from a single data source. To develop the questionnaire items, each research question was individually analyzed for main concepts. From each research question, three questionnaire items were developed that would aid the researcher in targeting these main concepts in the data to answer the research question. Many questionnaire items could also be used to answer multiple research questions. The questionnaire opened with two broad questions linked to the main research question. The remaining items were linked specifically to individual research sub-questions.

As suggested by Yin, construct validity for this questionnaire was achieved through its review by experts in the field. The questionnaire was delivered as an e-mail attachment and participants were asked to return it within a week to the researcher by email. Two respondents (66%) returned their completed questionnaires via email in the suggested timeframe. The third respondent returned their completed questionnaire shortly after a follow-up email from the researcher. As each completed questionnaire was received the data were placed in a cumulative data table.

Open-ended Questionnaire

Directions: In a separate typed file, answer each of the questions below to the best of your ability. You will be given one full week to complete this questionnaire. It should be submitted to the research team via email at figlian2@vt.edu. The completed questionnaire will be due by midnight on Tuesday September 4th. If you have any questions or concerns, you may contact the research team by emailing the same address.

1. For you, what does it mean to “integrate” subjects?
2. How would you describe an integrated unit?
3. What method is used to determine a unit theme?
4. How is content within each discipline selected for the integrated unit?
5. What are your main expectations for the students who complete your integrated unit?
6. In what ways do you collaboratively design the unit to purposefully make multidisciplinary connections?
7. What teaching methods do you use when implementing your portion of an integrated unit and why do you choose them?
8. List the activities you implement with your class and tell how you use them to ensure students will intentionally address content across disciplines?
9. What activities do you do together (same time) with the other instructors running the integrated unit?
10. In the activities your students complete, what ways do you have them demonstrate their ability to make multidisciplinary connections?
11. How do you design your activities to intentionally make multidisciplinary connections?
12. Do you and your team of teachers conduct any ongoing assessment of the unit while students are still engaged in class work? If so, explain.
13. If you were telling another teacher how to set up an integrated unit, what essential components would you say are needed to run a successful integrated unit?
14. Explain how you ensure your students are prepared for SOL testing using this integrated approach.

Figure 2. Open-ended Instructor Questionnaire

Analysis of questionnaire responses was guided by the research questions. The researcher read through the questionnaire data to identify and code for themes. Many of the same themes were found in the planning meeting transcript. This coding resulted in a listing of emergent themes as depicted in Table 8. The majority of the questionnaire items answered multiple research questions. For this reason the data gathered by these questions needed to be duplicated per research question to allow for data analysis.

Table 8
Coding results for emergent themes by research question

Questionnaire Item	Participant 1	Participant 2	Participant 3	Emergent Themes
RQ-Main				
1.	Deliberately Connections Content	Intentionally Connections Content	Connections	Purposefully Connections Content
	Across disciplinary Fields		Various Disciplines	Across Disciplines
2.	pair of teachers or a group		Various Disciplines	Instructional Partners
RQ-S1				
3	Brainstorm	Brainstorm		Brainstorming
4	Requirements of SOL's	SOL Requirements Teacher Interests	Each teacher selects material	SOL Requirements Teacher Interests
	Teacher Experiences	Past Experiences		Teacher Experiences
11		We informally meet at least once a week	Talk with team members to seek input	Discuss with team to be sure to make appropriate connections
RQ-S2				
7	Lecture	Direct Instruction	Lecture / Discussion	Lecture / Discussion
	Web Based Practice Activities	Experiential Activities	Web Quest	Internet Research Practice Activities
		Cooperative Activities	Small Group Collaboration	Group Work
8	Explicitly Call Attention	Directly ask the kids questions		Explicitly Call Attention
		Graphic Organizer	Graphic Organizer	Graphic Organizers
9				No Agreement
11		We informally meet at least once a week	Talk with team members to seek input	Discuss with team to be sure to make appropriate connections
14	If they do what we have given them the opportunity to do, they'll be prepared.	Repeatedly hit every SOL requirement	The SOL's are minimum competencies so in the course of a good program they will be addressed.	SOL's automatically addressed

Table 8 (Continued).

Questionnaire Item	Participant 1	Participant 2	Participant 3	Emergent Themes
RQ-S3				
3	Brainstorm	Brainstorm		Brainstorming
4	Requirements of SOL's	SOL Requirements		SOL Requirements
6	Plan Possible Topics	Agreed on a theme	Select Thematic Units	Agee on a theme
9				No Agreement
13		Trust one another	Trust each other	Trust
		Be sure enough to give up control of the planning and implementation of a unit	Willing to give up ownership of the content.	Give Up Ownership
		Commit yourself (Both time and energy)	Be willing to give their own time	Time
RQ-S4				
5	Connections across the discipline	Cross-curricular connections	Cross curricular connections	Cross curricular connections
8	Explicitly Call Attention	Directly ask the kids questions		Explicitly Call Attention
10	Oral Presentation		Project Presentation	Project Presentation
		Directly as the kids questions	Class discussion	Class discussion.
12	Assessment	Assessment dictated by time constraints	Informally	Ongoing Assessment
	Revising for next time topics and product list	To add something that is current / topical		Constantly Revising
14	If they do what we have given them the opportunity to do, they'll be prepared.	Repeatedly hit every SOL requirement	The SOL's are minimum competencies.	SOL's automatically addressed

The emergent themes in Table 8 were divided into their associated research question and then placed into several new tables. Tables 9 through 13 display the emergent themes and the strategies they are based on. Also given is an explanation of what each emergent theme means according to the questionnaire responses.

Those emergent themes that related to RQ-S1, "What strategies are used in lesson plans to purposefully integrate STEM content?" are displayed in Table 9. The same approach to data analysis used to present data in Table 3 was used here. This approach to data analysis allowed

the researcher to identify three strategies of purposefully integrating STEM content into lesson plans.

Table 9
Questionnaire Data Analysis of RQ-S1 Themes

Emergent Themes	Explanation of Emergent Themes	<i>f</i>	Lesson Planning Strategies
Brainstorming	Interacting with teachers and students to identify unit themes.	2	<ul style="list-style-type: none"> • Lesson topics are chosen through brainstorming, teacher interests, and experiences. • Lesson topics are driven by SOL's. • Constantly meeting with teachers in other disciplines.
SOL requirements	Content for the integrated unit is partially driven by SOL requirements	2	
Teacher interests	Content for the integrated unit is partially driven by teacher interests	2	
Teacher experiences	Content for the integrated unit is partially driven by teachers past experience with lessons	2	
Discuss	Constantly meeting with other teachers in other disciplines to be sure you are making appropriate connections to other disciplines.	2	

Data analysis of table 10 illustrates those emergent themes that help to answer RQ-S2, “What instructional strategies do teachers use, based on self-reflection, to teach purposefully integrated STEM content?” Using the same approach for data analysis as Table 3, the researcher was able to identify five instructional strategies.

Table 10
Questionnaire Data Analysis RQ-S2 Themes

Emergent Themes	Explanation of Emergent Themes	<i>f</i>	Instructional Strategies
Lecture / Discussion	A method of teaching where the teacher speaks to the class and holds a discussion on a topic.	3	<ul style="list-style-type: none"> • Methods of teaching include lecture / discussion, Internet research, practice activities, and group work. • Constantly meeting with teachers in other disciplines to be sure to make appropriate connections to other disciplines • Instructors specifically call attention to connections between disciplines. • Instructors encourage students to use methods such as graphic organizers to keep track of connections. • As minimum competencies, SOL's should be automatically addressed within lessons.
Internet Research	Student go off in teams and research a topic online.	2	
Practice Activities	Activities designed to help students practice some skill.	2	
Group Work	Students work on a project as a team.	2	
Explicitly call attention (ex. Questioning)	Making connections on purpose	2	
Graphic Organizers	A method some students use to keep track of cross disciplinary connections	2	

Table 10 (Continued).

Emergent Themes	Explanation of Emergent Themes	<i>f</i>
Discuss	Constantly meeting with other teachers in other disciplines to be sure you are making appropriate connections to other disciplines.	2
SOL's Automatically addressed	The SOL's are minimum competencies so in the course of a good program they will be addressed automatically.	3

The emergent themes that correlate with RQ-S3, “What collaborative teacher strategies are used in planning for purposeful integration of STEM content?” are displayed in Table 11. Five strategies were identified based on comparisons of emergent themes and explanations of those themes.

Table 11
Questionnaire Data Analysis RQ-S3 Themes

Emergent Themes	Explanation of Emergent Themes	<i>f</i>	Collaborative Strategies
Brainstorming	Interacting with teachers and students to identify unit themes.	2	<ul style="list-style-type: none"> • Planning for integrated units occurs through brainstorming which is driven by SOL requirements, teacher interest, and teacher experiences. • Instructors must agree on a common theme that will drive the unit. • All the instructors involved in the integrated unit must trust each other enough to give up control of the planning and implementation of the unit. • Instructors must be willing to give up personal time to develop integrated units.
SOL requirements	Content for the integrated unit is partially driven by SOL requirements	2	
Agree on a theme	Teachers must agree on an overarching theme for an integrated unit.	3	
Trust	Trust the other teachers that you are collaborating with to do a good job assessing and teaching topics.	2	
Give up Ownership	Be secure enough to give up control of the planning and implementation of a unit.	2	
Time	Must be willing to give your own time to develop the integrated unit	2	
Teacher interests	Content for the integrated unit is partially driven by teacher interests	2	
Teacher experiences	Content for the integrated unit is partially driven by teachers past experience with lessons	2	

Table 12 contains those emergent themes that correlate with RQ-S4, “What strategies are used to evaluate student recognition of multidisciplinary connections?” Two strategies were identified based on comparisons of emergent strategies and their explanations.

Table 12
Questionnaire Data Analysis RQ-S4 Themes

Emergent Themes	Explanation of Emergent Themes	<i>f</i>	Evaluation Strategies
Cross Curricular Connections	Making connections across several disciplines.	3	<ul style="list-style-type: none"> • Students are assessed for their knowledge of multidisciplinary connections through project presentation and class discussion. • Based on student recognition of multidisciplinary connections units are continually assessed and constantly revised.
Explicitly call attention (ex. Questioning)	Making connections on purpose	2	
Project Presentation	A method of alternative assessment used to cause students to demonstrate their ability to make multidisciplinary connections.	3	
Class Discussion	Directly as students questions in class to assess their ability to make multidisciplinary connections.	2	
Ongoing Assessment of Unit	Informally, integrated units are assessed on an ongoing basis.	3	
Constantly Revising	Constantly adding to the integrated unit to reflect something current or topical.	2	
SOL's Automatically addressed	The SOL's are minimum competencies so in the course of a good program they will be addressed automatically.	3	
Graphic Organizers (ex. A chart)	A method some students use to keep track of cross disciplinary connections	2	

The emergent themes that correlate with the main research question, “How are teaching/learning strategies, as reflected in exemplars of integrated instruction, used to promote the purposeful integration of STEM content?” are shown in Table 13. One strategy was identified based on the emergent themes and their explanation.

Table 13
RQ-Main Questionnaire Data Analysis

Emergent Themes	Explanation of Emergent Themes	<i>f</i>	Teaching / Learning Strategies
Purposefully Connection	Making connections on purpose	2	• As a team, teachers intentionally make connections in content across disciplines.
Content	Linking two or more disciplines	3	
Across Disciplines	Topics within a discipline	2	
Instructional Partners	Topic that cover several disciplines	2	
	Teachers from different disciplines collaborating to design integrated units.	2	

Cumulative analyses of data presented in Tables 9 through 13 indicate 15 distinct strategies. Their data gives some insight into the practitioner beliefs regarding teaching and learning strategies essential for successful integrative instruction.

Phase 3: Collection and Analysis of Lesson Plan Data

Phase 3 data collection required the acquisition of lesson plans from all three participants. Each participant provided hard copies or digital copies of lesson plans. Prior data analysis from both the planning meeting and questionnaire were used to guide the coding of lesson plan data. In this approach to triangulation, as Yin (2003) suggests, the researcher tries to see if the previously identified findings are present in other data sets and therefore corroborate those results.

Analysis of lesson plan data was accomplished through an iterative review process. In this process the researcher first read and coded all lesson plans. On the second read coding was compared with data analyzed from both the planning meeting and questionnaire, in an attempt to identify corroborating emergent themes. Lastly, frequency counts were taken of the emergent themes. These data were split into the following three categories; unit planning, assessment, and student work based on a logical grouping of themes.

The data that aid in answering RQ-S1, “What strategies are used in lesson plans to purposefully integrate STEM content?” are illustrated in Table 14. The data is logically grouped together as relate to unit planning. Three emergent themes and explanations help to identify a single strategy.

Table 14
Analysis of Lesson Plan Unit Planning Data

Emergent Themes	Explanation of Emergent Themes	<i>f</i>	Lesson Strategies
History Themes	Home discipline for themes	8	<ul style="list-style-type: none"> Lessons are based around historical themes that allow for connections to be made among other disciplines.
Themes	Lessons are based on a central theme	7	
Multidisciplinary	Connections are made among several disciplines.	7	

Table 15 contains data of the emergent themes related to the assessment category and helps to answer RQ-S1. This theme and explanation help to identify a single strategy.

Table 15
Analysis of Lesson Plans Assessment Data

Emergent Themes	Explanation of Emergent Themes	<i>f</i>	Assessment Strategies
Alternative Assessment	Final presentation	10	<ul style="list-style-type: none"> Projects are assessed through the use of a final presentation to illustrate multidisciplinary connections.

The emerging themes related to the student work category are shown in Table 16 and help to answer RQ-S1. Two emergent themes and explanations aid in identifying a single strategy.

Table 16
Analysis of Lesson Plan Student Work Data

Emergent Themes	Explanation of Emergent Themes	<i>f</i>	Student Work Strategies
Research	Students must research topics	4	<ul style="list-style-type: none"> Students will engage in group work that will require them to research a topic within the overarching unit theme in depth.
Group Work	Students work cooperatively in groups.	3	

It should be noted that lesson plans were minimal in quantity. This is not because the participants were in any way unprepared in their classroom preparations. To the contrary, as master teachers with more than 20 years of practicing integrative instruction, they no longer need long lesson plans and therefore resulted in a less robust source of data than the planning meeting and questionnaire.

Phase 4: Collection and Analysis of Student Artifacts Data

Data collection in Phase 4 required the acquisition of student artifacts. Student artifacts consisted of final projects from several six week units and were acquired and analyzed similarly to lesson plans.

The researcher first read through all the student artifacts. In an attempt to corroborate results of artifact analysis, results from the data analysis of the planning meeting and questionnaire were concurrently compared. From this comparative process the researcher identified emerging themes from the student artifacts (Table 17).

Table 17 contains the data that help to answer RQ-S4, “What strategies are used to evaluate student recognition of multidisciplinary connections?” Within this theme category, two emergent themes were identified and logically grouped as *research* (Group 1) and *alternative assessment* (Group 2). The final analysis step was to take the explanations of emergent themes and identify collaborative strategies.

Table 17
Analysis of Student Artifacts Data

Emergent Themes	Explanation of Emergent Themes	<i>f</i>	Evaluation Strategies
Research	Student research a topic to inform themselves about it.	5	<ul style="list-style-type: none"> Research on topics is formatively assessed to identify cross disciplinary connections.
Alternative Assessment	None paper / pencil assessment (ex. Presentation)	5	<ul style="list-style-type: none"> Students give presentations illustrating what they have learned and verbalizing the connections across disciplines.

It is of note that few student artifacts were provided by instructors. However, from those student artifacts it was possible to identify two strategies.

Triangulation of Data

According to Yin (2003), results generated in conducting a case study are strengthened by being able to triangulate data from several data sources. Using basic triangulation methods (Yin, 2003) the identified strategies from each of the four separate data sources were combined (Tables 18-22) and linked to their corresponding research question. Strategies in Tables 18 through 22 are listed in order by data source.

The strategies that help to answer RQ-S1, “What strategies are used in lesson plans to purposefully integrate STEM content?” are shown in Table 18. These strategies originated from data gathered regarding lesson plans and the questionnaire.

Table 18
Triangulation of RQ-S1 by Data Source

Item	Integrative Lesson Strategies	Data Source
a	Lessons are based around historical themes that allow for connections to be made among other disciplines.	Lesson Plans – Themes, History, Multidisciplinary
b	Projects are assessed through the use of a final presentation to illustrate multidisciplinary connections.	Lesson Plans – Alternative Assessment
c	Students will engage in group work that will require them to research a topic within the overarching unit theme in depth.	Lesson Plans – Research, Group Work
d	Lesson topics are chosen through brainstorming, teacher interests, and experiences.	Questionnaire – Brainstorming, Teacher Interests, and Teacher Experiences
e	Lesson topics are driven by SOL’s.	Questionnaire – SOL Requirements
f	Constantly meeting with teachers in other disciplines.	Questionnaire – Discuss with team to be sure to make appropriate connections

Contained in Table 19 are those strategies derived to answer RQ-S2, “What instructional strategies do teachers use, based on self-reflection, to teach purposefully integrated STEM content?” These strategies originated entirely in the questionnaire data source.

Table 19
Triangulation of RQ-S2 by Data Source

Item	Instructional Strategies	Data Source
g	Methods of teaching include lecture / discussion, Internet research, practice activities, and group work.	Questionnaire – Lecture/Discussion, Internet Research, Practice Activities, and Group Work.
h	Constantly meeting with teachers in other disciplines to be sure to make appropriate connections to other disciplines	Questionnaire – Discuss with team to be sure to make appropriate connections
i	Instructors specifically call attention to connections between disciplines.	Questionnaire – Explicitly call attention (ex. Questioning)
j	Instructors encourage students to use methods such as graphic organizers to keep track of connections.	Questionnaire – Graphic Organizers (ex. A Chart)

Table 20 contains the strategies that aid in answering RQ-S3, “What collaborative teacher strategies are used in planning for purposeful integration of STEM content?” These strategies originated from the planning meeting and the questionnaire.

Table 20
Triangulation of RQ-S3 by Data Source

Item	Collaborative Teacher Strategy	Data Source
k	Instructors must find common time to meet and plan the integrated unit.	Planning Meeting – Planning, Time
l	Instructors must trust each other enough to teach and assess content in an integrated way.	Planning Meeting – Trust
m	Units are driven by SOL’s and are designed around a central theme that comes from a single content area.	Planning Meeting – SOL, History
n	Connections are purposefully made across disciplines.	Planning Meeting – Interdisciplinary, Connections
o	Presentations are watched and graded by the entire instructor team and a single holistic score is awarded. This score will count in each participating course.	Planning Meeting – Alternative Assessment, Rubric, Present

Table 20 (Continued).

Item	Collaborative Teacher Strategy	Data Source
p	Lessons are set up to allow student to work in cooperative groups where they complete a project and conduct research on a topic.	Planning Meeting – Groups/Cooperatively, Research, Projects
q	During the planning of an integrated unit, it is helpful, though not necessary, to have the support of your schools administration.	Planning Meeting – Support, Admin
r	Planning for integrated units occurs through brainstorming which is driven by SOL requirements, teacher interest, and teacher experiences.	Questionnaire – Brainstorming, SOL Requirements, Teacher Interests, Teacher Experiences
s	Instructors must agree on a common theme that will drive the unit.	Questionnaire – Agree on a theme
t	All the instructors involved in the integrated unit must trust each other enough to give up control of the planning and implementation of the unit.	Questionnaire – Trust, Give up ownership
u	Instructors must be willing to give up personal time to develop integrated units.	Questionnaire – Time
v	Based on student recognition of multidisciplinary connections units are continually assessed and constantly revised.	Questionnaire – Ongoing Assessment of Unit, Constantly Revising, Cross Curricular Connections

The strategies that help to answer RQ-S4, “What strategies are used to evaluate student recognition of multidisciplinary connections?” are depicted in Table 21. Data sources include student artifacts and the questionnaire.

Table 21
Triangulation of RQ-S4 by Data Source

Item	Student Assessment Strategy	Data Source
w	Research on topics is formatively assessed to identify cross disciplinary connections.	Student Artifacts - Research
x	Students give presentations illustrating what they have learned and verbalizing the connections across disciplines.	Student Artifacts – Alternative Assessment
y	Students are assessed for their knowledge of multidisciplinary connections through project presentation and class discussion.	Questionnaire – Project Presentation, Class Discussion

The strategies that help to answer RQ-Main, “How are teaching/learning strategies, as reflected in exemplars of integrated instruction, used to promote the purposeful integration of STEM content?” are depicted in Table 22. Though four sources were analyzed, the most robust data source was the questionnaire.

Table 22
Triangulation of RQ by Data Source

Item	Collaborative Teaching/Learning Strategies	Data Source
z	As a team, teachers intentionally make connections in content across disciplines.	Questionnaire – Intentionally, Connections, Content, Across Disciplines, Instructional Partners

As described by Yin (2003) the use of multiple sources of evidence in case studies allows a researcher to address a broader range of issues. The case study method followed in this research utilized four very different sources of evidence in order to better understand the broader concept of integrative instruction. The goal of triangulation is the development of converging lines of inquiry. The convergence of data in this study is discussed in greater detail in the following section.

Convergence of Data

Any conclusions in a case study are more convincing and accurate when based on several different sources of information, with cumulative analyses used to corroborate findings (Yin, 2003, Miles, 1994). The data in Tables 18 through 22 reveal such converging lines of inquiry. Data found in one data source is similarly found in other data sources. For this reason, some of the identified strategies are very similar. These similar strategies have been combined and a final list of integrative strategies is displayed in Table 23.

Data convergence led to the identification of 15 strategies important to integrative instruction. The identified strategies help to answer RQ-Main, “How are teaching/learning strategies, as reflected in exemplars of integrated instruction, used to promote the purposeful integration of STEM content?” These 15 strategies are presented in rank order in Table 23. A simple total for frequencies was used to determine this rank.

Table 23
Strategies That Promote Purposeful Integration

	Convergence of Data Sets	<i>f</i>
1	Lessons are driven by SOL's and are based around primary and secondary themes that are agreed upon by all instructors involved, and allow for connections to be made among other disciplines. (b, f, n, t)	64
2	Lessons are designed to allow student to work in cooperative groups where they produce some product. (d, q)	33
3	Instructors must arrange for time to meet outside of school to develop integrated units. (c, v)	32
4	As a team, teachers intentionally make connections in content across disciplines. (a, o)	30
5	Presentations are watched and graded by the entire instructor team and a single holistic score is awarded. This score counts in each participating course. (p)	29
6	Students are assessed for their knowledge of multidisciplinary connections through project presentation and class discussion. (c, y, z)	20
7	All the instructors involved in the integrated unit must trust each other enough to give up control of the planning and implementation of the unit. (m, u)	12
8	Methods of teaching can include lecture / discussion, Internet research, practice activities, and group work. (h)	9
9	During the planning of an integrated unit, it is helpful, though not necessary, for faculty to gain the support of school administration. (r)	9
10	Based on student recognition of multidisciplinary connections units should continually assessed and constantly revised. (w)	8
11	Planning for integrated units occurs through brainstorming which is driven by SOL requirements, teacher interest, and teacher experiences. (e, s)	6
12	Student research on topics are formatively assessed to identify cross disciplinary connections. (x)	5
13	Teachers constantly should be meeting with teachers in other disciplines to be sure to make appropriate connections to other disciplines. (g, i)	4
14	Instructors specifically call attention to connections between disciplines. (j)	2
15	Instructors encourage students to use methods such as graphic organizers to keep track of connections. (k)	2

Chapter V: Discussion, Conclusions, Implications, and Recommendations

Using data analyzed from four sources including an audio taped planning meeting, a 14-item questionnaire, lesson plans, and student artifacts several conclusions can be drawn. Those conclusions are presented in this chapter as well as their implication to the field of integrative STEM education. Based on these conclusions and implications, several areas of further research are discussed.

Discussion

This study was guided by one main research question and four sub-questions. A discussion of data analyzed from the four sub-questions will be presented first in this chapter. Results of this analysis are then used as the basis for answering the main research question and drawing overall conclusions from the study.

The first sub-question dealt with lesson plans and asked, “What strategies are used in lesson plans to purposefully integrate STEM content?” To answer this question, lesson plans were collected from each of the three participants and independently analyzed. As discussed in the previous chapter, from those data six “lesson planning strategies” were identified:

- Design lessons around a central theme with interdisciplinary connections identified
- Choose lesson topics collaboratively through brainstorming, primarily guided by teacher interests and knowledge of practice.
- Purposefully align lesson topics with state content standards.
- Schedule regular meetings of teachers within the collaborative team.
- Design lessons with group work as the primary method of instruction.
- Design lessons that assess students through presentation of their knowledge of interdisciplinary connections.

These strategies represent a frame work for how practitioners would design their lessons to purposefully integrate content from multiple disciplines. Such lessons are designed around a central theme that specifies the general content to be covered. Brainstorming identifies specific

connections to be made across disciplines. Central themes allow each discipline to teach students from a different disciplinary point of view while purposefully integrating content of other disciplines. Collaborating teachers are assured of the connections being made across disciplines through regular team meetings. These regular meetings are a critical strategy because they provide time for teachers to confirm that appropriately planned connections are being made in their separate classes.

When implementing lessons, students should work in groups on projects. Planning for group projects is important for providing a structure where students have time to make multidisciplinary connections on their own. These group projects should be planned in such a way so as to end with an artifact and a presentation. These presentations are not restricted to being computer generated. Instead, students are encouraged to build on their individual content strengths to deliver a presentation that demonstrates their knowledge of connections across disciplinary content. This approach requires students to go beyond writing a paper and encourages them to discuss what they have learned.

Developing integrative instruction is not an easy task. It is an iterative process that will be constantly updated and modified. Planning the instruction clarifies what and how content should be taught. If planned using the six planning strategies, lessons can appropriately make connections across disciplines and have the potential of improving student learning.

The second sub-question asked, “What instructional strategies do teachers use, based on self-reflection, to teach purposefully integrated STEM content?” A 14-item questionnaire was administered to participants to answer this question. Results from the questionnaire yielded the following four “instructional strategies” used to teach integrative STEM content. Those instructional strategies are:

- Incorporate a range of student-centered instructional strategies, including lecture / discussion, Internet research, practice activities, and group work.
- Specifically call attention to connections between disciplines.
- Provide students with methods to intentionally track and/or reveal interdisciplinary connections.
- Regularly meet to share instructional strategies that ensure appropriate interdisciplinary connections are being made.

The identified strategies reflect the practitioners' beliefs' regarding what is needed to teach integrative STEM content. It is important that the instructor utilizes a range of student-centered instructional strategies in class. This diversity is critical for giving teachers different opportunities to ensure students make the intended connections thru their respective disciplines. To facilitate students' connections of content across disciplines, teachers must intentionally show students methods for keeping track of connections. This is an important strategy because if students are not shown how to keep track of connections they may not recognize them and therefore fail to internalize them. The variety of instructional strategies used by individual practitioners needs to be discussed regularly when meeting with the collaborative team to affirm they are making appropriate connections. In so doing, practitioners validate the strategies they are using as an integrative team.

It can be inferred that teachers' beliefs play a large role in how they teach. If a teacher believes in their ability to develop integrative instruction then it will be much simpler to accomplish than if the teacher did not believe they could do it. Positive teacher beliefs supported through collaborative teaching strategies provides teachers with the tools to develop meaningful integrative instruction.

The third sub-question asked, "What collaborative teacher strategies are used in planning for purposeful integration of STEM content?" To answer this question, data were gathered

through audio recording of a collaborative planning meeting. Analysis of this data produced the following 12 “collaborative planning strategies”:

- Find common time to meet and plan the integrated unit.
- Develop trust within the collaborative group to teach and assess content.
- Base units on state content standards and design around a central theme reflecting a single content area.
- Purposefully Connect content across disciplines.
- Grade projects collaboratively
- Plan lessons to use group work.
- Develop administrative support for integrated instruction.
- Plan integrative units around brainstorming that reflects state content standards, teacher interest, and teacher experiences.
- As a group, instructors agree on a common central theme around which to base the unit.
- Share control of planning.
- Create planning opportunities outside of school hours.
- Regularly assess and revise units.

The strongest common key element critical to collaborative planning is time. For successful collaborative planning teachers need to find time outside of the school day to meet and plan units. Concurrent with this key strategy are several other important collaborative strategies. One such strategy is gaining the support of school administration. This support can be gained by scheduling time to explain and convince school administration of the quality of integrative instruction and its ability to meet or exceed state content standards over silo instruction. With administrative support the collaborative team is afforded the increased flexibility necessary to meet and conduct their integrative instruction. Equality among stakeholders throughout the process is another collaborative planning strategy. As a team, members will give up some individual control in favor of collaborative decision making.

Findings clearly indicate that collaborative planning is a critical component of integrative instruction. By planning collaboratively, instructors ensure the development of units that equally incorporate the content from each discipline and that students make the appropriate cross

disciplinary connections. Attention to the 12 key collaborative planning strategies is important in developing truly integrative units.

The fourth sub question asked, “What strategies are used to evaluate student recognition of multidisciplinary connections?” Student artifacts were collected to answer this question. From analysis of those artifacts three strategies emerge:

- Formatively assess research of topics to identify student recognition of multidisciplinary connections.
- Design assessment to require demonstration of procedural and declarative knowledge.
- Design assessment requiring students demonstrate multidisciplinary connections through project presentation and class discussion.

Evaluation of student artifacts produced as part of an integrative unit is approached primarily through alternative assessment methods. Alternative assessment typically takes the form of demonstration of knowledge gained and understood through some method of presentation to the integrative team of teachers. Assessment conducted in a collaborative process following the three identified strategies facilitates successful team assessment of student abilities to make appropriate multidisciplinary connections.

Conclusions

Collectively, data analyzed to answer each individual sub question provides direction for answering the main research question of, “How are teaching/learning strategies, as reflected in exemplars of integrated instruction, used to promote the purposeful integration of STEM content?”

Many of the strategies identified through analysis of one data set were also identified in the analysis of another. Identification and elimination of these common strategies reduced the initial number of strategies from 26 to 15 (Table 23).

The 15 strategies, as revealed through analysis of data collected in this study are guidelines for instructors wanting to design and implement integrative STEM units. To organize these strategies a sum of frequencies was calculated. These frequencies related to how often a particular theme was identified during the coding process which specifically related to how often a theme was discussed by participants.

A careful review of these 15 strategies found there were broad strategy categories: Planning, Implementation, and Evaluation. These strategy categories were gleaned from the topics discussed and terms used within each strategy statement. In this way, each strategy could be shown to relate to specific aspects of the overall integrative instruction process. Organizing strategies in this manner allowed for a logical sequence that could be followed by practitioners.

Six strategies were found to address Planning. From the review of these six strategies eight concepts emerge: standards, themes, connections, group work, time, trust, support, and brainstorming.

Table 24
Strategies For The Planning Of Integrative Units

	Planning Strategies	<i>f</i>
1	Lessons are driven by state content standards and are based around primary and secondary themes that are agreed upon by all instructors involved, and allow for connections to be made among other disciplines.	64
2	Lessons are designed to allow student to work in cooperative groups where they produce some product.	33
3	Instructors must arrange for time to meet outside of school to develop integrated units.	32
7	All the instructors involved in the integrated unit must trust each other enough to give up control of the planning and implementation of the unit.	12
9	During the planning of an integrated unit, it is helpful, though not necessary, for faculty to gain the support of school administration.	9
11	Planning for integrated units occurs through brainstorming which is driven by state content standard requirements, teacher interest, and teacher experiences.	6

Across the three strategy categories Planning Strategies accounted for 59% of the total frequency counts from all four data sources. It is note worthy to discuss where the 59% of total frequency came from. Of the four data sources, the greatest contributor to the identification of planning strategies was the questionnaire which accounted for 61.5% of frequencies regarding planning strategies. When the questionnaire was designed several items specifically targeted planning which influenced the frequency that planning was discussed by participants. The collaborative planning meeting also contributed to the identification of planning strategies and produced 23% of frequencies regarding planning strategies. This is to be expected because the meeting was meant to discuss planning. The final data source that contributed to the identification of planning strategies was lesson plans, accounting for 15.4% of frequencies regarding planning strategies. Though planning was only minimally represented in lesson plans, it provides some corroboration of findings for both the questionnaire and the collaborative planning meeting. No data was found in student work to further corroborate these findings.

Participants identified several important concepts that need to be addressed as a collaborative group when planning integrative units. The collaborative group is comprised of those teachers in different disciplines who engage in integrative instruction together. The group will collectively make decisions on how and what should be taught. As a collaborative group member, individual teachers become components of the group. For this reason they lose their control over all aspects of unit design. This creates a situation where teachers must trust each other to develop units and lessons that are of high quality as decided by the group. There must also be allotted time for the collaborative team to meet. During the school day it becomes difficult to meet because each teacher may have different preparation times or free periods. This may cause meetings to be held after school. It can be inferred that a possible solution to the

problem of time is to gain administrative support for the integrative process. With this type of support teachers may be able to schedule common preparation time which would allow for in-school meetings. This may also grant teachers access to materials and supplies that otherwise would not be available.

Implementation is another key category, with strategies identified in all four data sources. On close review of these four strategies, four concepts emerge: intentional connections, methods of teaching, attention to connections, keeping track of connections.

Table 25
Strategies For The Implementation Of Integrative Units

	Implementation Strategies	<i>f</i>
4	As a team, teachers intentionally make connections in content across disciplines.	30
8	Methods of teaching can include lecture / discussion, Internet research, practice activities, and group work.	9
14	Instructors specifically call attention to connections between disciplines.	2
15	Instructors encourage students to use methods such as graphic organizers to keep track of connections.	2

After planning has been completed the focus shifts to implementing the integrative unit in the classroom. Strategies 4, 8, 14, and 15 represent strategies used for Implementation. Of the four identified Implementation strategies, three dealt with making connections. It can be inferred then that practitioners saw making connections to be an important component to the Implementation of integrative units. Instructors should be intentional about making connections. Connections should not simply occur; they are folded into each lesson and are appropriate. There may also be certain key connections that are made that should be specifically addressed to be sure students have understood them.

Implementation strategies received low frequencies accounting for 16% of the total frequency regarding Implementation. The two primary sources used in the identification of Implementation strategies were the questionnaire and the collaborative planning meeting both

accounting for 40%, respectively, of frequencies regarding Implementation strategies. During the planning meeting, participants tried to explain how they each taught in their own classrooms. Also, the questionnaire had specific questions targeting implementation and how teachers teach. The last data source used was lesson plans which accounted for 20% of the frequencies regarding Implementation. This source was used to corroborate the findings of both the planning meeting and questionnaire. No further data was found in student work to corroborate the findings.

Five strategies were found to address Evaluation which is the third category. From the review of these five strategies, five concepts emerged; holistic grading, alternative assessment, unit assessment, formatively assess students, and formatively assess units.

Table 26
Strategies For The Evaluation Of Integrative Units

	Evaluation Strategies	<i>f</i>
5	Presentations are watched and graded by the entire instructor team and a single holistic score is awarded. This score counts in each participating course.	29
6	Students are assessed for their knowledge of multidisciplinary connections through project presentation and class discussion.	20
10	Based on student recognition of multidisciplinary connections units should be continually assessed and constantly revised.	8
12	Student research on topics are formatively assessed to identify cross disciplinary connections.	5
13	Teachers constantly should be meeting with teachers in other disciplines to be sure to make appropriate connections to other disciplines.	4

Students and integrative units need to be evaluated on a regular basis. Students should receive formative and summative evaluations. Throughout the integrative unit the instructor should be sure students are making appropriate connections. Then at the end of the unit students are assessed through alternative assessment techniques such as a presentation. Units should also receive formative and summative evaluation. Throughout the unit, instructors should be meeting to confirm that appropriate connections are being made across disciplines. At the end of the unit

instructors should also evaluate where areas of improvement are so that next time the unit is implemented the same mistakes will not be made.

Evaluation strategies received frequencies accounting for 25% of the total frequencies regarding Evaluation. Most of the discussion of evaluation took place in the questionnaire which accounted for 50% of the frequencies regarding Evaluation strategies. This high percentage was due to several questionnaire questions being specifically targeted toward evaluation. Student artifacts also played an important role in identifying Evaluation strategies by accounting for 25% of the frequency of strategies regarding Evaluation. Student artifacts were very helpful in determining the type of assessment the instructors require. The collaborative planning meeting also contributed to the frequencies of evaluation strategies accounting for 12.5% of the frequencies related to Evaluation. This contribution was minimal in large part because the meeting was about planning and not evaluation. The final data source that contributed to frequency was lesson plans accounting for 12.5% of the frequencies related to Evaluation. Lesson plans informed the researcher of the methods of evaluation that would be used on students.

Frequencies reveal 15 strategies that the participants of this study viewed as important for developing integrative instruction. The question becomes to what use are these 15 strategies to practicing teachers. Although the 15 identified strategies do not represent a linear framework for implementation, they do represent a conceptual framework which provides direction for practicing teachers to begin developing integrative units. When placed in the three categories; Planning, Implementation, and Evaluation, the 15 strategies could be shown to relate to specific aspects of the overall integrative instructional process.

The 15 strategies reflect a complex iterative process that will take a significant amount of time, perhaps years, to fully implement. This study has illustrated that science, as a component of Integrative STEM education can be used to develop integrative instructional units. Practitioners who might use this list as a framework for initiating integrative units of instruction in STEM education must recognize the complexity and the amount of time needed for implementation. These complexities and time requirements were echoed by participants, who at a collaborative planning meeting stated that if they were asked to give advice to a new teacher who wanted to use integrative techniques to teach a unit, they would advise them to start small. These 15 strategies, as organized in categories revealed through this study, provide a mechanism for faculty to start small.

Implications

Science, technology, engineering, and mathematics (STEM) education literacy is a critical component of 21st century education (AAAS, 1989, 1993; NCTM, 2000; ITEA, 2000). Integrative STEM education is specifically concerned with how to make intentional connections between these four disciplines in order to create richer learning experiences for students. The purpose of this study was to identify integrative instructional strategies and the final analysis of results has implications for professional development, administrators, standardized testing, and time. These implications are discussed separately below.

Implications for professional development relate to both pre-service and current practitioners in the field. Integrative strategies should be incorporated into pre-service teacher education. Doing so provides teachers with the foundational knowledge necessary to begin their teaching careers using integrative instructional methodologies. Also, professional development for in-service faculty should be designed to educate practicing teachers on integrative methods.

This would not only inform them of different integrated methodologies, but would also initiate dialogue among teachers to begin cross disciplinary collaboration.

Implications for administrators relate to their support of integrative instructional practices. Integrative approaches are often perceived to inadequately meet state content standards. This concern is exacerbated by the need to meet “No Child Left Behind” (NCLB) standards. Practitioners who can show administrators that integrative instruction can meet or exceed standards are more likely to gain their support. With administrative support for integrative instruction, a valuable ally will be gained who can help facilitate integration by giving practitioners time and resources to plan instruction.

There are also implications to standardized testing. The concern is that teachers will not be able to try new pedagogies such as integrative instruction due to the need for students to pass standardized tests. Teachers will need to document student achievement as a measure of demonstrating that they can meet or exceed standards using integrative methodologies.

Time to meet and collaborate on lessons and projects has broad implications. Faculty and schools need to be willing to give substantial amounts of time, initially at least, to get programs started. This time may be spent during or after school hours depending on circumstances. In general, meetings during school hours are difficult because teachers have varying schedules that do not allow for common free periods, which is why meetings tend to occur after school.

Recommendations

From this research study several recommendations are offered to specifically address teacher preparation programs, replication, qualitative research methods, and areas of further research.

Recommendation 1

The strategies identified in this study should be included in both pre-service and in-service teacher preparation.

Recommendation 2

This study should be replicated to confirm its findings. The findings of this study do not generalize and therefore further study needs to be done in other geographic locations and across other STEM disciplines to identify whether the strategies identified in this study are similar to those found elsewhere.

Recommendation 3

The use of qualitative research methods in studying integrative practices should be increased. Qualitative methods allow researchers to go beyond pure numbers, and explore at greater depth the phenomena surrounding integrative methods. In so doing, researchers are afforded a richer account of events and greater insight into a very complex instructional process.

Recommendation 4

Through this research study, several areas of further research are identified. Those areas include,

1. Student Learning

- In what concrete ways are integrative STEM practices shown to enhance student knowledge acquisition equal to, or better than more traditional, single-subject approaches?

2. Integrative Practice

- What methods of professional development best prepare teachers to design and implement integrative STEM?

3. Assessment

- What are the best approaches to assessing the design of integrative instruction and the implementation of that instruction?

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Appendix A
IRB Approval



DATE: July 2, 2007

MEMORANDUM

TO: [Redacted]
FROM: [Redacted]

Approval date: 6/29/2007
Continuing Review Due Date:6/14/2008
Expiration Date: 6/28/2008

SUBJECT: **IRB Expedited Approval:** "Strategies for Integrating Stem Content: A Pilot Case Study", IRB # 07-344

This memo is regarding the above-mentioned protocol. The proposed research is eligible for expedited review according to the specifications authorized by 45 CFR 46.110 and 21 CFR 56.110. As Chair of the Virginia Tech Institutional Review Board, I have granted approval to the study for a period of 12 months, effective June 29, 2007.

As an investigator of human subjects, your responsibilities include the following:

1. Report promptly proposed changes in previously approved human subject research activities to the IRB, including changes to your study forms, procedures and investigators, regardless of how minor. The proposed changes must not be initiated without IRB review and approval, except where necessary to eliminate apparent immediate hazards to the subjects.
2. Report promptly to the IRB any injuries or other unanticipated or adverse events involving risks or harms to human research subjects or others.
3. Report promptly to the IRB of the study's closing (i.e., data collecting and data analysis complete at Virginia Tech). If the study is to continue past the expiration date (listed above), investigators must submit a request for continuing review prior to the continuing review due date (listed above). It is the researcher's responsibility to obtain re-approval from the IRB before the study's expiration date.
4. If re-approval is not obtained (unless the study has been reported to the IRB as closed) prior to the expiration date, all activities involving human subjects and data analysis must cease immediately, except where necessary to eliminate apparent immediate hazards to the subjects.

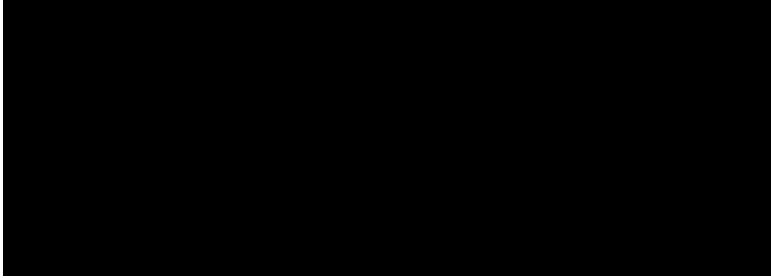
Important:

If you are conducting **federally funded non-exempt research**, this approval letter must state that the IRB has compared the OSP grant application and IRB application and found the documents to be consistent. Otherwise, this approval letter is invalid for OSP to release funds. Visit our website at <http://www.irb.vt.edu/pages/newstudy.htm#OSP> for further information.

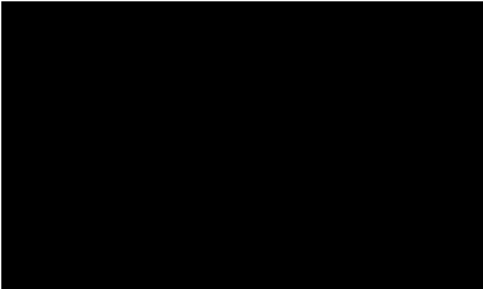
cc: File

Appendix B

School District Approval



July 25, 2007

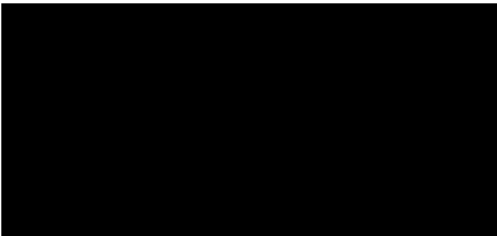


I have reviewed the proposal you submitted to conduct the study *Strategies for Integrating STEM Content: A Pilot Case Study*, with three teachers and their students at [REDACTED]. I completed this review in consultation with [REDACTED] Principal. As I understand your project description, your proposed research activities would include meeting with three [REDACTED] teachers, analyzing their lesson plans and their responses to an open-ended survey, and analyzing work samples from their students. This letter serves as notification that [REDACTED] has approved your request at the district level.

This letter allows you to approach [REDACTED] to request school-level approval of your project. The final decision as to whether [REDACTED] will participate in the project will rest with [REDACTED]. [REDACTED] will discuss the project with the three targeted teachers before making a decision. If [REDACTED] approves the project, it is the district's understanding that both verbal and written consent will be obtained from the participating teachers, and that no personally identifying results or information will be shared in the completion of your project.

If you have questions or need any further assistance, please don't hesitate to contact me.

Sincerely,



Appendix C
School Approval



Back to inbox

Delete Reply Reply All Forward Redirect View Source Move to: This message to Message **1043** of **1123**

Date: Mon, 27 Aug 2007 14:27:40 -0400

From: [Redacted]

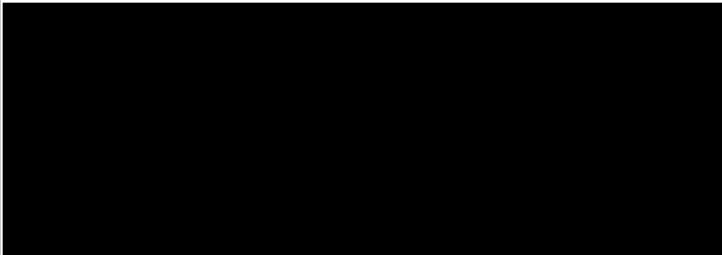
To: [Redacted]

CC: [Redacted]

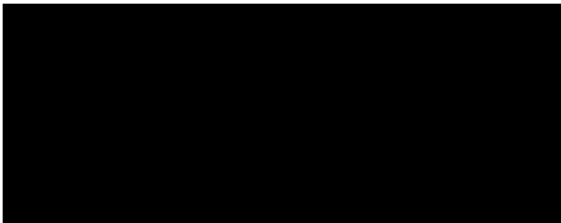
Subject: Re: Research Project

After looking over your materials and talking with [Redacted] I will approve and support your request.

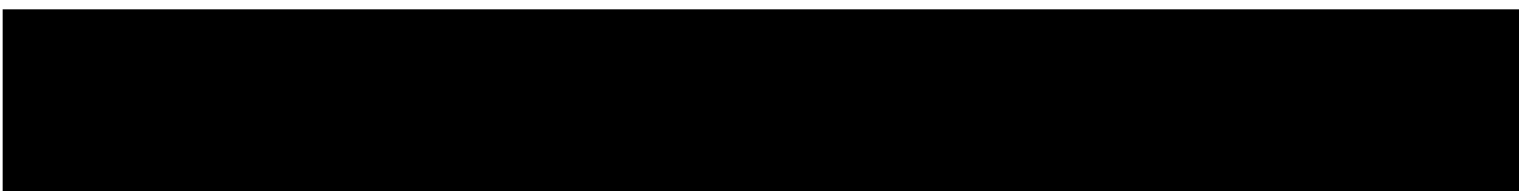
Thanks!



>
> I wanted to follow up and be sure that you received my earlier e-mail with
> all
> the material pertaining to my research study attached to it. Please let me
> know.
>
> Thank you,



Delete Reply Reply All Forward Redirect View Source Move to: This message to Message **1043** of **1123**



Appendix D

Informed Consent for Participants

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Informed Consent for Participants
In Research Projects Involving Human Subjects

Title of Projects: Strategies For Integrating STEM Content: A Pilot Case Study

Investigator(s):



I. Purpose of this Research/Project

The data gathered from this study gives educational practitioner's strategies to use when designing instruction to purposefully integrate STEM content. Ultimately, the purpose of this study was to identify and examine those strategies used by practitioners to deliver integrated instruction. Three subjects will be used in this study; a History, English, and Biology teacher.

II. Procedures

Lesson plans will be collected from the three subject area teachers (Biology, History, and English). This session will take approximately one class period (45 minutes)

The teachers will respond to open-ended questions that are then collected by the investigator. This session will take approximately one class period (45 minutes)

Data will be collected through the recording of one planning session that happens every six weeks. This session will take approximately one class period (45 minutes)

Students' final interdisciplinary projects for one, six-week unit will be collected with help from the instructors. The most critical components that need to be collected are the students' journal and observation entries. When available, these entries will be collected to get a better understanding of the process students used when developing their final projects. This session will take approximately one class period (45 minutes)

Total time needed from each participant = 3 hours

III. Risks

There will be no risks to the participants during the course of this research project.

IV. Benefits

The benefit of this research will be to provide a model of interdisciplinary instruction that other educators can use to implement such instruction in their own schools.

No promise or guarantees of tangible monetary benefits have been made to encourage you to participate.

Subjects may contact the researcher at a later time for a summary of the research results. If subjects are children, the parent/guardian must make the request.

V. Extent of Anonymity and Confidentiality

All materials collected will be kept anonymous and confidential. Names will be omitted from all documents.

Audio recordings will be kept in the office of [REDACTED] under lock and key. The recordings will be transcribed by [REDACTED]. Only the research team will have access to the recordings and they will be destroyed after one year.

VI. Compensation

There will be no compensation for participation in this study.

VII. Freedom to Withdraw

Any participant may withdrawal from this study at any time without penalty.

VIII. Subject's Responsibilities

I voluntarily agree to participate in this study. I have the following responsibilities:

1. Give the researcher lesson plans for a complete six-week unit
2. Fill out an open-ended questionnaire
3. Take part in a planning meeting that the investigator will record
4. Give the researcher copies of final student projects for a six-week unit

IX. Subject's Permission

I have read the Consent Form and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

_____ Date
Subject signature

_____ Date
Witness

Should I have any pertinent questions about this research or its conduct, and research subjects' rights, and whom to contact in the event of a research-related injury to the subject, I may contact [REDACTED]