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An Analysis of the Model and Enacted Curricula for a History of Science Course in a Nationwide Teacher Education Program

Noushin Nouri
University of Arkansas, Fayetteville

An Analysis of the Model and Enacted Curricula for a History of
Science Course in a Nationwide Teacher Education Program

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by

Noushin Nouri
Zanjan University, Zanjan, Iran
Bachelors of Science in Physics, 2000
Shahid Rajaee University, Tehran, Iran
Master of Science in Physics, 2009

August 2017
University of Arkansas

This dissertation is approved for recommendation to the Graduate Council.

____
William McComas, Ph.D.
Dissertation Director

____
Stephen Burgin, Ph.D.
Committee Member

____
Cathy Wissher, Ph.D.
Committee Member

Abstract

The UTeach program, a national model for undergraduate teacher preparation, includes *Perspectives on Science and Mathematics*, a class designed to share content about the History of Science (HOS) with preservice teachers. UTeach provides a model curriculum as a sample for instructors teaching *Perspectives*. The purpose of this study was (a) to describe and evaluate the model science lessons provided; (b) to compare the relationship of the various versions of the *Perspectives* class with the model curriculum; (c) to determine the factors that led to instructors' success or failure in implementation of the model curriculum; and (d) to highlight the instructors' best practices as a basis for improving the UTeach model curriculum. In addition, the study highlighted the relationship between *Perspectives* and the nature of science (NOS) by following the possible links to the NOS in the model curriculum and instructors' classroom practices. This study includes information collected from 11 sites by conducting 16 instructor interviews, reviewing syllabi and other course materials, and analyzing survey responses. Qualitative analysis of the 11 case studies showed no explicit connection to the NOS in the curriculum though the model is written using topics the literature recommends for teaching the HOS. The curriculum corrects some student misconceptions and introduces controversial issues, failures, and successes in teaching the HOS. Most instructors do not adhere strictly to the model curriculum but adapt portions. Factors determining an instructor's decision to adapt the model included background, experience, teaching methods, local conditions, and standards. Instructors' best practices included performing historical experiments, and role playing. Providing a list of objectives for a class in the HOS that meets National Science Standards can be helpful to course instructors.

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Table of Contents

B. Table of Tables

C. Table of Figures

Chapter I

Introduction

Statement of the problem

In the continuing campaign to enhance science instruction we are winning the battle to include aspects of the social sciences including both philosophy of science (usually called the "nature of science" NOS by science educators) and elements of the history of science (HOS). The nature of science is defined as

> a fertile hybrid arena which blends aspects of various social studies of science including the history, sociology, and philosophy of science combined with research from the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors (McComas et al., 1998 p.4).

The *Next Generation Science Standards* (NGSS Lead States, 2013) accepts the consensus view of NOS and includes recommendations for NOS elements such as the law/theory distinction, the role of creativity, cultural and social elements, and the necessity of empirical evidence in scientific research. However, even with agreement on the character of NOS in science instruction, we face the challenge of *how* to include this domain in the classroom.

One way to engage students is the use of lessons about the foundations of science based on the history of science (HOS). "HOS can be both a vehicle to convey important lessons about how science functions and a destination in its own right" (McComas, Nouri, 2017, p.2) HOS lessons can humanize the sciences with their inclusion of the personalities who have shaped the direction and products of the scientific enterprise and meet the recommendation in the National Science Education Standards to show "science as a human endeavor" (NRC, 1996).

Concurrently, HOS content can also be used to tell the tale of how science works, what its rules and traditions are, and how knowledge is established in the sciences.

Recommendations for the use of HOS in science teaching are vast beginning with comments to the British Association for the Advancement of Science in 1855 (Matthews, 1992) to more recent endorsements from Sherratt (1982, 1983), Matthews (1994), Rutherford (2001) and Hodson (2008). McComas (2010) summarizes 14 rationales offered from a variety of sources supporting the inclusion of the history of science in science teaching.

Some researchers believe that using history of science increases knowledge about science content (Galili & Hazen, 2000), in addition to NOS concepts (Kolsto, 2008; Clough, 2006; Irwin, 2000), and helps students to create connection between science content and other disciplines (Matthews, 1994) which highlights the social side of science (Allchin, 2013). Empirical studies have demonstrated the impact of using HOS in understanding NOS (Abd-El-Khalick and Lederman 2000; Lin and Chen 2002; Rudge, Cassidy, Fulford, & Howe, 2014). According to Allchin (2013), "History allows teachers to shift from the alienation of prescribed answers to the wonder or unsolved problems that motivate learning. The original context makes the reasons for doing science 'real'" (p. 30). Allchin adds seeing science as a human endeavor may promote students' desire to pursue a career in science. However, despite these recommendations, there is very little inclusion of the history of science either in textbooks or in classroom discourse.

Considering the importance of HOS and its potential to teach NOS, the next goal should be to improve science teachers' knowledge of HOS and NOS and help them to reflect this knowledge in their teaching through engaging lessons. To reach this goal, science teacher preparation programs must provide preservice teachers with knowledge of HOS and NOS and methods of teaching it in the classroom. Although research has shown that teachers prefer to use activities they learned in their method classes or professional development programs when compared with designing new ones (Herman et.al, 2013a; Wahbeh, & Abd-El-Khalick, 2014; Donnelly and Argyle, 2011), it is critical that these activities help preservice teachers themselves use HOS and learn relevant NOS content. Those aspects of NOS that are well learned and internalized in the context of activities, narratives, discussions, historical case studies, and/or science contents have an increased chance of classroom use (Wahbeh, & Abd-El-Khalick, 2014). Enhancing what teachers know about HOS and NOS and how to teach them requires a strong teacher preparation program that offers courses related to HOS and NOS.

UTeach is a national model undergraduate secondary math/science teacher preparation program established at the University of Texas in 1997. It is now in use across the United States at 42 universities in 21 states and the District of Columbia (https://uteach.utexas.edu). One required aspect of the UTeach model is that each site offer a course called “Perspectives on Science and Mathematics” (herein called *Perspectives*) to promote students’ pedagogical content knowledge (PCK) of the history of science (HOS). While NOS is not an explicit objective in the class, there is much potential in *Perspectives* to include such content. This course is offered to science and mathematics students together and is an upper-level course that students must take in their senior year. In the Instructors' Course Guide on UTeach website this course is defined as:

> This course is designed to put history in the service of science and mathematics education by covering a selection of topics that can and should arise in high school classrooms. Specifically, the course looks at how scientists and mathematicians originally devised innovative solutions to outstanding problems. Rather than reify an idealized account of "scientific discovery," the course seeks to disclose actual pathways by which various inquiries and breakthroughs were made. This is not a "Nature of Science" course, nor even a typical "Introduction to the History of Science," that one finds in history departments. Instead, it is a product uniquely designed for its particular audience of future mathematics and science teachers.

Although the course description explicitly states that “this is not a nature of science course” when the history of science (HOS) but we are reminded that a history focus is one of the recommended methods for teaching NOS (Clough, 2006, McComas, 2008, 2010;. Given the widespread use of the course, the prominence of UTeach as a model instructional program, and the fact that history can be a vehicle for the teaching of NOS (Adúriz-Bravo, & Izquierdo-Aymerich, 2009), there is great potential in investigating this curriculum and the experiences of the instructors who teach the course. At the time of this study, there were 42 higher education institutions using the UTeach model; 31 in existence long enough to have taught the *Perspectives* class. There is a model curriculum on the UTeach users’ website that is supposed to be used as a guideline by instructors who are teaching this course. Since the class is offered to mathematics and science students together, this model curriculum has both science and mathematics lesson plans. Because my background is science and I lack expertise in mathematics education, the focus of the project detailed here is on the science part of the *Perspectives* curriculum.

Purpose of the Study

All science teacher preparation programs should give graduates to a strong background in the history and nature of science. The Uteach course “Perspectives on Science and Mathematics” (herein called *Perspectives*) is designed to accomplish this and is therefore worthy of study as a model curriculum. The purpose of this study was to evaluate and analyze the curriculum for this course to see if it is written based on the recommendations of the research and was able to help preservice teachers to make pedagogical content knowledge of nature and history of science. Hearing the voices of instructors of the course provided me with the opportunity to see how much they find the curriculum useful and beneficial for preservice teachers. The way that faculty at each site approach the course and learning what their main rationales and methods are was helpful in providing a wide picture of this kind of course.

In the current study, I wanted to determine how much providing a model curriculum was beneficial for the instructors of the course. In addition, I describe the way different UTeach sites implement the course, identifying general rationales, methods, and recommendations for these kinds of courses.

Significance of the Study

This study is important because it could provide information on the issues of teaching NOS/HOS to preservice teachers. The analysis of a model curriculum that has been examined, re-conceptualized and field-tested by educators across the nation provided a unique opportunity to examine a curriculum innovation and its adoption. The results of this study can potentially serve to improve the curriculum in a way that is more parallel with the results of research in the issues of teaching NOS/HOS to preservice teachers and as a result the program will introduce NOS to teachers who will eventually be more able to help their students to be more scientifically literate citizens.

The research questions guiding this study are:

1) How do the history of science (HOS) lessons and instructional methods in the UTeach Model curriculum for the class "Perspectives on Science and Mathematics" (*Perspectives*) compare with recommendations in the science education literature?
2) How do the science elements of the Intended curricula developed by those teaching versions of the *Perspectives* course at various UTeach sites correspond with the Model curricula provided by the UTeach Institute?

3) What reasons are expressed by the instructors who teach *Perspectives* at various sites for any changes they made to the Model curriculum?
4) Following a review of instructional methods, course content and rationales provided by those who teach *Perspectives* at various sites, what suggestions might enhance the Model curriculum for a HOS/NOS class for preservice science teachers?

Overview of Research Method

I used a qualitative research model to address the questions posed. Question one was addressed using content analysis method coupled with a reflection on a review of the literature. The data with respect to Questions two, three and four came from writing eleven case studies based on interviews, syllabi, and surveys of 16 instructors teaching in eleven sites that have offered *Perspectives* (among 31 sites).

A survey was sent first via SurveyMonkey TM to each instructor of *Perspectives* at all sites where indiviudals indicated that they would assist. The survey contained ten multi-answer questions with extra space for adding additional personal thoughts. After collecting surveys, I asked for each instructor's syllabus. I designed each instructor's semi-structured interview questions based on their survey responses and their syllabi. Finally, a cross case analysis was conducted. Similarities and differences among these sites and precise analyzing of data resulted in answering research questions. My focus was to find links between the categories shared between the cases and to examine any outliers of exception practices reported..

Assumptions of the Study

For this research, I assumed that useful and clear suggestions for writing a curriculum or teaching NOS/HOS to preservice teachers may be found in the existing literature. In addition, I trusted that the instructors of the *Perspectives* course responded to questions honestly.

Limitations on Generalizability

There were certain limitations within this study. The study was limited because only eleven of the 31 identified UTeach sites were included in the research. Several of the sites with a history of offering "Perspectives on science and math" chose not to participate in the study. It is likely that information from these sites could have contributed to the richness of the research. In addition, because the sites were all around the country, interviews occurred by phone and this may have impacted full understanding on my part. A researcher needs to sit in on all of the sessions of a course or video record all of them to learn about enacted curriculum, but this opportunity was not available to me given the design of my study. Therefore, information was limited to instructors' self-report in surveys, syllabi, and interviews.

This research was limited to the HOS course defined with UTeach science teacher preparation program; a broader perspective may obtain with investigating other HOS classes for preservice teachers. Besides, although I investigated the UTeach class "Perspective on Science and Mathematics", and I understand why the UTeach Institute includes math, but because I was most interested in learning about the science part I did not analyze the lesson plans related to mathematics.

Delimitations Regarding Nature of Project

Most of the information came from the instructors themselves. It was great if there was the possibility of attending in the instructors' classroom and to add observations to the data. Besides, student reactions to the *Perspectives* course would likely add the information about the effectiveness of this course in building pedagogical content knowledge about NOS/HOS in preservice teachers. Collecting such information was not possible within the timeframe and overall scope of this project.

Chapter II

Review of the Literature

In this research, the rationales and recommended methods for teaching nature and history of science will be used to analyze how a curriculum is written for the course "Perspective on Science and Mathematics" (herein called *Perspectives*) a required class in the national UTeach program of undergraduate science and mathematics teacher preparation. The literature review provided here specifies the position of NOS/HOS in the science education and will guide research by providing recommendations for teaching NOS/HOS, and a framework for analyzing curriculum. Therefore, this literature review has two main parts: 1) discussion of the importance and position of NOS/HOS and useful methods for teaching them and 2) issues related to curriculum analysis and implementation fidelity. Figure 1 depicts the literature map for this chapter with the relationship noted for the different topics.

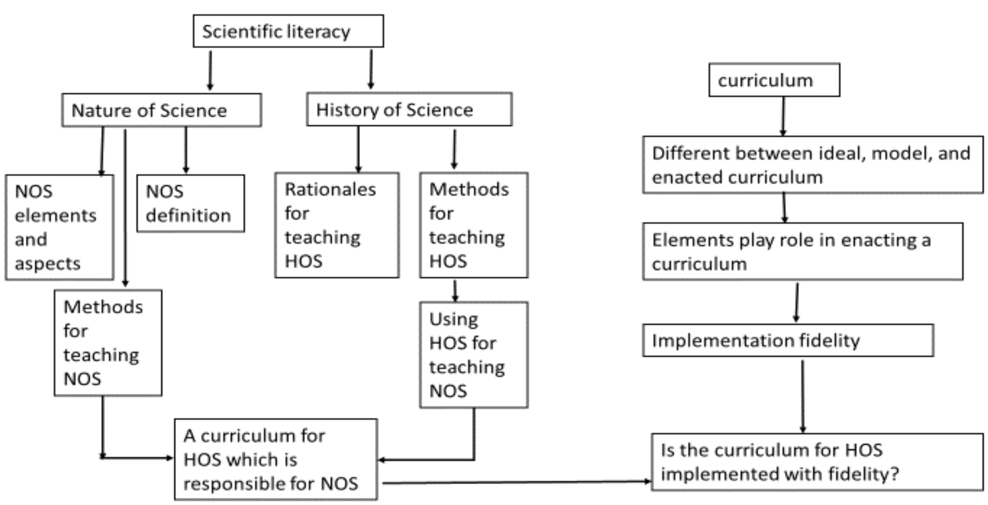

Figure 2. 1. Literature map depicting the various elements discussed in this chapter.

History and Nature of Science

Scientific literacy as defined by National Science Education Standards (NRC, 1996) is "the knowledge and understanding of scientific concepts and processes required for personal decision-making, participating in civic and cultural affairs, and economic productivities" (p. 22). Based on the Benchmarks for Scientific Literacy (AAAS, 1993):

> When people know how scientists go about their work and reach scientific conclusions and what the limitations of such conclusions are, they are more likely to react thoughtfully to scientific claims and less likely to reject them out of hand or accept them uncritically. … They can follow the science adventure story as it plays out during their lifetimes. (p. 3)

Producing scientifically literate citizens with enough background to evaluate scientific information and apply them to make informed choices is one of the goals of science education (AAAS, 2009). The National Research Council (NRC, 2011, p. 4-5) defined U.S. STEM education's third goal asincreased STEM literacy for all students, including those who do not pursue STEM-related careers or additional study in the STEM disciplines. Having scientific literate citizens has been the goal of education for a long time. Hodson (2008) defines science literacy as:

> To be fully literate, students need to be able to distinguish between good science, bad science, and non-science, make critical judgments about what to believe, and use scientific information and knowledge to inform decision making at the personal, employment and community levels. In other words, they need to be *critical consumers* of science. (Hodson, 2008, p. 3)

What is Nature of Science and why it is important?

According to DeBoer (2000) nature of science (NOS) is a central component of scientific literacy. The "nature of science is a fertile hybrid arena which blends aspects of various social studies of science including the history, sociology, and philosophy of science combined with research from the cognitive sciences such as psychology into a rich description of what science is, how it works, how scientists operate as a social group and how society itself both directs and reacts to scientific endeavors” (McComas et al., 1998 p.4). It targets “issues such as what science is, how it works, the epistemological and ontological foundations of science, how scientists operate as a social group and how society itself both influences and reacts to scientific endeavors” (Clough, p. 463). Elements of the nature of science have the potential to provide students with the opportunity to make better sense of science and increase their interests in science, develop their scientific reasoning skills, and increase their scientific literacy, so NOS as a main part of scientific literacy is emphasized in nearly all of the national science education standards documents in the U.S. (Rudolph, 2000). The nature of science increases students’ scientific literacy by creating individuals who understand scientific issues and are able to use this knowledge to make informed judgments and decisions (Hazon, 2002). Moreover, NOS as a metacognitive knowledge about science is central in scientific literacy (Lederman in Matthews, 2014).

Driver, Leach, Millar, and Scott (1996) suggest that there are five arguments that provide NOS with the potential to increase scientific literacy. These arguments are:

***Utilitarian*:** Understanding NOS is necessary to make sense of science and manage the technological objects and processes in everyday life (p.16);

***Democratic*:** Understanding NOS is necessary for informed decision-making on socio-scientific issues, and participate in the decision-making process (p.18);

***Cultural*:** Understanding NOS is necessary to appreciate the value of science as part of contemporary culture (p.19);

***Moral*:** Understanding NOS helps to develop an understanding of the norms of the scientific community that embody moral commitments that are of general value to society (p.19);

***Science learning*: Understanding NOS facilitates the learning of science subject matter. (p.20).

Various rationales advocate for science educators to include aspects of NOS in the science curricula. The numbers of articles published about elements of NOS proper for school science confirms the importance of doing this.

Zeidler et al. (2002) emphasize the importance of NOS understanding for making sense of socio-scientific issues and decision-making. Bravo et al. (2001) believe knowing about science, how it has progressed through history and its relationship with society and culture are essential for being an educated citizen of the twenty-first century. McComas et.al (1998), in highlighting the value of NOS for teaching and learning, discussed NOS knowledge is useful to enhance: understanding of science, interest in science, decision-making, instructional delivery, understanding of socio-scientific issues, enhance argumentation skill.

It seems that there is no doubt that helping students to develop an understanding of NOS should be a part of school science to assist learners in becoming more informed citizens. The next question to pursue is what elements of NOS should be included in school science?

What aspects of NOS should be included in school science?

Disagreement about a single definition of the term NOS has little to do with the importance of NOS as an element of school science instruction. For more than 100 years, studies and expert opinion (Lederman, 1992; McComas, 1998; Matthews, 2014) have demonstrated the importance of including elements of the "nature of science" (NOS) in school science programs. "Where consensus does not exist, the key is to convey a plurality of views so that science teachers and students come to understand the importance of the issues and complexities regarding the NOS," (Clough, 2006, p.463). To fulfill this objective, science educators have recommended a number of different aspects of NOS to include in K-12 science teaching.

By reviewing recommendations from several sources, (Abd-El-Khalick, 1998, 2004; Bell, 2004; Chen, 2006; Lederman, 1998; Lederman and Lederman, 2004; Liu and Lederman, 2002; McComas, 2004; and Osborne, et al., 2003) Al-shamrani (2008) found 12 aspects recommended by at least two science educators consulted. These 12 aspects, called a proposed master list of Aspects of the Nature of Science, are provided includes:

1. Scientific knowledge is not entirely objective
2. Scientists use creativity
3. Scientific knowledge is tentative but durable
4. Scientific knowledge is socially and culturally embedded
5. Laws and theories are distinct kinds of knowledge
6. Scientific knowledge is empirically based
7. The absence of a universal step-wise scientific method
8. The distinction between observations and inferences
9. Science cannot answer all questions (and is therefore limited in its scope)
10. Cooperation and collaboration in development of scientific knowledge
11. The distinction between science and technology
12. Experiments have a role in science

This list has most of the important components, but I prefer the McComas (2005) list because it is more organized and approachable in part because of the clarity of the nine recommended aspects of NOS suggested to inform school science teaching (See Figure 2.2). In addition, these recommendations are, in part, used in Appendix H of the *Next Generation Science Standards* and have been adapted from this work.

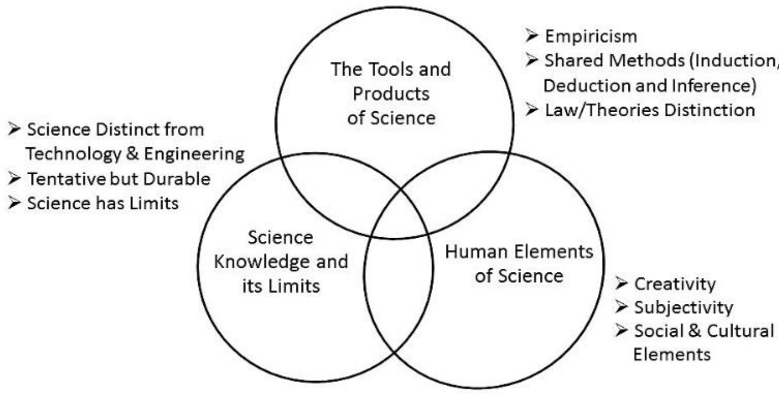

Figure 2. 2. The major sub-elements of NOS as appropriate for inclusion in science instruction arranged in three related clusters introduced by McComas (2008)

In the *Next Generation Science Standards* (NGSS) (Achieve, 2013), the nature of science is a fourth major recommendation. Eight NOS elements (called categories in NGSS) and related illustrations are included in Appendix H. These categories are mentioned in Table 2.1 Most teachers will soon teach in NGSS-approved states and therefore will have to know something about NOS.

Table 2. 1. Categories of NOS in the Next Generation Science Standards

Category	**NOS categories in NGSS**
I	Scientific investigations use a variety of methods
II	Scientific knowledge is based on empirical evidence
III	Scientific knowledge is open to revision in light of new evidence.
IV	Science models, laws, mechanisms, and theories explain natural phenomena
V	Science is a way of knowing
VI	Scientific knowledge assumes an order and consistency in natural systems
VII	Science is a human endeavor
VIII	Science addresses questions about the natural and material world

Reasons for Including Nature of Science in Teacher Preparation Programs

The NSTA Preservice science standards (2012) emphasize that teachers' lesson plans should reflect the nature of science. They make this point by saying:

> Develop lesson plans that include active inquiry lessons where students collect and interpret data using applicable science-specific technology in order to develop concepts, understand scientific processes, relationships and natural patterns from

> empirical experiences. These plans provide for equitable achievement of science literacy for all students (p.3).

and

> Included in the National Science Education Standards (1996) is that "teachers of science should not assume that students have an accurate conception of the nature of science in either contemporary or historical context" (p. 170). Understanding the history and nature of science will enable the students to recognize science from non-science, and leading to an understanding of "what science and technology can and cannot reasonably contribute to a society" (NRC, 1996, p. 171) (p.10).

In addition, in NSTA (2012), there is the suggestion that "Good professional development will "allow teachers to rethink their notions about the nature of science, develop new views about how students learn, construct new classroom learning environments, and create new expectations about student outcomes" (Rhoton and Bowers, 2001, p. iv) (p.11).

There are other reasons that make awareness about NOS/HOS critical for preservice teachers. The lack of deep understanding of NOS leads teachers to present science as a collection of facts instead of a discipline (Abd-El-Khalick, Lederman, 2000). NOS is important in constructing science teachers' PCK, which helps them better represent scientific ideas in the classroom (Alshamrani, 2008). Bravo (2004) emphasizes NOS from the meta-theoretical perspective that can positively affect teachers' pedagogical autonomy. Turgut (2011), in reflecting on this view, names teachers "the most important educational actors [in] that NOS instruction is central to their preparation" (p. 493). There is a relationship between the conception of science and teaching actions (Brickhouse, 1990). Grossman, Wilson, and Shulman (1989) believe that:

> Teachers who lack knowledge of the syntactic structure of the subject matter fail to incorporate that aspect of the discipline in their curriculum. We believe that they consequently run the risk of misunderstanding the subject matters they teach…teachers who do not understand the role played by inquiry in their disciplines are not capable of adequately representing and, therefore, teaching that subject matter for their students (p. 30).

Students' thoughts, feelings, and actions (Hammerich, 1998) and their understanding of the world (DeBoer, 1991) are affected by their conceptions of NOS (Alshamrani, 2008). There is no doubt that "NOS can help students understand and appreciate the inner working and limitation of science as a way of knowing" (McComas in Matthews, 2014, p. 1996). Scientific knowledge describes the "rules of the game" by which scientific knowledge is generated and evaluated (McComas, 2004, p. 25). Teaching NOS helps students overcome the shallow learning of just "final form science", as Duschi (1990) named it, for situations in which students learn "only the conclusion of science" and do not have any chance to realize how the findings were developed and made (McComas, 2014, p. 1996). More reasons mentioned by Abd-El-Khalick include:

> Helping science teachers develop deep, robust, and integrated NOS understandings would have the dual benefits of not only enabling teachers to convey to students images of science and scientific practice that is commensurate with historical, philosophical, sociological, and psychological scholarship (teaching about NOS), but also to structure robust inquiry learning environments that approximate authentic scientific practice, and implement effective pedagogical approaches that share a lot of the characteristics of best science teaching practices (teaching with NOS) (Abd-El-Khalick, 2013, p.2087).

Recommendations for How to Teach NOS

Nature of science can be taught in methods courses, in science content classes, or in formal courses or units of study (McComas, et.al, 1998). To summarize the method of teaching NOS, I reviewed six journals mentioned by three experts as top journals in science education to find recommendations. I choose articles based on the titles of articles published from 2011-2015 in six journals: *Science & Education, Journal of Science Teacher Education, International Journal of Science and Mathematics Education, Journal of Research in Science Teaching, International Journal of Science Education,* and *Science Education.* The rationale for conducting research in NOS is categorized by researchers in ten clusters. Recommended methods for teaching NOS are number one and two in this cluster, so I developed these categories, their illustrations, and a number of articles in each category in Table 2.2. The total number exceeds 81 because of multiple rationales exhibited in the same article.

Table 2. 2. Rationale for conducting research in NOS based on reviewing 81 articles related to NOS in six journals. I am interested in Categories 1&2.

Category	Formulated Meaning	Number of articles in this category
1. Improving students' NOS knowledge	These researchers used or suggested methods help students increase their knowledge of NOS. These strategies vary from developing materials to using history of science, role playing or other explicit-reflective methods. Students are from kindergarten to college level.	12
2. Improving teachers' knowledge of NOS	These articles used or suggested different methods for increasing teachers' knowledge of NOS. All articles used research sample of teachers, pre-service teachers, and teacher-students.	11
3. Classroom practice of teachers and knowledge transfer	These articles investigated teachers' classroom practice, how they transfer their knowledge to students and the relationship between their own NOS knowledge and classroom practice	12
4. Instrument issues and measuring NOS views	These articles either by introducing a new instrument or by using previous instruments try to measure students' or teachers' NOS knowledge.	13
5. Review of a book, position paper, critique	These articles are a review of a book (introducing chapters and critically looking at them), a critique of one article or answering a critique	9
6.Analyzing textbooks, curriculum, articles	These articles used different methods to analyze books, articles, or curriculums.	8
7. Theoretical issues in NOS	These articles theoretically explain some aspects of NOS	6
8. Comparing knowledge about NOS and other topics	These articles try to find relationships between NOS view and other topics like values, choice making, believing in evolution	4
9. Scientists and science educators view of NOS	These articles interviewed scientists or science educators to extract their views on NOS	7
10. Introducing materials	These articles introduce materials for teaching NOS; some were used practically.	8
Total number of articles		90

As I mentioned, Categories 1 and 2 are related to improving teachers' and students' knowledge of NOS. Their finding is summarized here:

Category 1: While some research in this area uses different random methods for explicit-reflective teaching of NOS (Akerson, Nargund-Joshi, Weiland, Pongsanon, & Avsar, 2014; Quigley, Pongsanon, & Akerson, 2011), others tried to provide a context for socio-scientific issues or argumentation or even different contents to help students to obtain better knowledge of NOS (Eastwood, Sadler, Zeidler, Lewis, Amiri, & Applebaum, 2012; Schalk, 2012; Papadouris & Constantinou, 2014).

Table 2. 3provides an overview of suggested approaches for increasing students' NOS knowledge.

Table 2. 3. Summary of methods used by researchers to increase students' knowledge of NOS

Methods used by researchers	**Articles**
Teaching NOS explicitly in the context of socio-scientific issues (SSI),	Eastwood, Sadler, Zeidler, Lewis, Amiri, & Applebaum, 2012; Schalk, 2012; Khishfe, 2013
Combining Scio-scientific issues and argumentation skills	Khishfe (2014)
Using argumentation	Khishfe (2012)
Using self-regulation strategies	Peters's (2012)
Using a special content as a context to combine different related methods	Papadouris & Constantinou, 2014
Teaching explicitly-reflectively via different methods	Akerson, Nargund-Joshi, Weiland, Pongsanon, & Avsar, 2014; Quigley, Pongsanon,& Akerson, 2011
Using historical narrative	Schiffer and Guerra's (2014)
Using historical episodes	Paraskevopoulou & Koliopoulos (2011)
Using role-playing	Cakici, Bayir (2012)

Teaching NOS explicitly in the context of socio-scientific issues (SSI) is one of the ways for increasing students' knowledge of NOS (Eastwood, et.al, 2012; Schalk, 2012; Khishfe, 2013, 2014). According to Eastwood, et.al (2012), both socio-scientific teaching contextualized in contemporary issues and explicit-reflective teaching the content; with exploring NOS aspects in the context of associated research increased students NOS knowledge somewhat equally. Only SSI group provided better examples of social and cultural aspects of NOS. Schalk (2012) reached the conclusion that SSI-based intervention helps increase both students' knowledge of NOS and social issues that affect their lives.

Khishfe (2013) showed that explicit NOS instruction in the context of controversial socio-scientific issues not only increases students' knowledge of NOS but also provides them with the opportunity to transfer this knowledge to similar non-familiar contexts. Khishfe (2014) explored this same thing with adding argumentation skills to the previous investigation with new students. The finding supports an explicit, contextual approach, that integrates NOS and argumentation simultaneously, as useful in increasing students' knowledge. Moreover, some transfer was observed for both argumentation and NOS to unfamiliar contexts. Khishfe (2012) tried to find a relationship between high school students' understandings about NOS aspects and their argumentation skills in the context of two controversial socio-scientific issues. There was a higher correlation between counterargument, compared to argument and rebuttal, with the emphasized NOS aspects. Increasing the correlation in the second scenario confirmed the role of interest in the topic and being familiar with it. Research conducted in this way not only showed that using explicit-reflective NOS teaching in socio-scientific contexts is effective for helping students to obtain proper NOS knowledge, but also showed that it can be used by teachers to find good examples of what researchers did in these articles to duplicate them. In Peters's (2012) study, a group of students was given a self-regulatory intervention. Those who developed nature of science knowledge explicitly via inquiry outperformed the implicit group with respect to NOS and content. Goal setting and self-monitoring as key processes in self-regulating can help students to reflect on NOS. Other findings in this article correlated content knowledge with NOS knowledge positively.

Cakici and Bayir (2012) found that portraying two scientist's life stories (Isaac Newton and Marie Curie), asking many critical/thought-provoking questions regarding aspects of NOS and using discussions and reflections increased students' knowledge of NOS. While none of the children in their sample held informed views of scientific method before engagement with role-play activities, 72 percent changed after role play. Children's understanding of the tentative, empirical and creative/imaginative aspects of the NOS, and the subjective/theory-laden and social–cultural embeddedness of science are improved.

Papadouris, et.al. (2014) developed teaching and learning materials (TLMs) targeting the topic of energy to promote sixth graders' knowledge of NOS. Narrative from history along with other activities were used to combine conceptual elaboration with epistemic discourse and resulted in putting students in the better position to: "(i) recognize observations and interpretations and to differentiate between them, based on epistemological criteria, (ii) appreciate invention as a legitimate and significant component of science and associate it with the process of formulating interpretations and (iii) appreciate energy as an invented construct and associate it with the epistemic act of interpreting"(p. 777).

Akerson, et.al (2014), discussed NOS explicitly-reflectively in a third-grade class for one year and reached the conclusion that different learning styles of students need different kinds of approaches. For example, while using a science notebook is useful for some students, class discussions work better for others. In addition, in the end, students' achievements are at different levels. While the low-achieving students were able to discuss NOS ideas, the medium-achieving students discussed and wrote, and the high-achieving students discussed, wrote, and raised questions about NOS ideas. Quigley, et.al (2011) used different methods and increased students' knowledge of NOS especially in tentative nature of science and roles of observation; this study also emphasized that the level of improvement varies from student to student.

Using history of science is another popular way to increase students' knowledge of NOS. Paraskevopoulou & Koliopoulos (2011) used the Historical Episode of the Millikan-Ehrenhaft dispute to improve students' knowledge especially in subjective and constructive aspects of NOS. Moreover, the answers to the questions "what is science" and "how science does operate" were clearer for students. Historical narrative used in Schiffer and Guerra's (2014) work resulted in students' better understanding of NOS.

Category 2:

In category two, I summarized and organized the methods used for improving preservice and inservice teachers' knowledge of NOS.

- *Random contextualized or decontextualized NOS activities:* Some researchers used a combination of different methods to teach NOS to preservice or inservice teachers. For example, Cofré, et.al used a one year professional development program that included both self-contained NOS mini-courses and science content mini-courses with NOS lessons embedded in them to improve in-service elementary teachers' knowledge of NOS (Cofré, Vergara, Lederman, Lederman, Santibáñez, Jiménez, & Yancovic , 2014). The interviews showed that, excepting empirical nature of science (teachers had a more informed view of it before instruction), teachers' knowledge about other aspects improved after instruction.

- *Laboratory and inquiry activities:* Laboratory activities that have pre-readings about NOS and are followed with labs and discussions are used by same researchers. Ozgelen, Hanuscin, and Yilmaz-Tuzun (2013) provided preservice teachers with a written laboratory guide that had one aspect of NOS for each session and then after lab, they discussed and reflected on that aspect. Capps and Crawford (2013) used an inquiry-based approach within the context of geology, evolutionary concepts and explicitly debated NOS during a week-long intensive Professional Development. Their results show an increase in teachers' knowledge of NOS. They emphasized the importance of reflections on NOS.
- *Using context to teach about NOS:* Using socio-scientific issues, such as the impact of UV radiation (Heap, & France, 2013), climate change, and global warming (Bell, Matkins, Gansender, 2011) is another approach for teaching NOS. In this case, teachers have access to web-based resources; the following discussion in the context helps preservice teachers to build their knowledge about NOS. Additionally, demarcation was the context Turgut, Zoll (2011) used for teaching NOS.
- *Being in contact with scientists:* Working with scientists, interviewing with them, or inviting them to the classroom is another strategy used for helping teachers make sense of NOS. For example, Tala and Vesterinen (2015) engaged students-teachers with scientists and asked them to interview with scientists.
- *Using history of science:* Rudge, Cassidy, Fulford., & Howe (2014), taught a unit about an industry where they applied background historical information in their unit and concluded this approach, and reflecting on NOS, has the effect of improvement in some aspects of understanding of NOS. Allchin, Andersen, & Nielsen (2014), used inquiry,

historical cases, and contemporary cases for helping experienced upper secondary science teachers, involved in short-term professional development, to make sense of NOS.

As it can be seen, using history of science for teaching NOS is examined and suggested by researchers, but there are more reasons for using HOS in science classrooms that I mention in the next section.

Rationales for using History of Science in Classroom Science Instruction

History of science emerges from both categories discussed as an important method for teaching NOS**.** This section now moves into a more focused analysis of further rationale and methods for teaching HOS**.**

To talk about science, Milne (2011) mentions the distinction between Indigenous knowledge and Eurocentric science. Indigenous knowledge is more local, dependent on ancient stories and dynamics, while Eurocentric science is more global and universal science, science in a form that can be found in school curricula (Milne, 2011). School science mostly provides a picture of science as “steadily advancing, never putting a step wrong, a source of solutions for all the world’s ills. Mistakes or side-paths were ignored” (Milne, 2011, p. 9). Duschl (1990) critiqued much science instruction as final form never giving students the opportunity to see where the knowledge came from. When using history of science in the classroom, there is more chance for indigenous knowledge.

Historians, philosophers, and science educators introduce the use of the history of science as a source to develop knowledge of NOS (e.g., Matthews 1994). As mentioned in the previous section, integrating the history of science is one of the suggested methods for contextual NOS instruction (Clough, 2006; Hodson, 2009). According to (McComas, 2010):

> "History of science can be both a vehicle to convey important lessons about how science functions and a destination in its own right. HOS lessons can humanize the sciences with their inclusion of the personalities that have shaped the direction and products of the scientific enterprise." (p.39)

Some researchers believe that using history of science increases knowledge about science content (Galili & Hazen, 2000), in addition to NOS concepts (Kolsto, 2008; Clough, 2006; Irwin, 2000), and helps students to create connection between science content and other disciplines (Matthews, 1994) which highlights the social side of science (Allchin, 2013). Some empirical studies have been done to investigate the impact of using HOS in understanding NOS (Abd-El-Khalick and Lederman 2000; Lin and Chen 2002; Rudge, Cassidy, Fulford, & Howe, 2014). Going back to standards for including NOS, like NGSS, and the consensus view of NOS, using history of science can depict science as a human endeavor and highlight how science is culturally and socially embedded. Adúriz-Bravo, & Izquierdo-Aymerich (2009), emphasize

> Key nature-of-science ideas can be taught to science teachers using the history of science as a meaningful vehicle. It has been shown that selected historical episodes, carefully reconstructed, can work as 'settings' that give meaning to rather abstract epistemological notions and promote their transference to other situations. (p.1179)

According to Allchin (2013), "History allows teachers to shift from the alienation of prescribed answers to the wonder or unsolved problems that motivate learning. The original context makes the reasons for doing science 'real'" (p. 30). Allchin adds seeing science as a human endeavor may promote students' desire to pursue a career in science.

McComas (2010) summarized the rationales offered in the literature for using the history of science I have reproduced that list in full here.

The inclusion of the History of Science in Science Instruction potentially can:

1. Increase student motivation
2. Increase admiration for scientists
3. Help students develop better attitudes toward science

4. Humanize the sciences
5. Demonstrate that science has a history
6. Assist students in understanding and appreciating the interaction between science and society
7. Provide authentic illustrations for the way science actually functions
8. Reveal both the link and distinction between science and technology
9. Help to connect the science disciplines by showing the commonalities
10. Make instruction more challenging and thus will enhance reasoning
11. Provide opportunities for the development of higher order thinking skills
12. Contribute to a fuller understanding of basic science content
13. Help to reveal and dispel classic science misconceptions (this rationale is linked to what is called historical recapitulation in which some learners are seen to proceed through stages of misconceptions that are occasionally linked to incorrect ideas held by scientists in the past)
14. Provide an interdisciplinary link between science and other school subjects with an emphasis on bridging the gap between the "two cultures" (humanities and sciences)
15. Improve teacher education by helping teachers with their own science learning

Approaches for the Incorporation of HOS into Science Education

Monk and Osborne (1997) point out that

> Instead of the prevalent model, which sees HOS as additional and supplementary, provided to add cultural information or human interest, our proposed model for incorporating HPS, requires past scientists' views on natural phenomena to be set alongside those of students' views as other perspectives for consideration, making HPS a central feature of mainstream science education" (p.406).

Like other methods for teaching NOS, using HOS is not effective unless paired with an explicit approach to teaching NOS (Abd-El-Khalick & Lederman, 2000). Students' attention should be drawn to NOS ideas and they should reflect on them. Otherwise, as Kolsto (2008) warns, superficially going through history in the classroom may "reinforce a naïve positivistic view of science" (p.995). Different research has been conducted to investigate possible approaches to using HOS in classrooms. McComas (2010) developed a taxonomy for distinct kinds of approaches for teaching HOS. This taxonomy and illustration about each category are provided in Table 2.4.

Table 2. 4. A Taxonomy developed by McComas (2010) for different possible approaches with HOS and an illustration for each.

	Different possible approaches with HOS and an illustration for each
1.0	Interactions with original works (or selections) in the history of science
	1.1 Original works in their entirety (may include additional commentary)
	1.2 Original works abstracted (may include additional commentary)
	Explanation: For first-hand interactions with original works, students read the actual accounts of science as written by the scientists themselves and then engage in guided discussions regarding what they have read. Such accounts are most likely limited to the original papers appearing in scientific journals but in rare cases, might also consist of a review of working documents (such as laboratory notebooks, etc.). The classification at this level is further subdivided in recognition of the fact that students may read the original works in their entirety, may read abstracts of those works, may encounter a single paper or read sets of related papers from the same scientist or scientists associated with the same discovery or phenomenon.
2.0	Case studies, stories and other similar illustrations of the history of science (including those with original written materials)
	2.1 Case studies (with original content)
	2.2 Science stories
	2.3 Shorter illustrations, vignettes and examples
	Explanation: The case study or case method approach to instruction has been attempted in many disciplines and science is no exception. For instance, there even exists a center for the use of case studies in the teaching of science (http://library.buffalo.edu/libraries/projects/cases/case.html) with an extensive set of such studies along with rationales for their use (Herreid, 1994). The explicit use of the history of science has also been used in a case method format. Much of the early inspiration and advocacy for the use of the history of science in science instruction came from James B. Conant, scientist and president of Harvard University who expressed the view that ". . . it is my contention that science can best be understood by laymen through close study of a few relatively simple case histories . . ." (1947 p. 1).
3.0	Biographies and autobiographies of scientists and their discoveries
	3.1 Autobiography of a Scientist
	3.2 Biography of Scientist (Written)
	3.3 Biography of Scientist (Dramatic Presentation)
	Explanation: Scientists report their life and researches in autobiographies or they can be found in biographies written by others. Examples of these documents: Darwin (2002) Autobiographies, James Watson (1996) The Double Helix and Richard Feynman (2005) The Meaning of it All, and biographies such as Galileo's Daughter (Sobel, 1999), Einstein (Issacson, 2007), Rosalind Franklin (Maddox, 2002) and Issac Newton (Gleick, 2003). Some strategies like having a rubric for students and discussions after reading are suggested to make them more effective. Videos about scientists' lives that are made for educational purposes can be used with the same aim.

Table 2.4 (cont'd.)
Different possible approaches with HOS and an illustration for each

	Different possible approaches with HOS and an illustration for each
4.0	Book length presentations of some aspect of the history of science
	4.1 Account of the General History of Science
	4.2 History of a Particular Scientific Discipline
	4.3 History of a Particular Scientific Sub-discipline such as genetics, evolution or quantum physics
	4.4 History of a Single Discovery of Event (such as an eclipse, the problem of longitude, appearance of Halley's Comet, etc.)
	4.5 Accounts of classic experiments
Explanation: More generalized discussions can be found in book presentation of HOS instead of focusing on one individual.	
5.0	Role playing and related activities with respect to historical personages
Explanation: students take on the roles of historical personages in the history of science to act out, debate or respond to questions as those persons.	
6.0	Textbook inclusions related to the history of science
Explanation: Textbook inclusions related to the history of science is something typically found in schools, and it does not seem an effective method to increase students' knowledge about NOS. experimental reenactments is connecting a typical experiment to the historical background of it.	
7.0	Experimental reenactments and other "hands-on" approaches to engagement with historical aspects of science
Explanation: The final level in our proposed classification plan is that of the use of classic or historical experiments in the teaching of science.	

It is clear that there are a variety of rationales to include HOS in a science classroom when there are many options and methods to do this. What is needed is a curriculum which tries to cover most of the rationales and at the same time has the different learning style of students in the mind. The next section talks about what the characteristics of such a curriculum are.

Examples of Curricula Designed for NOS

Creating new curricular materials to insert historical perspectives was the focus of some researchers (Clough & Olson, 2004; Conant, 1957; Klopfer & Cooley, 1963; Rutherford, Holton, & Watson, 1970). Perhaps the most famous and organized works belong to projects done with Harvard University including Harvard Case Histories in Experimental Science (Conant, 1957), Harvard Project Physics (Rutherford, Holton, & Watson, 1970), and History of Science Cases (Klopfer and Cooley, 1963).

Although Conant (1957) case studies were designed to help students from other disciplines (not science) to learn about science's function, they do not have that much explicit NOS in them; and the length of them, due to explaining details, prevents teachers from using them (Kruse, 2010). Klopfer and Cooley's (1963) case studies are shorter and more NOS issues are included in them; they are in a booklet format. According to Stinner et al. (2003), in Harvard Project Physics, students were asked to draw their own conclusion from featured historical elements. Reid-Smith (2013) and Kruse (2010), in their Doctoral dissertation used historical short stories, informed by the NOS and HOS literature, to examine secondary students' and teachers' views. These short stories were designed by Clough et al. (2006).

Characteristics of a Curriculum for HOS

There are some recommendations for writing a curriculum for HOS. McComas (2010) warns:

> From a curricular perspective, it would seem that HOS can only be effectively included in instruction if it is integrated within rather than appended to instruction, and if HOS is somehow aligned with standards and other curricular goals and if the focus of HOS (and HOS derived learning) is featured in science assessment so that students take it seriously (p.11).

He continues, stressing the importance of upgrading curriculum models to focus on teaching HOS while integrating HOS in a way that balances teachers and classroom limitations with the importance of the subject.

Models for using history of science:

SHINE research model. The name SHINE is an acronym (Science, History, Interaction and Education) and introduced by Seroglou and Koumaras in 1991 and extended later.

SHINE research models have eight steps:

1- The areas in the history of science where there is a difference between early scientific ideas and currently accepted ideas should be determined. 2-Research on the learners' understanding of the topic should be carried out. 3-Research on learners' ideas about science and the nature of science should happen. 4- Data from Steps 1 and 3 should be compared to see if this topic is useful. 5- Research on the work of scientists who have had effect in the promoting the idea should be carried out. 6- Instructional material and activities should be designed based on this research. 7-Materials should be evaluated. 8- Students understanding should be evaluated regarding NOS.

Monk and Osborne (1997) introduced a model for teaching HOS in a science classroom in an integrated way. Their model has six steps:

1-Presentation: in this stage, the idea is introduced by the teacher. 2- Elicitation: students create ideas related to the topic. In this step, teachers encourage students to talk about their ideas and the ideas' roots. This stage is critical because these ideas will be compared with historical ideas. 3- Historical study: historical background of the idea like social, political … the context of them is introduced by a teacher in the shape of historical vignettes.

McComas (2008) suggested using examples from different disciplines to give a broader view to students since most historical examples are from physics, and Kolsto (2008) suggested using traditional and contemporary history of science at the same time to provide students with the opportunity to compare them.

Heilbron (2002), asked science educators to collaborate with historians and philosophers to write historical materials that are easy to use in classrooms.

Here I summarize suggestions in the literature for writing lessons in the history of science which would guide me in analyzing UTeach's model curriculum:

1- It should help preservice teachers to have enough knowledge to recognize misconceptions and myths in the textbooks, and complete the faulty picture that the textbooks present of science. Postman (1994) criticizes textbooks that provide:

> [N]o sense of the frailty or ambiguity of human judgment, no hint of the possibilities of error. Knowledge is presented as a commodity to be acquired, never as a human struggle to understand, to overcome falsity, to stumble toward the truth (p.116).

2- It should help preservice teachers to depict a correct and accurate picture in students' minds of what scientists do. Eccles (2005) concluded we do not give a good picture of scientists to our students and they see scientists as an "eccentric old men". He thinks to show a social and human picture of scientists is very necessary if we want to encourage women in science. In addition, we should not portray scientists as larger than life, or more complex than they are (Allchin, 2003).

3- The lesson plan should not be written in a way that distracts students from science content by introducing difficult vocabularies and lots of historical stories. Heilbron (2002) highlights this point:

> Finally, wherever possible the case studies should carry epistemological or methodological lessons and dangle ties to humanistic subject matter. But never should the primary purpose of the cases be the teaching of history (p. 330).

4- It should both illustrate the development of fundamental science ideas and should communicate important NOS ideas (Metz et al. 2007; Clough, 2007).

5- The topics should be parallel with classroom science (Clough, 2006).

6- They should be written with the flexibility to give teachers possibility to choose (Clough, 2010).

7- Past and present should be portrayed to avoid dismissing accurate NOS ideas (Clough, 2010).

8- Words of scientists should be used to provide authenticity to the NOS ideas (Clough, 2010).

9- It should have components that open discussion about NOS and has potential to draw students' attention to NOS (Clough, 2010).

10- It should be written in a way that avoids the possibility of converting history to myth (Allchin, 2003).

11- They should show failures and critiques and explain errors at the same time as celebrating successes (Allchin, 2003).

This list which was obtained from reviewing literature can be used as a checklist for creating a curriculum in the history of science.

The Nature of Curriculum: An Introduction

According to Marsh and Willis (2003), "Curriculum is all planned learning experiences for which the school is responsible". Olivia's (1997) definition from curriculum is "A series of experiences undergone by learners in a school" (p.4). Pratt (1980) defines curriculum as a written document that systematically describes goals planned, objectives, content, learning activities, evaluation procedures and so forth. The way I will use the curriculum in this research is based on Pratt's definition.

Varieties of Curricula: Ideal, Model and Enacted Curricula

There are different types of curricula. Porter and Smithson (2001) mention "the enacted curriculum refers to the actual curricular content that students engage in the classroom" and "[b]y the intended curriculum we refer to such policy tools as curriculum standards, frameworks, or guidelines that outline the curriculum teachers are expected to deliver".

Model curriculum, on the other hand, as is clear from its name is "based on common structures and degree programs" (Gorgone, Valacich, Topi, Feinstein, & Longenecker, 2003) and provides an example or model of how target aims can be changed from the written curriculum. Some researchers (Remillard, 2005) used the written curriculum to refer this model curricula. In this research, Model NOS/HOS Curriculum is the curriculum model that is provided by the UTeach Institute and shared with those who will be teaching the *Perspectives* class.

The enacted NOS/HOS Curriculum is the curriculum model that is produced (as evidenced in a syllabus) by any instructor who will teach the *Perspectives* class.

Different Approaches for Analyzing Curricula

According to Remillard (2005) when researchers look at curriculum, their approaches are placed in one of four categories, as shown in Table 2.5.

Table 2. 5. Four Perspectives/Assumptions Underlying Research on Curriculum.

	Assumption	**Explanation**
1	Curriculum Use as Following or Subverting the Text	Many studies of curriculum material use take the text as the starting point and then consider the degree to which teachers follow or subvert it. These studies hold to a somewhat positivist stance on text and assume that close fidelity between the written and enacted curriculum might be achieved under ideal conditions (p.216)
2	Curriculum Use as Drawing on the Text	By looking at the classroom before the text, some researchers have described curriculum use as ways in which teachers draw upon and incorporate texts into their instruction. These researchers place emphasis on the agency of the teacher and view texts as one of the many resources that teachers use in constructing the enacted curriculum (p.218)
3	Curriculum Use as Interpretation of Text	A third stance that researchers have taken when studying teaching and curriculum materials is to frame the teacher as an interpreter of the written curriculum. This outlook holds to an interpretive view of text and assumes that fidelity between classroom action and written words in a teacher's guide is impossible, that teachers bring their own beliefs and experiences to their encounters with curriculum to create their own meanings, and that by using curriculum materials teachers interpret the intentions of the authors. p.219)
4	Curriculum Use as Participation with the Text	Another, less common perspective taken by researchers studying teachers and curriculum materials focuses on the teacher–text relationship, or the activity of using the text. This perspective treats curriculum material use as collaboration with the materials. Central to this perspective is the assumption that teachers and curriculum materials are engaged in a dynamic interrelationship that involves participation on the parts of both the teacher and the text. As mentioned earlier, there are significant overlaps between this view and the view that focuses on use of interpretation. The core difference is the focus of the analyses. Although researchers in either category may view curriculum use as a process of interpretation through interaction with the text, the researchers in this group seek to study and explain the nature of the participatory relationship. In other words, the distinguishing characteristic of this perspective is its focus on the activity of using or participating with the curriculum resource and on the dynamic relationship between the teacher and curriculum (p.221)

My perspective aligns with the last category since I believe the curriculum define the objectives and ideas for teachers, but teachers' interpretation of the text and their abilities and knowledge play important roles at the same time.

One example of research in this category backs to Lloyd's (1999) study in which he looked at two teachers' implementation of a new curriculum and their successes and failures in doing it. He noticed "curriculum implementation consists of a dynamic relation between teachers and particular curricular features" (p. 244). He also mentioned the teachers changed the curriculum in a way to be responsive to students' needs.

The Relationship between the Teacher and the Curriculum

Remillard (2005) offered a framework which describes the way that different dimension play roles in the enacted curriculum. This framework is depicted in Figure 2.3. I should emphasize my research uses the same model curriculum framework as the framework in this figure.

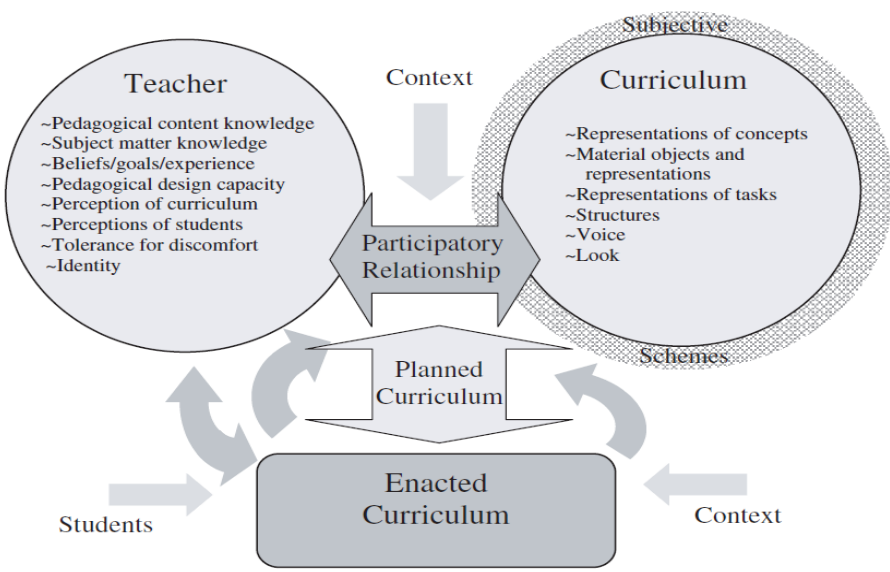

Figure 2. 3 .The framework of components of teacher–curriculum relationship. Adapted from Remillard (2005).

According to the Remillard framework, teachers and curriculum play a very important role in enacted curriculum when students and context have an effect too. Each of these two components, as is clear in the figure, has elements that each of them contributes to what in reality is happening in a classroom.

Kang and Kilpatrick (1992) talked about how much knowledge in its abstract form is parallel to or different from the knowledge represented in the curriculum. Most of the research in analyzing curriculum tries to find the amount of agreement between objectives and assumptions of curriculum and what it is representing (Remillard, 2005). In addition, researchers introduce different elements that represent a curriculum. Remillard (2005) talks about text's voice. He mentions "Voice refers to how the authors or designers are represented and how they communicate with the teacher and the students" (p.233). The visual dimension of materials is another dimension he mentions that affects how materials look. "The resources provided in any curriculum represent a complex set of plans, activities, scripts, suggestions, information, explanation, and messages that have both textual and visual entailments and are likely to speak to different readers in different ways" (Remillard, 2005, p.234).

Teachers as another important component, according to Ben-Peretz (1990), are an active part of the curriculum; their interaction with students leads to changes in what is written as the curriculum. She believes there are two phases in curriculum development. The first phase is the way curriculum writers conceptualize their work and the second phase is how teachers change and translate it and make it approachable for their students. Brown and Edelson mention that "teachers actively shape the instructional environment using available resources in order to achieve their goals" (p. 9). According to Remillard (2005), "any model of teachers' curriculum use must be able to capture and represent the design work undertaken by teachers". Moreover, he believes teachers should make "on-the-spot decisions" about using a curriculum depending on class conditions. Remillard (2005) also mentions different teachers' different beliefs and knowledge as another important factor in the changes they make to the written curriculum.

What Does it Mean to Implement a Curriculum with Fidelity?

Questions about program operations, implementation, and service delivery are answered by evaluating program fidelity (Rossi, Lipsey, & Freeman, 2003). Implementation fidelity is often defined as "the degree to which a particular program follows an original program model" (Hasson, Blomberg & Dunér, 2012). This model generally is defined by the program developers. Generally, demonstrating the implementation fidelity by a program increases the likelihood that the program produces better outcomes (Becker, Tanzman, Drake, Tremblay, 2001). According to O'Donnell (2008), fidelity of implementation can be measured based on five criteria: (a) adherence—whether the components of the intervention are being delivered as designed; (b) duration—the number, length, or frequency of sessions implemented; (c) quality of delivery—the manner in which the implementer delivers the program using the techniques, processes, or methods prescribed; (d) participant responsiveness—the extent to which participants are engaged by and involved in the activities and content of the program; and (e) program differentiation—whether critical features that distinguish the program from the comparison condition are present or absent during implementation. There are several reasons that make understanding of fidelity important as summarized in the following list:

1. A complete understanding of reasons behind the outcomes of the intervention can be obtained if we have a measure of implementation fidelity and we can realize how outcomes can be improved (Carroll, Patterson, Wood, Booth, Rick & Balain, 2007).

2. If program implementation fails, the results of the program are not interesting anymore, because it is difficult to understand the reason behind outcomes (Hasson, et.al, 2012).
3. Realizing the relationship between dose or quality of intervention and success of the program is very important and understanding fidelity helps to realize it (Hasson, et.al, 2012).
4. Ensuring internal validity (Hohmann & Shear, 2002).
5. The feasibility of an intervention can be understood with information about fidelity.

Why Interventions Cannot Always be Implemented as Designed

There are various reasons for omitting, modifying, or adding components to the content of a program. According to Carroll and his colleagues, some adoptions in programs are due to “local conditions” (Carroll, Patterson, Wood, Booth, Rick, & Balain, 2007, p.5). Sometimes, the changes in the intervention based on local conditions improve it, “as long as the essential elements of an intervention are implemented with high fidelity” (Hasson, et.al, 2012, p.2). Durlak and DuPre (2008) identified three factors which influence implementation failure: community factors, provider characteristics, and intervention characteristics. In educational programs, teachers are a very important factor in implementing a program. According to Woolley, Rose, Mercado, Orthner (2013), the characteristics of teachers which influence implementation fidelity are: 1) Teachers’ perceptions of the intervention 2) Their beliefs about the need for the intervention 3) Teachers’ self-efficacy 4) Their teaching experience and skill competence (novice teachers are more flexible regarding new programs compared with experienced ones) 5) Teachers’ confidence about using the intervention.

As we learned in this part, after writing a curriculum, different characteristics and conditions play a role in implementing this curriculum. Knowing these conditions can help the program organizer to improve the curriculum.

Description of the Perspectives on Science and Mathematics

UTeach is a STEM teacher preparation program started in Austin, Texas and currently used nationally. UTeach Courses for preservice teachers include: Step 1: Inquiry Approaches to Teaching; Step 2: Inquiry-Based Lesson Design; Knowing and Learning in Mathematics and Science Classroom Interactions; Project-Based Instruction; Apprentice Teaching; Functions and Modeling; Research Methods; and Perspectives on Science and Mathematics.

The last one, Perspectives on Science and Mathematics, is described in the course home (on the UTeach website with restricted access) as a 3-credit upper level history course. On the website, the course purposes are described as

- It is intended to help future math and science teachers learn how to think about math and science “from the outside”—to ask questions about what scientists and mathematicians do and why, about where science and technology came from and how they got to be so important in the world today, and about what kinds of questions scientists and mathematicians have tried to answer and why.
- It is designed to strengthen students’ skills in the liberal arts, including sophisticated research and information analysis, fluent writing, and substantive argument.
- It requires students to put to work the insights and skills they have learned in science and math pedagogy classes by designing secondary school lesson plans that are built around events and concepts from the history of science and mathematics.

Core components of the course for UTeach include: an instructor with expertise and a research background in the history or philosophy of science; course content related to secondary science and math; emphasizes on sophisticated research, information analysis, and intensive writing; 5E lesson plans as assignments; and discussions and inquiry as instructional methods. The 5E lesson plan has 5 stages including Engage, Explore, Explain, Elaborate, and Evaluate. The 5E lesson plan is an instructional model based on the constructive approach to learning.

Sample artifacts of students, and sample syllabi from different instructors can be found in the website. In addition, a model curriculum is provided on website for this course that includes: course description, course syllabus, 17 lesson plans in science and math, instruction's note for each topic, supplementary activities and quizzes for each topic, sample midterm and final exam.

Summary of Literature Review

I started this section by introducing the nature of science and its importance in schools' science curriculum. Then, after mentioning different possibilities and methods to teach NOS, I brought support from the literature that the history of science is one of the examined recommended contexts for teaching NOS. In addition, I referred to literature to show there are other rationales, besides NOS, for having a course for preservice teachers in the HOS. With mentioning different methods of teaching HOS, I introduced recommendations for a good HOS curriculum. After that, I talked about what is curriculum and which elements are important in enacting a curriculum. Later I talked about implementation fidelity and reasons for failure in implementing a curriculum.

Gaps in the Literature

Although there are lesson plans and curricula available for teaching aspects of the history of science in the literature, still there is not any evidence about what students learn from any HOS curriculum, the lack of which is examined. To have a more widely accepted HOS curriculum, it would be useful to see what is happening in HOS classes for preservice teachers. Finally, and more importantly, I have not found any research about implementation fidelity in the area of history and/or nature of science. As mentioned, it is very important for a program developer to be aware of what is happening in the classroom to improve their program.

Conclusions and Research Motivations

The nature of science as an important component of scientific literacy is introduced in this chapter and its elements and the importance of including it in K-12 is debated. There are many rationales for including the history of science in science curricula and it is introduced as one useful method for teaching NOS if explicit discussions and reflection on NOS are included. There are different methods for teaching the history of science suggested by researchers. Some of them are examined empirically and some not. There is a need to look at what has been done until now and to summarize this work in an organized way.

Teachers, as one of the important components of enacting any curriculum, should be educated in such a way that they have a desire to teach NOS and are able to teach it. This will not happen unless teacher preparation programs use an effective curriculum.

Combining these facts together, we need a proper curriculum that uses history of science effectively in service of teaching NOS. Regarding the existence of a course, namely "Perspectives on Science and Mathematics" in the UTeach preparation program, there is a potential for analyzing what is going on regarding the implementation of a model curriculum and it is very useful to see different sites' approach to teaching HOS.

Chapter III

Specific Research Methods

Introduction

This chapter provides the research questions, the procedures related to data collection and analysis, and an explanation of the method used for answering the questions. This multiple case study derived data from surveys, review of syllabi, and interviews of instructors who are teaching a course named "Perspectives on Science and Mathematics" (here called *Perspectives*) taught as part of the national UTeach program designed to prepare undergraduates to be science and mathematics teachers. The syllabi were used to triangulate answers given from the surveys and interviews.

Nature of the Study

This study is a qualitative case study, since data were collected as they exist within a model curriculum that UTeach provided for the *Perspectives* class and inner experiences of subjects who are the instructors of the class. I described and explained their experience with the course using multiple sources of evidence, such as analyzing a curriculum, reviewing surveys, checking syllabi, and interviewing with the instructors of course.

A case study is an investigation of a single system or an "instance drawn from a class of phenomena" (Merriam, 1988, p.45). According to Yin (2003), case studies are very useful in describing a complex phenomenon because "the case study method allows investigators to retain the holistic and meaningful characteristics of real-life events" (p. 2).

According to Yin (2003), if one these conditions occur a case study is proper: 1- Research questions are "how" and "why" questions; 2- The researcher cannot manipulate the behavior of those involved in the study; 3- The researcher believes contextual conditions have an effect in the study and wants to cover them; 4- The boundaries between the phenomenon and context are not clear.

Almost all these conditions were applicable for this research since I analyzed eleven sites and wrote a case study for each, resulting in a multiple case study approach.

> A multiple case study enables the researcher to explore differences within and between cases. The goal is to replicate findings across cases. Because comparisons will be drawn, it is imperative that the cases are chosen carefully so that the researcher can predict similar results across cases, or predict contrasting results based on a theory (Yin, 2003, p. 548).

The Cases and Units of the Study

In this study, the curriculum that is the main target of study is a model outline for a class called "Perspectives on Science and Mathematics" (generally referred to here as *Perspectives*). This curriculum is taught in the higher education intuitions that have adopted the UTeach teacher preparation program.

In a case study style of investigation, the "Researcher selects the cases purposefully to illustrate typical examples of cases or representative cases" (Creswell, & Maietta, 2002, p.163). In the fall of 2015, among 42 institutions with UTeach, 31 had offered *Perspectives*. I asked for the email addresses of instructor or instructors of the course at each site and I received 22 responses. I asked these individuals if they would provide information related to the research questions. All completed the survey, 20 provided syllabi and 16 agreed to be interviewed resulting in data from 11 sites, since some sites had multiple instructors.

Miles and Huberman (1994) define a case as, "a phenomenon of some sort occurring in a bounded context" (p. 25). In this case, eleven sites had been chosen as cases of study.

Data Collection Process and Technique

To generate depth of understanding and breadth of knowledge, different methodologies, perspectives and techniques are necessary (Fossey, Harvey, McDermot & Davidson, 2002) and therefore I used different sources for data. The data must be rich so that they lend themselves to the thick description of case studies and later for cross-case comparison. Rich data enables thick description, thick interpretation and thick meaning (Cohen, Manion & Morrison, 2007). The research questions guiding this study are:

1) How do the history of science (HOS) lessons and instructional methods in the UTeach Model curriculum for the class “Perspectives on Science and Mathematics” (*Perspectives*) compare with recommendations in the science education literature?
2) How do the science elements of the Intended curricula developed by those teaching versions of the *Perspectives* course at various UTeach sites correspond with the Model curricula provided by the UTeach Institute?
3) What reasons are expressed by the instructors who teach *Perspectives* at various sites for any changes they made to the Model curriculum?
4) Following a review of instructional methods, course content and rationales provided by those who teach *Perspectives* at various sites, what suggestions might enhance the Model curriculum for a HOS/NOS class for preservice science teachers?

Figure 3.1 provides a visual description of the research questions and data sources used.

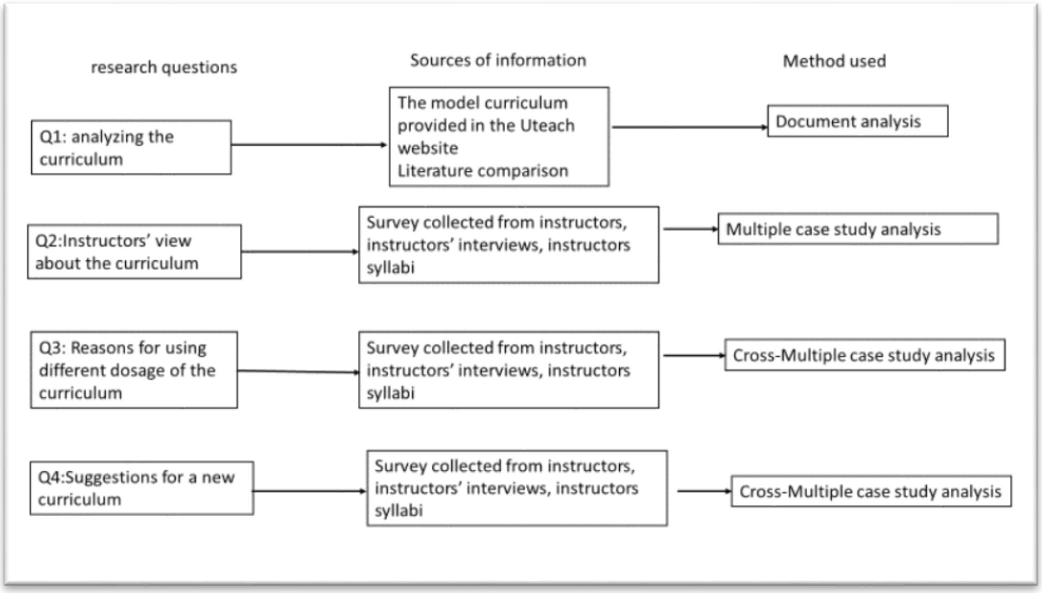

Figure 3. 1 Overview of sources of information and methods for each research question.

I examined two groups of documents for current research; the model curriculum provided by UTeach, and syllabi of instructors of the course. Surveys guided me in designing the interviews and provided me with another source for obtaining deeper information (Appendix A). Interviews were used for figuring out instructors' feelings about using the curriculum and provided me with a picture of each instructor's version of the course as they have personalized for their contexts, interests, and skills (Appendix B).

Documents Analyzed

The model curriculum can be found on the UTeach website. Due to copyright problem and restriction access, I am not able to share it in this document. This document was chosen since it is a sample curriculum for History of Science (HOS) that is used in teacher preparation programs. Syllabi from 16 instructors of the course were collected and analyzed (although I gathered 20 syllabi, I did not include the four courses for which I was not able to interview the instructor in additionl).

Interviews as a Data Source

Interviews are useful because they allow researchers to gain informative views and depict several perspectives on a phenomenon (Johnson, 2001). I captured depth and complexity of the curriculum by interviewing instructors who are engaged with it. The interview helps to “understand the world from the subject’s point of view, to unfold the meaning of people’s experiences, to uncover their lived world prior to scientific explanations” (Kvale, 1996, p.1). I interviewed course Instructors to get a complete picture of the syllabi they use. These interviews were semi-structured since there were prepared questions designed using instructors’ syllabi and surveys. I asked some additional questions based on answers I received. All interviews were conducted by phone except one interview that was via Skype. The list of interview questions can be found in the Appendix B. These interviews helped me to realize how each site implemented the course and to hear their opinion about NOS. Interview questions are found in Appendix B.

The interviews were taped so that they would be available for review later. Data are stored in a hard copy and kept in a confidential place to prevent unauthorized access to the information. Participants’ documents are stored with numbers, not with names and the list linking these two is kept in a secure and separate location. I used pseudonyms, so I referred to subjects by the instructor’s number instead of their name.

Surveys

I designed 10 questions in a SurveyMonkey platform for distribution to the instructors. First, questions were for gathering general information, like the number of times an instructor has taught a course or from which department he/she is. The rest of the questions provided choices for the instructor about the method of teaching, rationale for this course, and nature of science elements. There was extra space in the case they wanted to add something. The last questions were related to using the model curriculum. I sent the survey to four experts and made some changes based on their suggestions. The survey questions are included in Appendix A.

Specific Research Procedures

1) What content and instructional methods exist in the UTeach Model Curriculum for the "Perspectives on Science and Mathematics " class provided by the UTeach Institute?

To address the first question, I analyzed the model curriculum for the course "Perspectives" (just the science part) using document analysis. I created criteria based on the literature review, which mainly asks about nature of science. In each part of the curriculum, a strong point was highlighted along with some suggestions for improvement.

2) How does the intended curriculum developed by those teaching various versions of the "Perspectives on Science and Mathematics" course across the UTeach collaborative correspond with the model NOS/HOS curricula as provided by the UTeach Institute?

The answer for this question came from gathering Syllabi of instructors, their answers to survey and interview with them. These sources of data together helped to realize how the course had taught at each site and whether they are using the model curriculum or not.

3) What rationales are expressed by the instructors who teach "Perspectives on Science and Mathematics" for any changes made when taking the Model curriculum and creating a personal version of the HOS/NOS curriculum?

The sources for answering this question included survey responses, review of syllabi, and interviews which helped me to realize what peoples' perspective is about the course, its rationale and importance of NOS in it. This information provided me with opportunities to explore why they changed model curriculum, or why not. By combining these three sources of information, I explained each site as one case. In a case study researcher should “describe each case and provide an analysis of issues or themes that the case presents” (Creswell, & Maietta, 2002, p. 164). These themes came from a careful review of each case and cross-case to find similarities, differences, challenges, methods, and perspective about NOS.

Upon collection of surveys and syllabi and transcription of interviews, the researcher reviewed the transcripts and coded similar responses of individuals trying to ascertain the factors which seemed important in each site's approach to the course. The researcher was looking for elements of each case that were unique or elements that were similar or obviously different among cases.

4) What HOS/NOS preservice curriculum might be proposed after reflecting on the ideal, model and intended HOS/NOS curricula examined?

All the data, including the model curriculum, survey, syllabi, and interviews, helped me to suggest elements that should be considered writing a curriculum for “perspective on science and mathematics” that has the most overlap with suggestions of literature and instructors of the course and meets the program and course’s objectives.

Methods for Data Reduction

For analyzing data, first, the interview was transcribed. For each instructor, I saved responses to the survey, important points in the syllabus, and narratives from his/her interview in a single case record. Then I put this information for instructors who are from the same site beside each other and wrote a solid case based on them. These documents can be found in the Appendix C-M. Then I read each case over and over carefully and did cross-multiple cases analysis to find some themes in the data. These themes emerged from parts that most of the instructors have talked about them. First, I highlighted each theme in data with a special color and then I put them in tables for each site. Later, for answering research questions, I tried to put information from these tables in categories and make sense of them.

Researcher's Experiences and Potential Bias

The role of the researcher in qualitative studies is that of an instrument of data collection and interpretations (Denzin & Lincoln, 2003). The researcher should be aware of his or her own biases, experiences, and expectations and mention them (Greenbank, 2003). To satisfy the interest of readers in knowing what biases I might hold, let me say that I am interested in the nature of science (NOS) and took a course in this topic and have studied this topic in an organized fashion for three years. Moreover, I was in a teacher preparation program, so I know the conditions and background of preservice teachers. I have enough knowledge in the topic to analyze the efficiency of the curriculum. Likewise, as a teacher both at the high school and collegiate levels, I know it is not an easy task to teach about NOS even when you know about it. This background enabled me to integrate my theoretical and practical knowledge to help the preservice teacher to have a pedagogical content knowledge about NOS and HOS.

Triangulation

Triangulation is a combination of methodologies in the study of the same phenomena and is a way to strengthen a study (Patton, 1990). In data collection, using various kinds of sources helps researchers to have considerable confidence in the reported data (Yin, 2011). Triangulation is one of the suggested methods to increase internal validity of a qualitative research. Merriam (1998) defines triangulation as using" multiple investigators, multiple sources of data or multiple methods to confirm the emerging findings" (p.204). In the current research, data triangulation-the use of a variety of data sources in a study- is used. Collecting data from surveys, interviews, and documents provided me with opportunities to gain the most complete picture possible.

Audit Trail

Audit trails enable the researcher to address the issue of confirmation of the results. Audit trails document the entire process of developing research. According to Koch (2006), all the theoretical, methodological and analytical choices of research are clarified for the reader which enables the reader to examine the research process. “In order to develop a detailed audit trail, a researcher needs to maintain a log of all research activities, develop memos, maintain research journals, and document all data collection and analysis procedures throughout the study (Creswell and Millar, 2000 cited by Carrying, 2009, p.15)”. The audit trail helps other researchers to follow steps and determine the reliability of the results (Carcary, 2009)

In this research, data, including electronically recorded materials such as tapes, field notes, transcripts, and research results kept in a secured external file and google drive of researchers.

Chapter IV

Results and Analysis

Introduction and Chapter Organization

Chapter II mentions reasons supporting the inclusion of a course in the history of science (HOS) and/or nature of science (NOS) in a preservice science teacher education program. The UTeach science and mathematics teacher preparation program offers such a class with elements of both HOS and NOS, called Perspectives on Science and Mathematics" (herein called *Perspectives*). When a program is established, it seems necessary to evaluate it to reinforce the strengths and eliminate the weaknesses. The result of such an evaluation can guide similar programs as well. This research project specifically focused on an analysis of the *Perspectives* model curriculum by exploring how this class is taught at a variety of UTeach sites around the U.S.

Sixteen instructors (from eleven sites) were willing to contribute to this study and responded to a survey, provided their syllabi and later answered some additional questions (The survey and interview questions are included in Appendix A and B). Ultimately, I wrote eleven case studies (one per site) based on the information I gathered from these instructors. The eleven case studies drew on data obtained from the surveys, syllabi, and interviews. I introduced themes that emerged from a cross-case analysis and put that information in tables. Most importantly, the themes are related to instructors' views about the model curriculum and nature of science, rationales for having such a course from their perspective, different methods and resources they used, and their suggestions. In addition, some data about the model curriculum is provided.

In this section, first I have explained the *Perspective* and its model curriculum as a data resource for question one and then I have provided an overall description of the 11 sites from which at least one instructor contributed data to the study. These case studies along with themes came out from multi case analysis provide data for answering question 2-4

The first question that data regarding the model curriculum answered is:

1) How do the history of science (HOS) lessons and instructional methods in the UTeach Model curriculum for the class "Perspectives on Science and Mathematics" (*Perspectives*) compare with recommendations in the science education literature?

The model curriculum for "Perspectives on Science and Mathematics" is provided by the UTeach Institute and made available to all program-adopters via the website. On the course home page, there is an explanation about the course, including the following paragraph:

> The course provides historical perspectives on how practical needs, social conflicts, and even individual personalities shaped the content and direction of the sciences. Another objective of the course is to convey that scientific and mathematical concepts are not static. The meaning of the term "species," for example, has changed over time, and even today some biologists disagree about how, or even whether, to define it. The goal, then, is to promote among UTeach students the understanding that even the most basic ideas of science are dynamic, despite the way this information is presented in K-12 textbooks (UTeach website).

Core components of the course and course objectives which are elements that UTeach emphasizes sites should consider are organized in Tables 4.1 and 4.2.

Table 4. 1. Core Components of the *Perspectives* as determined by UTeach on the Perspectives's web page

	Core Components of the *Perspectives* class
1	The course is taught by a faculty member with expertise and a research background in the history or philosophy of science.
2	Course content topics and themes are relevant to secondary science and math teaching.
3	The course emphasizes sophisticated research and information analysis.

Table 4.1 (cont'd.)

	Core Components of the *Perspectives* class
4	The course emphasizes intensive writing.
5	Students design, present, and revise middle and high school science and math lessons (using the 5E lesson plan model) that incorporate the history of science or math.
6	Key instructional approaches include modeling of effective direct-teaching and questioning strategies, interactive classroom discussions, and student presentations of inquiry-based lessons in the history of science and/or mathematics with peer, master teacher, instructor and/or teaching assistant feedback provided for improvement.

Table 4. 2. The Listed Objectives for the Perspective Class as determined by UTeach on the Perspective's web page

	Course Objectives
1	Students will be able to . . . describe the historical development of aspects of science and mathematics relevant to future teachers.
2	. . . describe several analytic frameworks for understanding the history of science and mathematics.
3	. . .analyze the history and content of evolutionary theory.
4	. . . express ideas and opinions clearly and effectively in formal writing.
5	**. . .** develop skills in searching for, retrieving, and evaluating the provenance and reliability of source materials, on- and offline, including specific resources available to teachers.
6	. . . integrate approaches and material learned in the course with independent research and science or math content to design middle and high school science and math lessons.
7	. . . reflect on and critique their own work, particularly lesson plans, and that of others.

Right now, there are "recently contributed resources" part on the UTeach website which provides some examples. I just have analyzed the model curriculum which was the available one in the time of this research on the UTeach website and still exist there. The model curriculum currently includes 17 lesson plans (9 for math and 8 for science); the plan assumes that all preservice math and science students will take the same class together. Each lesson plan has two parts, including the explanation of the topic and instructors' notes for that topic. There is a complete list of references in the end of each lesson plan. In addition, supporting activities and worksheets for each lesson plan can be downloaded from the course page. Sample midterm exam, final exam and each lesson plan's quizzes are other supplementary materials. A list of the lesson plans is provided in Table 4.3.

Table 4. 3. Topics of Lesson Plans in The Model Curriculum

Topics of Lesson Plans in The Model Curriculum and short overview of them	Topics Analyzed	Called in This Document
Topic 1: Course Orientation **This class period focuses on communicating the primary purpose of the course, which is to analyze how science progresses through readings and discussions about the sometimes-bumpy development of key notions and theories in various fields.**		
Topic 2: What Is Science? What Is Mathematics? **This topic deals with ambiguities and disagreements about what counts as science and as mathematics.**	*	Perspectives Model Lesson Plan #1
Topic 3: Plato's Philosophy of Mathematics **This topic centers around an analysis of Book 7 of The Republic by Plato. Students reflect on whether mathematics is independent or empirical knowledge, whether it is invented or discovered**		
Topic 4: Revolutions in Astronomy **This topic focuses on the development and acceptance of new theories in astronomy, particularly on how observable evidence changed human understanding of the earth's motion**	*	Perspectives Model Lesson Plan #2
Topic 5: Paradoxes of Division **This topic explores fascinating paradoxes relating to the operation of division: division by zero, division by negative numbers, division as the inverse of multiplication, and "baseball division."**		
Topic 6: Minus Times Minus Is What? **In this topic, students reflect on the rules of signs in algebra. They discuss the history of negative numbers and consider that axioms and proofs are the result of humans establishing ordered grammatical conventions of a language or a systematic game.**		
Topic 7: Radical Puzzles **In this topic, students are presented with apparent mathematical paradoxes involving the manipulation of square roots. They debate the logic and mathematical assumptions supporting different approaches to various problems**		

Table 4.3 (cont'd.)

Topics of Lesson Plans in The Model Curriculum and short overview of them	Topics Analyzed	Called in This Document
Topic 8: Species, Monsters, and Things in Between **Students discuss problems in the usual definition of species: "a group of organisms that breed to produce fertile offspring."**	*	Perspectives Model Lesson Plan #3)
Topic 9: Darwin's Path to Evolution **This topic examines the development of Darwin's theory of natural selection as the driving process of evolution.**	*	Perspectives Model Lesson Plan #4)
Topic 10: Questions and Evidence on Evolution **This topic emphasizes often overlooked types of evidence that are in fact useful in teaching evolution to high school students, particularly in response to typical questions they might ask.**	*	Perspectives Model Lesson Plan #5)
Topic 11: Secrets of the Alchemists **This topic delves into the history of alchemy, showing how it contributed to the development of modern chemistry.**	*	Perspectives Model Lesson Plan #6)
Topic 12: Impossible Chemistry **This topic examines the discovery of radioactivity to illustrate how scientists are often compelled to change previously held notions about what is possible by the detection of surprising, seemingly incredible, phenomena.**	*	Perspectives Model Lesson Plan #7)
Topic 13: Discovery of the Electron **This topic centers around the discovery of the electron. Textbooks often attribute the discovery singularly to J.J. Thomson in 1897**	*	Perspectives Model Lesson Plan #7)
Topic 14: Infinitely Small **Students debate whether 0.999… = 1 and analyze the intuitions leading them to their divergent judgments. The instructor compares their disagreements to debates among mathematicians over the existence and meaning of infinitely small quantities**		
Topic 15: Prisoners of Probability? **Students learn about particular aspects of the origins and development of probability theory.**		
Topic 16: The Age of the Earth **Students discuss the history of efforts to ascertain the age of the earth.**		
Topic 17: Non-Euclidean Geometry **Students discuss the history of efforts to ascertain the age of the earth and analyze how scientists brought together different kinds of evidence, including historical records, religious scriptures, fossil findings, and the physics of radioactivity, geological processes, and thermodynamics, to answer this question.**		
Topic 18: Philosophies of Mathematics: Choose or Sleepwalk **This topic explores various philosophies of mathematics, including a review of Platonism and formalism, which were discussed previously.**		

Research questions 2, 3, and 4 that the case studies and tables will answer are:

2) How do the science elements of the Intended curricula developed by those teaching versions of the *Perspectives* course at various UTeach sites correspond with the Model curricula provided by the UTeach Institute?
3) What reasons are expressed by the instructors who teach *Perspectives* at various sites for any changes they made to the Model curriculum?
4) Following a review of instructional methods, course content and rationales provided by those who teach *Perspectives* at various sites, what suggestions might enhance the Model curriculum for a HOS/NOS class for preservice science teachers?

Cases Studies that Depict What is Going on in the Universities

Table 4.4 includes a basic overview of each of the 11 sites and 16 instructors. Each of these sites is rendered as a case study with data derived from surveys, syllabi and each site has a UTeach program. I had the opportunity of collecting data from more than one instructor for some sites. The background of each instructor and number of times they have taught the class are mentioned in the table. Figure 4.1 shows a map depicting all UTeach sites in the time of this study in Fall 2015. The sites are included in cohorts linked to the time the program started. Since sites in cohort 1-3 are older they offered the *Perspectives.*

Table 4. 4. Basic Information about instructors' backgrounds and teaching experience

Number of Sites	**Number of Instructors Teaching *Perspectives* at the site**	**Instructor's Department**	**Number of times each instructor has taught the course**	**Main Emphasis of Each Instructor's Class**
1	2	Education	R:6	History of Science and Mathematics
			J:1	History of Science and Mathematics
2	1	Science	R:4	History of Science

Table 4.3 (cont'd.)

Number of Sites	**Number of Instructors Teaching *Perspectives* at the site**	**Instructor's Department**	**Number of times each instructor has taught the course**	**Main Emphasis of Each Instructor's Class**
3	4	History	A:17	History of Science
			M:6	History of Science
			V:2	History of Science
			B:5	History of Science
4	2	Philosophy	K:6 (master teacher)	Philosophy of Science
			J:1	Philosophy of Science
5	1	Education	J:2	History of Science
6	1	Education	J:10	Philosophy of science and math
7	1	Education	R: 8	History of science
8	1	Philosophy	G:3	History and Philosophy of Science
9	1	Mathematics	Sh:5	History of Science and Math
10	1	History	M:1	History of Science
11	1	History	A:1	History of Science

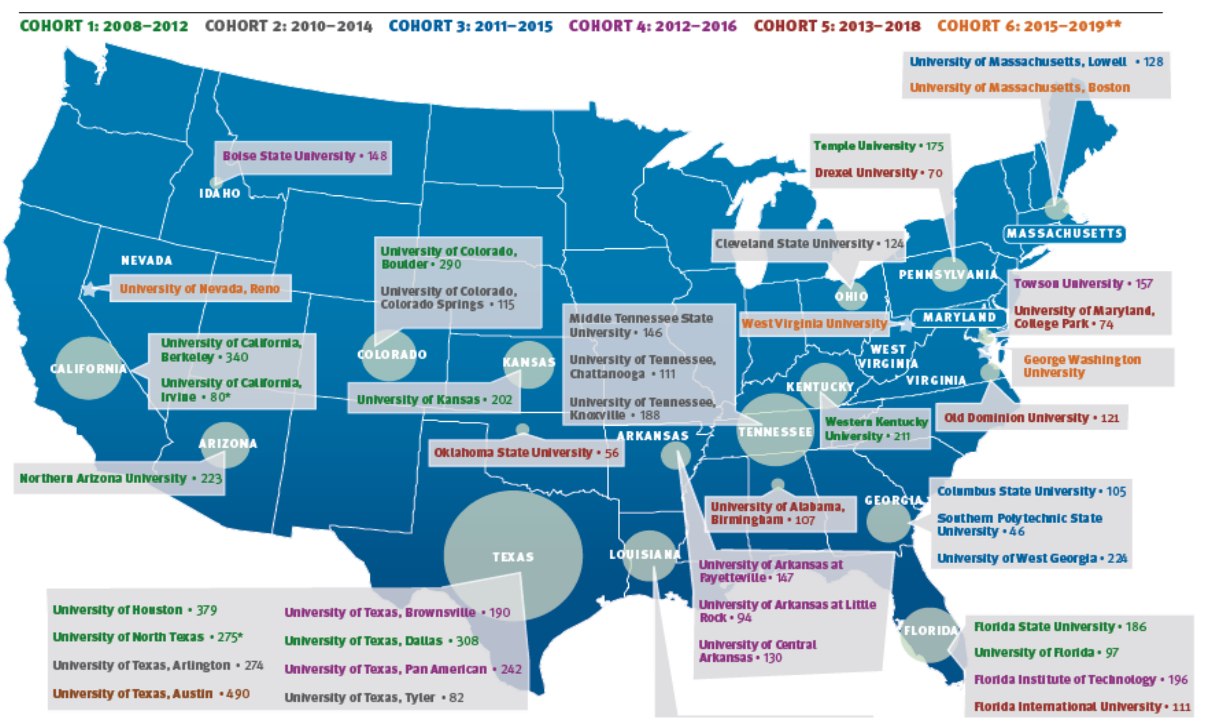

Figure 4.1. Different sites of UTeach and their associated cohort. Source: UTeach report at https://institute.uteach.utexas.edu/uteach-impact

As it mentioned there are 11 case studies.The case studies are presented here as introductory vignettes with full case studies included in Appendixes C-M. Each case summarizes information obtained from that site's instructors' responses to survey and interview questions and their syllabi. Since some aspects of NOS and implementation of the model curriculum were important for me in writing these cases, I added personal interpretations if it was necessary. Sometimes I realized in the interview that some information in the survey is not precise, in this case, after asking for more clarification, I relied on the interview.

Since providing an entire case needs much space and would interrupt the flow of the narrative here in Chapter IV, I have just included a vignette of each site with the related complete case study included in Appendices C-M. For these vignettes, I have provided the most important data related to each site, the nature of instruction, instructor's view about the model curriculum, and in addition, although the *Perspectives* class dealt with HOS, I looked critically at the NOS elements recommended by the literature as well.

Perspectives Class: Site Number 1, SW State University (Full Case Study Appendix C)

> Perspectives is an important course because it gives [students] a bigger view on science and math and in the same times provides the student with liberal art perspective, critical thinking, analyzing resources, connecting science, math, technology, society, and culture. Instructor 1

This site, SW State University, is a public research university with a student population of almost 17 thousand. The SW State site offered Perspectives six time since 2012. During this time, the *Perspectives* class has been taught by two instructors, both from the education department, with the syllabus prepared by the first instructor. The first instructor has taught the course 6 times while the second one only taught it once.

Their instructional method is basically to provide lectures about weekly articles (since the textbooks are separate, they do not discuss them in the class; students write a reflection on it). Each week students read a chapter from their textbook along with extra articles provided by the instructors. Instructors give lectures in the class about articles and open a discussion. Students write weekly reflections on their reading from their textbook. Both instructors emphasize their role in helping students to engage in inquiry through something called they call the “Umbrella Project” which I will discuss in greater detail later in the case. Both instructors believe since students find everything related to their topic themselves, their class is inquiry based.

The first instructor is not using the model curriculum; he uses his own model which is history, culture, and mathematics. “I got the general idea from it, but I want my students to get the big picture and to be able to perform it in their own classroom.” The second instructor’s class was an additional section that was added at the last minute, so he did not have that much time to prepare for the class and based his class directly on that of the other instructor. He says the main reason for not using the model curriculum is the time limitations he had, so he looked at some parts of it, but due to lack of logic and inquiry decided to not use it. He believes if he had time the class would be more inquiry based.

The "Umbrella Project" is the main assignment of the course. In the first week, the instructor introduces the project and asks students to find a partner and identify a topic from science/ mathematics content that they like. The topic should target the standards for a high school, such as electricity and atomic models. The project requires four people in a group working in pairs within that group. One student pair works on one topic and another pair on another topic. In our example, one pair works on the history of electricity and another pair works on the history of atomic models. In the first phase of the project, both pairs investigate the history and cultural context for their topic and write a four-page paper. Then, in the class, these two pairs read each other's paper, debate it and critique it. In the second phase, they find historical people who have contributed to their topic and write about them and again review it together, in the last part they should put what they learn from the history of their topic in the context of a classroom teaching for 45 minutes and write a 5E lesson plan.

Regarding NOS, the first instructor did not talk explicitly about it in his class, but he thinks connecting to NOS/NOM comes from their reading and activities. "Students write reflections on their reading and it naturally happens via them that they learn something about science. It is naturalistic inquiry without pre-structure. I move with students and facilitate their learning." The second instructor thinks to improve curriculum, it should be more inquiry base, and it makes the course less challenging for students and instructor. His suggestion for UTeach is providing more information on how mathematics changed over time.

Perspectives Class: Site Number 2, Beta State University (Case Study Appendix D)

> One of the things I ask [students] to do the entire courses is just to be thinking about the difference between how we are scientists or teachers of math and science to view math and science and how general public might view that and what are the responsibilities when we are talking about math and science.
>
> The sole instructor of this site

This site, Beta State University, is a public master university with a student population of almost 8 thousand. The Beta State site offered Perspectives once a year since 2010, which means it was being taught for the sixth time at the time of the interview. The instructor I interviewed by phone is from the Department of Chemistry & Biochemistry and has taught the course four times. Mostly she lectures in the class. She tries to lecture for 15 minutes and then poses a specific question related to main idea of lecture, trying to initiate a discussion. That discussion takes the class and then she comes back again with maybe 5 to 10 minutes of some additional information and then asks another question to see if she can get again some more discussion going with that. In addition, she does some kind of hands-on activity to help students get involved with the activity.

She talked about Valentine's key activity from the model curriculum as an example of a topic that students love. (In this lesson plan students use Alchemical symbols to understand the meaning of some key Valentine’s pictures which are provided in the lesson plan along with some texts). She said this lesson plan opens discussion about alchemy as a crazy, superstitious or whatever side of science and certainly there are some students like that, and some of them are more serious. She asks preservice teachers to be thinking about the difference between how we are scientists or teachers of math and science to view math and science and how general public might view that and what are the responsibilities when we are talking about math and science. So, in alchemy she does an experiment where she takes a clean copper penny and coats zinc on to the penny and then heats the zinc and the penny turns gold, (not a real gold, it is just bright). It looks like she just turned the penny into gold so she uses that to talk about how it doesn't mean it really happens, we can trick public. So, it is important how as a scientist or a teacher we talk to the public.

That first year that she taught it she relied extensively on the model curriculum. She had about two weeks between the time she was asked to teach the class and its start. She had no idea what she was doing so she used that modern curriculum quite heavily. The previous instructor had used a little bit of it but not the whole of it, so she just pulled a few things that the previous instructor had done and then relied on that modern curriculum to figure out what it was.

She also takes the few of them from areas she does not know, such as math lesson plans. She intentionally used some of those math plans to get some math guidance about things that she had to learn to target her own knowledge. She came up to speed very quickly. She chose some lesson plans and then as she got more experience, changed what she used from year to year, sort of based on what the students bring to class.

In the interview, she mentioned preservice teachers will learn about characteristics of science via explanations and readings. Sometimes she discusses them, but she focuses on the history of science. Generally, from her explanation, it seems she refers to the nature of science in her class. She did not provide any suggestions for UTeach regarding *Perspectives* because she likes it this way.

Perspectives Class: Site Number 3, Mega State University (Case Study Appendix E)

> Science is not just about knowledge/rules and results. Too much of science education gets students to learn what we already know. Here is the periodic table learn it. That is essentially repetitive and it is similar to engineering. What history of science capture very nicely is the process.
>
> Author of the model curriculum

This site, which I will call Mega State University, is important because it is the home of the overall national program and of the author of the model curriculum. The Mega State site is a very large public research university with a student population of almost 51 thousand. The *Perspectives* class has been taught by several instructors, all from the History Department, each using different syllabi. This class meets three times per week for a total of three hours per week. I interviewed four instructors from this site including him. One of them was the first instructor of the course and taught the course five times, the author of the curriculum taught the course 17 times. The other two were current instructors alternatively teaching the course in the spring and fall; having taught the course two times and six times respectively.

All of the instructors are from the history department which seems a tradition at this site and makes sense given the history orientation of the class. Each of them has developed an individual syllabus, but the method of instruction and main topics are very similar. None of them use the model curriculum; they prefer to use their own materials that they have from previous similar classes. All instructors' classes consist mainly of the history of science. Generally, all instructors at this university state a desire that preservice teachers learn to find events by digging into the actual history, and they think in this way, they find the ability to overcome misconceptions in students' minds.

The classes at this site are oriented around lecture, discussion, and completing of various activities. Some lectures are used to give background and discussion around readings, writing papers and lesson plans. The students are usually paired in groups to do lesson plans which are about putting a historical topic related to content in the typical Uteach 5E structure. Students also have field trips around the campus. There are some small differences among instructors' teaching methods. Instructor 3 allocates half of his class to doing historical experiments.

Instructor 3 uses many different resources for teaching the course, such as lab resources, different resources at the university such as the art museum, and some of the math lesson plans written by the author of the model curriculum. Instructor Number 4 has more activities about science content. Her emphasis is on science and society, so she connects history to socio-scientific issues. For example, the history of climate change is one of her favorite topics. She believes the author of the model curriculum is more interested in correcting misconceptions.

Instructor 3 uses some of the math lesson plans from the model curriculum, but he criticized the book "Science Secrets: The Truth About Darwin's Finches, Einstein's Wife, and Other Myths" because "myth is a philosophically loaded term and students do not really understand what myth means". He thinks that even an accurate story (lesson plan) in the "myth" book may give students a "wrong philosophical impression". He is a very strong supporter of re-enacting historical labs and his suggestion to UTeach is to add that part. He thinks this, since labs are hands-on activities and are useful for students with practical learning style. He says he got good feedback from students about it.

For the first instructor, the model curriculum is just a resource, a starting point, and example for people who want to start it. He thinks because most historians of science do not experience teaching it to preservice teachers, the model curriculum can help them to get the idea.

Instructor number 4 at this site thinks that having a model is great to get the idea, but it does not feel right to use another person's material. Instructor number 3 said the model curriculum is written perfectly and he wishes he was the author.

The author of the model curriculum likes his material and believes it is the result of much feedback and subsequent change, but at the same time is very open to any changes other instructors decide to implement. He knows that there are several versions of "Perspective" and his version is just one of them. His belief is the mathematics part is written better and feedback from students has confirmed this belief for him. The author of curriculum mentioned disagreements and different perspectives in the history of science and mathematics are the focus of his curriculum and his class.

Regarding NOS, there is an obvious sensitivity about the word among those interviewed. The first instructor of the course told me that the first director of the UTeach criticized NOS and this influenced the way the course was orientated. The instructors believe the word is created by science educators and it does not make sense to have a list of characteristics of science. All of them separately told me historians of science and science educators have a different language.

The author of the curriculum thinks that since nature of science people are not able to dig deeply into the history, they believe what they hear and there are more chances that they transfer wrong information to students.

They have some struggles with lesson plan part. Thus, instructor number four suggested UTeach to have a website to teach students how to do research in the history, which resources to use and how put the results in the 5E lesson plan model.

Perspectives Class: Site Number 4, Alpha State University (Case Study Appendix F)

> I think having teachers in high school who are well acquainted with the philosophy of their field will help their understanding as well as their students' understandings of not just of learning to present lots of materials but to understand why this is happening in the first place and what led to this point.
>
> Instructor of this site

This site, Alpha State University, is a large public research university with a student population of almost 37 thousand. Alpha State site has offered the *Perspectiv*es class since 2010. The *Perspectives* class has been taught by philosophy graduate students; each instructor develops a personal syllabus but expectations are the same with just some readings and expectations changed. I talked with one of the instructor-students and a master teacher who monitors those teaching this course. The master teacher has a bachelor degree in chemistry, master's degree in education leadership and a Ph.D. in chemistry with an emphasis in education. Some of these graduate students taught the course several times and two of them taught it just one time. The graduate student who I interviewed has taught the course just one time.

The master teacher told me that the class is focused on lectures, discussions, and presentations by students. Their students should do 5E lesson plans just one time and with a partner. She says the history of math is a larger part of their curriculum because they have many math students compared with those in science. She thinks there is not a single model curriculum for this course because it depends on which department would teach it.

The instructor often introduces a basic concept or question at the beginning of the class like "what is philosophy" and has students break into groups of two or three to generate a response to the question. Then they come together and discuss each of their answers from the group, and the instructor provides a broad answer.

He said some of the people who taught the course before him copied some part of the class from the model. So, he thinks they use a combination. They implemented a lot of class activities throughout the semester, some long-term projects like the lesson plans from the model curriculum, and some shorter project, and they have lots of dialogues about each day's topic.

He looked at the syllabus of people who have taught at his university in the past, and used a lot of what had been done before. He altered few things to suit his own tastes or experience based on what he thought should be emphasized. So, he thinks that having a model is important because some level of standardization is important, but it should be left open to modifications by the instructors.

The instructor mentioned that several areas related to NOS should emphasize including the ideas that 1) science/math are not just something that exist already constructed, they are things that humans engage with, so understanding science as a human endeavor is very important. 2) Saying "scientific method" is like calling something a salad, meaning that we have different ways of doing science. 3) Science is also political, because it's a human endeavor, so the kind of research is defined by where the money comes from, so the role of society is important. These elements are included in readings, and class discussions.

My contact at this site suggests that there should be a collaborative document that people can share and modify with their own ideas about the course. He thinks that having a diverse group of people who are working collaboratively on a model for the course would be best just to make sure that the model does not represent just one person's ideas.

Perspectives Class: Site Number 5, Delta State University (Case Study Appendix G)

> Science and math are human endeavors . . . only humans do but if the students don't understand that it's a human thing then they won't enter in it themselves so the history of science is placed that role.

The only instructor of the course in this site

This site, Delta State University, is a large public research university with a student population of almost 23 thousand. The Delta state has offered the *Perspectives* class every academic semester since 2010, which means it had been taught ten time at the time of the interview. I interviewed an instructor from education who has taught the course five times and is currently only instructor of the site. He has degrees in both science and the history of science making him quite unique among those teaching this class.

As mentioned in the survey, interview and syllabus, the instrucors uses lectures, discussions, field trips and performing historical experiments. For field trip, He and his students went to the University of Oklahoma library to see their collection which features many first editions of actual works. Students get to see, touch and even hold them. He thinks students feel more connected with the document in this case compared with online resources.

He suggested that he does not spend class time having students watch videos but has them engage in primary research with an optional creative expression/demonstration related to the integration of science and mathematics to humanities. In explaining his method he said

> I'm more prone to some discussion and as well as I do lecture but it's also lead that to the point so we can have a discussion. And then I do. I spend half of the class repeating historical experiments.

This instructor began by attending a workshop on the model curriculum where he took everything they had because he was asked to replicate the class. Then, step by step, he brought new materials and ideas he had from OU and this changed the nature of instruction

> It's very good it's (to cut) some mistakes that need to be edited for spelling mistakes, grammar mistakes but it's a good document to use and it saves the kids from buying a book, and then other than that there are number of articles that I like just from the history of science. I don't buy a lot of books, don't use big books. The other stuff in the "UTeach" course which is about the curriculum stuff there's lot of (prepared) questions, short phrases, I don't find those really useful but they're not bad.

He thinks the books and other resources that are introduced in the model curriculum are good, and some of the lesson plans can be used to get ideas.

This instructor believes that nature, philosophy, and definitions of science are raised directly out of the study of the history of science, so aspects of the nature of science are a direct outcome of this class. He said that even with the high school students he talks about issues like humanities explicitly in the class. He said that by "human activity" he means that science is limited, makes mistakes, self-correcting, and has a certain context. He believes that the nature of science is infected by human nature, because for example in ancient time people insist the earth is flat just because it helped the church to keep its power.

When I mentioned that in addition to humanity there are other elements in the model curriculum which are related to NOS such as different methods for doing science he added that scientists do scientific work with different methods but when they want to communicate it, they explain it in order because they want everyone to understand it and this same method of communication can mislead people that there is just one scientific method.

Perspectives Class: Site Number 6, Zeta State University (Case Study Appendix H)

> I find history and philosophy too limited. I am not interested in facts. I am interested in the swing of ideas going from ancient to postmodern, I want to do enough of content to show changes over time in math and science. How they integrated, how they serve each other and who they are part of the society and how society had an impact on them.
>
> Instructor of this site

This site, Zeta State University, is a public university with highest research activity with a population of almost 50 thousand students. Zeta state has offered the Perspectives class twice a year since 2010. It was taught for the eighteenth time when the interview took place. It is typically taught twice each semester. The instructor who taught the course 12 times was from the Education Department.

The first part of his class consists of NOS/NOM instructor activities; the second part consists of student presentations which I have explained in the assignment section to come.

His method is using activities that present ideas and then through discussion and debriefing, he works with student to extract the meaning of those lessons. He has an activity that models NOS and he called it PPT model (Process, Product, Technology model). These are hands-on lessons and activities that are designed using Electricity in a science context, and depict process, product, and technology and interaction between all that. It is related to observations. “We show students how science has changed from Aristotle to the Renaissance and how doing experiments added to what scientists used to do (In ancient time scientists had their interpretation from their observations only, without conducting an actual experiment or probing more deeply). The point is that he wants to teach with a high level of student involvement.

There are times he lectures using PowerPoints which the students can download to their laptops. Groups of students are then assigned particular slides and are asked to review them and talk about their viewpoints and understanding of assigned slides in a presentation for the rest of their classmates. When the instructor feels there is a misconception or misunderstanding, he clarifies the content. Some of the topics he uses are the same with UTeach model but all in all he has his own model. In addition, He wants to teach by inquiry, engagement, and the use of hands-on activities -- beyond just memorization.

The instructor believes that UTeach model curriculum is stagnant but thinks it is reasonable for UTeach to present such a model. He says that UTeach has its own vision, but instructors modify it to show their specific views, focus and styles. He believes that instructors make choices because of fears. In other words, if we fear doing something we avoid that, so if there is a part in a model curriculum that we do not feel confident about teaching it, we ignore it. He added, one of his personal fears is to engage students with philosophical debates because he does not feel confident in that field. Therefore, he is not willing to do philosophical things.

In his syllabus, he offers many connections to NOS, such as, the difference between inference and observation, the role of culture and society in science, the tentative nature of science, the role of empirical evidence and experiments in science. He helps students develop a view of the nature of mathematics and science through reading, discussions, and writing reflections in which philosophical bases, assumptions, strengths, and limitations of mathematics and science are included. He introduces many resources for the course including several reference books about the nature of mathematics and science.

Perspectives Class: Site Number 7, Gamma state University (Case Study Appendix I)

> When teachers come into teaching they usually have a degree in science and so they feel good about the topics they are teaching, but the nature of science and this idea of how science works, is something very few people walk in with, so I I've taught this course in many different forms in different universities for about ten years, and I have never had students . . .really having an idea about how science works.

The only instructor of this site

This site, Gamma State University, is a very large public research university with a student population of almost 28 thousand. The Gamma State site has offered *Perspectives* since 2010. The course has been offered for ten semesters. The instructor of this site has taught the course eight times and has a background in education. At Gamma, they only teach *Perspectives* to science students; there is a different a version of *Perspectives* for the mathematics students to take.

The instructor's class is a seminar course with two distinct halves. The first half is very academic. They do not talk much about teaching but dive into the literature of the history and philosophy of science and science studies.

In the second half of the course, students focus on teaching the ideas they have gained. Together they think about pedagogy and how they adapt their teaching ideas to the Next Generation Science Standards. In addition, students do other projects and are in charge of twenty minutes of a class to run a workshop on an idea, but most of the class is reading and discussion.

There are important elements he spends a lot of time talking about, for example, the fact that there is not a single scientific method. Students read a lot of accounts about what scientists actually do. For instance, he has students read the original paper from the discovery of messenger RNA and then they read a chapter of the autobiography of the scientist involved, so, they can see the difference between the story told in the scientific journal paper and what really happened. He thinks his class is a very different class from than specified by the UTeach model of the *Perspectives* course.

Regarding the necessity of the model curriculum, he thinks he has a unique background as a science educator so it was better for him to design his own curriculum. However, for someone who doesn't have a background in philosophy and history of science having something as a model is important. At the same time, if historians and philosophers were to teach the class, since they would have no way of talking about pedagogy, a model curriculum could help.

He explained to me that his method was accepted by UTeach and other instructors.

> A couple of years ago, they asked me to do pre-conference workshop in this class. And there were three or four of us who presented about how we do the class, and everyone else did the class like the model, but mine was very different. I was a little nervous about going to Uteach but doing something completely different, but after I finished, most of the people in the audience wrote me and asked for my materials. So, that gave me some nice feedback that other people are seeing this as a relevant thing to do.

From his point of view, NOS and *Perspectives* are very similar classes, but he noticed after attending UTeach conferences in Austin, what has presented there is very much a history of science class. He thinks it makes sense because a lot of places get a historian of science or a philosopher of science to teach and not a science educator.

Perspectives Class: Site Number 8, Phi State University (Case Study Appendix J)

> I find that in science education people tend to do what is called "normal science", which doesn't tend to be particularly critical of the paradigm itself, so, I think a course like this can show the long run picture of how science unfolds.
>
> The only instructor of the course

This site, Phi State University, is a public moderate research activity university with a population of almost 30 thousand students. The Phi State site has offered Perspective once a year since 2014, so it had been taught four times at the time of the interview. All the sessions have been taught by the instructor who I interviewed. His background is in philosophy, with a minor in the history of science.

The instructor's instructional method is lecture and discussions. He emphasized in the interview that the focus of the class is comparing primary and secondary documents to give a "more historically accurate picture".

As he explained in his syllabus,

> In this class, we read original scientific and mathematical texts written by the great scientists and mathematicians themselves. These primary texts present the theories and results from the perspective of their original formulation rather than in the isolated and sterilized form in which they often appear in textbooks. These primary texts are supplemented by secondary sources that provide the philosophical and historical background within which these scientific theories and mathematical results developed. Between the primary and secondary texts we try to understand the questions and goals of the individual scientists and mathematicians. We examine what problems they were trying to solve or what phenomena they were trying to explain.

He thinks students like the course, especially when they see there are disagreements in history. Students use to think that everyone agrees with everything in math, and they get excited to learn about disagreements. Furthermore, when students make a mistake, they do not feel silly after they realize Newton (as an example) made similar errors. He believes that students find the course challenging and difficult but useful.

He thinks *Perspectives*' model curriculum is great because it's flexible enough and yet there is a required core component. He thinks the model has to be flexible because people from different backgrounds are teaching it.

The research, essay and the presentation (discussed in the assignment section) are his favorite parts of the overall curriculum. He did criticize the requirement that students write a lesson plan because he thinks students learned that skill in other classes.

The first time he taught the course, he was not aware of the materials on the website. After learning about these resources, he used them the second time he taught that class, and now selects a few that he thinks are useful. He believes the mathematics lesson plans and the book "The Cult of Pythagoras" are useful, especially because the book is an extension of lesson plans.

Demarcation problems, philosophical questions, talking about [Thomas] Kuhn, normal science, scientific questions, paradigm shifts, something about difference between induction and abduction on one hand and deduction on the other side, scientific method, are parts he mentioned he covers in his class when I asked about what is he does with respect to NOS. He added that the course is 80 percent history and 20 percent philosophy but it is not about nature of science. NOS needs a pure philosophy course from his point of view, so he strongly believes this is not a NOS class. He then mentioned "as long as we look at nature of science from broader perspective it can be an outcome of this class."

Perspectives Class: Site Number 9, Kappa State University (Case Study Appendix K)

> I think if you know how those historical things happen. It helps you to understand present a lot better and to teach the present science a lot better.
>
> Instructor of the course in this site

This site, Kappa State University, is largest public research university in a state with a student population of 22,285. Kappa State has offered *Perspectives* five times since 2013 at the time of the study reported here. The instructor of this site who was interviewed, has taught the course these five times but had just retired at the time of the interview (Fall 2015). He majored in mathematics and history making him an interesting subject particularly from a mathematics focus.

The instructor asks students to read the assigned text prior to the coverage of a given topic in the class and bring questions or comments to class for this discussion. As he explained in the syllabus, many classes include open discussions and activities to demonstrate the ideas of the topic and probe more deeply. In the interview, he explained his method for teaching the class is a quite a bit of lecture but with activities mixed in almost every class.

He thinks students know some content in their area but they do not know much beyond, so this course is a good opportunity for them to learn a little about other science branches and mathematics. So, besides the history of science, he does a little of the content of science especially modern science.

He thinks most of the history is, in fact, the development of new content that people had never thought about before and students need to have the content background to have a better sense of the history and to be teaching across in an interdisciplinary way. He senses that the model curriculum did not contact much of the actual content of science as he thinks is necessary and finds that problematic. He tried to show with readings and discussions, there is an interaction among mathematics, science and culture.

He thinks the model curriculum is generally good, but teacher candidates need more background information in the content of science before taking this course and even during this course. He thinks the model helps instructors in putting structure into a course when they teach it for the first time, but he is glad they didn't say that he had to follow the model curriculum exactly as they presented it. Ultimately, he used a few lesson plans from the model curriculum.

He thinks people who don't know very much about how science works are the people who sometimes dispute science, don't believe in evolution, and don't accept global warming. “They say, oh it is just a theory; you have not proven anything. They do not know it is the nature of science”. He added that students should know the work of science is asking questions and after scientists have tested things and learn how they work, they are open to further questions and possible changes. He emphasizes that science is never going to “prove” something. He thinks that the problem in political discussions recently is due to lack of knowledge of NOS. Because of this, he suggests that part of history class should teach students a little bit better about how we understand science and how we accept it. Even with these ideas in place, the point is that he does not mention NOS explicitly in his class and believes students will learn these points from readings and discussions.

Perspectives Class: Site Number 10, Sigma State University (Case Study Appendix L)

> I hate to say it, but I picked things which spoke to my strengths, even maybe didn't try the things it did not fit my strengths, so maybe I was playing it safe.
>
> The only instructor of the course

This site, Sigma State University, is largest public research university with a population of almost 50 thousand students. Sigma state has offered the *Perspectives* class once a year since 2010, which means it had been taught 5 times when data were collected for this study. In addition to the survey and a review of the syllabus, I interviewed an instructor from the history department who has taught the course one time as the current instructor of the class.

Due to time constraints on the interview, I had to draw the following information directly from the syllabus. This class meets on Tuesday for 50 minutes and on Thursdays for two hours. Most Tuesdays are for discussing ideas and concepts pertinent to that week's readings and lectures. As the semester progresses, Tuesdays are used for lesson plan demonstrations. Thursdays are mostly lecture and discussion of important historic periods, ideas and people. This is an upper-division history course. The assigned readings vary in length, and come from primary and secondary texts. For example, in week five, the readings include a chapter from one of the textbooks and two primary resources. Primary resources are both written by Galilei. The first half of the semester has much more reading than the second half.

He strongly wants students to learn methods of historical research with particular focus on the analysis of the origin and reliability of print and internet sources. He explained that learning to do research in history is a process that students should learn via reading lots of valid documents.

The instructor believes that the model curriculum is very helpful and he used some of the lesson plans, activities and reading with some changes. In answer to a question about his rationale for using some lesson plans but not others, his answer was:

> I hate to say it but I picked things which spoke to my strength, even maybe didn't try the things it did not fit my strengths. So maybe I was playing it safe, because it was a new course. I think if I try it again I will try one of the other one or lesson plans I don't like.

He thinks the course is a very well organized at the Texas level, and makes a good connection to the science curriculum and other aspects of ordinary life and professional life and it can be a very valuable course. He believes a lot of people just repeat their old history of science courses as they teach this course, and he does not think that is right. He thinks instructors should try to make it fit the goals of UTeach as a teacher preparation experience.

He starts the semester talking about the scientific method formally defined and then talks about the different ways that people actually do science. He also discusses the role of society in the science. Interestingly, when I told him about NOS by giving him the definition and introducing some elements of it, he answered he does not have any idea about it and he does not do anything related to it because this is a history of science and math class. Yet, it is clear that some ideas many would recognize as NOS are part of his instruction.

The instructor's suggestion is more support for the history and philosophy of mathematics. He thinks most of the people who teach the course have more resources and experiences with history of science compared with math, so it would be helpful if UTeach would introduce and provide resources for teaching history of mathematics. He even suggested maybe in one of the workshops they should invite a math historian to share more ides of teaching history of math with the instructor of *Perspectives*.

Perspectives Class: Site Number 11, Pi State University (Case Study Appendix M)

> When I was a graduate student in the nineties there was a lot of focus on how science was socially constructed, so I think many instructors still focus on it in history of science classes.
>
> The only instructor of the course

This site, Pi State University, is a very large public research university with a student population of almost 40 thousand. The Pi State site offered *Perspectives* for first time in the Spring 2016. I interviewed the sole instructor at the site in the summer just after his first teaching experience.

The sole instructional method this instructor uses is a technique called “Reacting to the Past” (http://reacting.barnard.edu) which consists of elaborate games, set in the past, in which students are assigned roles informed by classic texts in the history of ideas (such as, Frederick Douglass, Slavery, Abolitionism, and the Constitution).

He explained that using this method, students consider the scientific careers of Galileo and Darwin as case studies, but they are "gamified" as a way of increasing student engagement. Instead of the typical seminar format, they play games to draw students into the past, promote engagement with big ideas, and improve intellectual and academic skills. It's also a lot of fun. But it is a lot of work too. “We will be playing ‘games,’ but with a serious purpose. Ultimately students will be assessed on how well they demonstrate a deep understanding of the roles they are playing and the texts they are reading.”

He believes with this method students are very engaged, and to play the game they must present some of the scientific theories. For example, in the Galileo game students come to understand how observing the phases of Venus helped disprove the Copernican model.

He thinks students need a background in the history of science to play the game successfully and the game's website provides supporting materials and resources for students. Many history professors are using the game and they are able to get support from the website. He says he is not a trained historian of science although he is interested in the subject, so if he can use the game, others can too. He says it is not easy for students to present ideas.

He does not use the model curriculum because he had a successful experience teaching with these games and wanted to try out teaching using that strategy. He thinks that lesson plan writing is very challenging and he gets help from master teachers. In addition, in his visit to one site, he found students do not like *Perspectives* but at the same time his students liked the game, so he decided to replace it with the model curriculum and he got a good feedback from students. He is very happy UTeach people liked his model.

He involves NOS in instruction implicitly and believes it comes out around the games, but he does not have a part of the course that explicitly includes NOS topics. The elements he mentioned that are connected to NOS are: paradigm shift, importance of evidence, induction, social context of science, and controversy issues. Interestingly, his reason for ignoring NOS was they do not need to connect science teaching to NGSS although NGSS makes it very clear that this is not the case.

He would like to go to Austin and offer his version of the class as a workshop for other insturctiors and work with them to focus on other episodes of the game and integrate them with goals they have for teaching *Perspectives*. He thinks classes should be more interactive and UTeach should use different methods rather than just lecturing if wants students to be prepare to be a teacher who are using creative methods.

Emergent Themes Appearing Across the Cases

This section provides a report of a cross-case analysis that resulted in the generation of findings that were seen across all sites. Similar ideas or themes were aggregated into categories each with a relevant title. The important points from each category are summarized here in Tables 4.5-4.12. I am not providing any interpretation here in this chapter but will revisit these data in Chapter V while addressing the research questions.

Implementation Fidelity and Instructors' view about the Model Curriculum

The use of the model curriculum varies considerably with some sites barely using it at all, to others that made considerable changes. From a quantitative perspective, ten instructors do not use the model curriculum at all, four got some ideas from it, and two generally use it. This information can be found in the table 4.5. Although both positive points and negative points are mentioned by instructors regarding the model curriculum, they all agree that having a model is necessary.

UTeach accepts any changes to the model curriculum if the instructors keep the main assignments of the course and follow same rationales for the course. Also, the author of the original model curriculum has stated an openness to any changes people make; he typically requests that people use it once and then make decisions to change it. He also is very interested in getting feedback.

The author of the model curriculum stated, "Anyone who tries to prepare materials for education will meet natural obstacles, which is why someone at a different university is not going to do what I have done." (Personal communication, November 13, 2015) In addition, he thinks due to copyright problems, many lesson plans on the website are not a complete version of what he does in the classroom. Besides, the name of his book “Science Secrets” is different from the name referred to in materials on the website “Secret and Myth in Science and Math”. He believes that this may be confusing to the instructors. The fact is the book should be there to give a complete picture of a lesson plan.

The following table (Table 4.5) summarizes the various instructors’ perspectives about using or not using the model curriculum.

Table 4. 5 .Instructors’ thoughts about the use of the model curriculum provided

Site Number and Instructor ID		Instructor’s Thoughts About the Model Curriculum	Is the Model Curriculum Used? 0 = not at all and 3= perfect alignment	Reasons for Not Using/ vs. Using Model Curriculum	Similarities Between Instructor’s Syllabus and Model
1	1	Instructor got general ideas from the model but wants his students to get the big picture and to be able to perform HOS in their own classrooms.	0	It is not inquiry-based and does not help students to learn what to do in their classroom.	No similarities except the requirement that students write a 5E lesson plan.
	2	No idea.	0	Limited time to review. Looked at some parts of it, but due to lack of logic and inquiry decided to not use it.	No similarities except 5E.
2	1	It is very useful. Without it, instructors would be confused about the purpose and methods.	2 The lesson plans fit more to her (chemistry) background. The instructor uses the mathematics lesson plans.	The first year, limited time to prepare, and she did not have a background in the HOS, so she relied heavily on the model curriculum. Previous instructor had used a little bit of it but not all of it, so she just pulled a few things that the previous instructor had done and then really relied on that model curriculum. She still uses the curriculum with alteration.	Some similarities in topics and assignments.

Table 4.5. (cont'd.)

Site Number and Instructor ID		Instructor's Thoughts About the Model Curriculum	Is the Model Curriculum Used? 0 = not at all and 3= perfect alignment	Reasons for Not Using/ vs. Using Model Curriculum	Similarities Between Instructor's Syllabus and Model
3	1	The model curriculum is just a resource, a starting point, and example for people who want to start it.	0	He started teaching the course before the existing model curriculum.	Main topics are the same.
	2	The instructor likes his material and believes it is the result of lots of feedback and change, but at the same time he is very open to any changes other instructors decide to implement, according to his interview. He believes there are several versions of perspective and that his version is just one of them. His hope is that when someone uses and modifies his materials, they will follow up by sending the modified lesson plans to UTeach. By providing different versions of materials, we can have a community that helps us to have better and better lesson plans step by step.	(author of the curriculum)		
	3	"It is written perfectly but the use of the "Science Secrets" book can be problematic for students. Mathematics lessons are perfect. The science part is not as content-focused as mathematics. Having a curriculum is good for some places where a graduate assistant teaches the course, for first-time instructors, or for getting ideas, but it should be used as an aid, not as a master."	1 Instructors use one or two of the mathematics lesson plans from the model.	Using many different resources for teaching the course, such as lab resources, different universities' resources, art museums. There is just time for using some parts of the model curriculum. The first time he was offered to teach the course, it was sudden so he had to modify his own history of science. He knew about materials, but he did not have time to use them. Then, later he attended all workshops and national conferences and learned about materials and read them and used some lesson plans.	Assignments used at this site are close to those in the model curriculum.

Table 4.5. (cont'd.)

Site Number and Instructor ID		Instructor's Thoughts About the Model Curriculum	Is the Model Curriculum Used? 0 = not at all and 3= perfect alignment	Reasons for Not Using/ vs. Using Model Curriculum	Similarities Between Instructor's Syllabus and Model
	4	"It is written perfectly."	1 The instructor uses some of the mathematics lesson plans.	Having a model is great to get ideas, but it does not feel right to use another person's material completely.	5E lesson plans.
4	1	She thinks there is not a single model curriculum for this course because it depends on which department would teach it.	0		No similarities except 5E.
	2	"The model curriculum is good for those who want to teach using a historical focus, not people who focus on philosophical things too. The materials are useful if you are starting your course. Having some level of standardization is probably important, but it should be left open to modifications."	0	Understanding philosophical points makes more sense than knowing a history of a topic.	No similarities except 5E.
5	1	"Good, but there are some grammatical mistakes. It is necessary when teaching the course for the first time."	1 More the first time; later semesters a few lesson plans and some of the cited articles.	The lack of educational perspectives in the course, lack of historical experiments, and lack of hands-on activities. Finding more useful resources.	No obvious similarities.
6	1	"It is reasonable for UTeach to present a model curriculum. They offered their vision of it and teachers modify it to show their opinion, styles.. Teachers should recognize students' abilities and limitations." -It is too stagnant. -He likes to be constructivist and he does not think there is "just one recipe to make a taco." He thinks we all have our individual ideas and should be creative.	0	-It is very lecture based. -It does not have emphasis on NOS.	No similarities.

Table 4.5. (cont'd.)

Site Number and Instructor ID		Instructor's Thoughts About the Model Curriculum	Is the Model Curriculum Used? 0 = not at all and 3= perfect alignment	Reasons for Not Using/ vs. Using Model Curriculum	Similarities Between Instructor's Syllabus and Model
7	1	From his point of view, NOS and "Perspectives" are very similar classes, but he noticed after attending UTeach conferences in Austin, what was presented there is very much a history of science class.	0	Lack of science and engineering practice - Lack of NOS - He had a graduate-level course and when he compared his materials with the model he decided to keep his course.	No similarities.
8	1	The first time that he taught the course he was not aware of the materials on the website and mostly used them the second time. Now he just picks from what is available. He thinks the mathematics part is useful and likes the book "The Cult of Pythagoras" because it has details to support lesson plans and this book is his textbook. The research, essay, and the presentation (in the assignments) are his favorite parts of the overall curriculum.	0 Whole assignments. Some of the mathematics lesson plans. Recommended textbook.	They're written just from one person's point of view. A philosophical view is necessary for asking the kinds of questions scientists and historians do not ask.	Assignment part is a copy of the model curriculum.
9	1	He thinks the model curriculum is generally good and helps instructors to structure their courses when they teach them for the first time. He thinks students have had experience writing lesson plans in other courses and they do not need them in this course.	1	He thinks teacher candidates need more background information in the content of science before taking this course and even during this course.	No similarities.
10	1	He thinks the course is very well organized at the Texas level, but not in terms of publications. The curriculum makes a good connection to the science curriculum and other aspects of ordinary life and professional life; it can be a very valuable course. He believes a lot of people just repeat their old history of science courses for teaching this course, and he does not think that is right. He thinks instructors should try to make it fit the goals of UTeach.	2	He thinks the model curriculum is very helpful, and he used a couple of them with some changes.	No similarities except 5E.

Table 4.5. (cont'd.)

Site Number and Instructor ID	Instructor's Thoughts About the Model Curriculum	Is the Model Curriculum Used? 0 = not at all and 3= perfect alignment	Reasons for Not Using/ vs. Using Model Curriculum	Similarities Between Instructor's Syllabus and Model
11 1	Instructor thinks that the lesson plan writing is very challenging, but he got help from master teachers.	0 Just some of the assignments.	-He ignored the model curriculum because he was interested in using the game "Reacting to the Past" that was not included in the model. -In his visit to one site, he found students do not like "Perspectives"; his students in history class liked the game, so he decided to replace it with the model curriculum and he got positive feedback from students.	No similarities except 5E.

Position of Nature of Science in the Instructors' Classroom

According to a review of the literature, nature of science can be an outcome of a history of science class. In this research, in addition to looking at the principle questions of interest, I was also focused on analyzing the model curriculum and instructors' approaches looking for aspects of NOS. This is a challenge because in the Instructor's guide for the model curriculum instructors are warned that this is not a nature of science class.

> This course is designed to put history in the service of science and mathematics education by covering a selection of topics that can and should arise in high school classrooms. Specifically, the course looks at how scientists and mathematicians originally devised innovative solutions to outstanding problems. Rather than reify an idealized account of "scientific discovery," the course seeks to disclose actual pathways by which various inquiries and breakthroughs were made. This is not a "Nature of Science" course, nor even a typical "Introduction to the History of Science," that one finds in history departments. Instead, it is a product uniquely designed for its particular audience of future mathematics and science teachers. (Instructor's guide in the model curriculum)

One of the first instructors of the course, who was involved in defining it, believes this statement came from UTeach's first director who was opposed to NOS, thinking that it is not a discipline. It must be said that this in direct opposition of the views of the science education community (Abd-El-Khalick and Lederman 2000; Lin and Chen 2002). Needless to say, this statement stands in direct opposition to the views of countless science educators worldwide who feel strongly that NOS is a vital foundation for science teaching and learning.

What I have found is that many instructors of the *Perspectives* class believe that NOS is a natural outcome of this course even if it is not emphasized in the model curriculum. There are some other instructors who talked explicitly about NOS, but two instructors even went further and changed their class to a nature of science class. Table 4.6 summarizes what each instructor thinks about NOS and what elements of it discussed either explicitly or implicitly by instructors.

Table 4. 6. Instructors' view about Nature of science and elements of NOS that are discussed either explicitly or implicitly by instructors

Site Number and Instructor ID		**Instructor's view about Nature of Science**	**Nature of science is discussed in the classroom explicitly**	**Nature of science is discussed in the classroom implicitly**
1	1	Connecting to NOS/NOM comes from their reading and activities. "Students write reading reflections and it organically happens through this process. It is naturalistic inquiry without a pre-structure. I move with students and facilitate their learning."	No.	Showing science is a part of society and changes over time. Culture is a central factor in science.
	2	He is not sure he connected his lesson plans to NOS because his main rationale for this course is that students realize mathematics and science have a story and to be able to use them in classrooms.	No.	Students learn about Kuhn and paradigm shift.
2	1	She is a scientist, so although she is not familiar with the term, she uses some elements of it.	Science changes over time and is always open to new questions. Context and society are important to science. Communication is important in science.	

Table 4.6. (cont'd.)

Site Number and Instructor ID		Instructor's view about Nature of Science	Nature of science is discussed in the classroom explicitly	Nature of science is discussed in the classroom implicitly
3	1	He believes rather than defining the term NOS, it is more useful to look at actual examples, and work with science that has been done in the past and then students will pick on some characteristic of it. He thinks it makes more sense compared with making the list of characteristics of the nature of science.	No.	
	2	He thinks what is happening in the nature of science is talking abstractly, but instead, he is talking historically. "Nature of Science never became a profession. Let me clarify this in this way: someone in the nature of science is using history of science, but they are not conducting research in the history of science." He thinks since nature of science people are not able to dig deeply into the history, they believe in what they hear. He believes there is a greater chance that they transfer inaccurate information to students. He believes what a historian of science tells to students is unique and is with awareness of society and culture of that time.		Humanizing science via history. Showing creativity role. Showing society and culture's role. Position of experiment and observations. Existence of different scientific methods. Existence of disagreements among scientists.
	3	He thinks NOS is all over the course, and a nature of science course would be an advanced discussion of elements that emerges from this course. History of science is a subset of NOS because NOS is history, philosophy, society, and all of that.		Observation, Scientific method, Hypothesizing, Foundation of science learning, Metaphysics, Commitments, Paradigms.
	4	She is familiar with nature of science via reading articles in the *Journal of Science & Education*. She also is familiar with Matthew's readings. She hopes when she discusses history, she communicates them implicitly. She thinks historians of science and science educators just have a different language.	Socio-scientific issues, Testability, Publishing.	
4	1	She is a master teacher, and she thinks this course is a philosophy and ethics course.		
	2	He tries to select readings that are asking NOS questions that he wants his students to be asked; then in the class discussions, he brings those questions out explicitly and challenges students.	Understand science as a human endeavor. Existence of more than one scientific method. Science is political, and money defines research topics most of the time. Values are embedded in science.	

Table 4.6. (cont'd.)

Site Number and Instructor ID		Instructor's view about Nature of Science	Nature of science is discussed in the classroom explicitly	Nature of science is discussed in the classroom implicitly
5	1	He believes nature, philosophy, and the definition of science are raised directly out of the history of science, so learning about the nature of science is a direct outcome of this class. He believes the nature of science is affected by human nature because, for example, in the ancient times people insisted that the earth is flat just because it helped them look more powerful.	Science is a human activity. Science makes mistakes, is self-correcting, is limited, and has a certain context. Scientists have a different method of doing science but the same method of communication.	
6	1	He uses the content of science and history of science as a vehicle to teach NOS.	Almost all elements of NOS. Showing difference between mathematics proving stuff and science supporting, confirming, but never proving.	
7	1	He thinks the nature of science and this idea of how science works both at the large macro level and the small micro level is something vital for teachers. NOS and "Perspectives" are very similar classes from his view.	Almost all elements of NOS. How we really do science vs. scientific method. Credibility.	
8	1	He thinks the course is 80 percent history and 20 percent philosophy, but it is not about nature of science. It needs a pure philosophy course, so he strongly believes this is not a NOS class. He then mentioned "the point that the nature of science changes with different paradigms" prevents us from looking at it as an outcome, and "as long as we look at nature of science from broader perspective it can be an outcome of this class, but we do not want certain things that we consider the science to be an outcome."	Demarcation problems Philosophical questions Normal science Scientific questions Paradigm shifts Difference between induction and abduction on one hand and deduction on the other hand. Scientific method and how many versions of it we have.	
9	1	He thinks students need to know NOS to not deny evolution and climate change. It helps to realize the position of proving in science.	No.	Science is about asking questions and trying to answer them with evidence. Science cannot answer all questions. Science is embedded in culture and politics.
10	1	He did not have any idea what NOS is and even after the researcher's explanation did not seem to recognize it.	No	Different scientific methods. Errors are part of science.
11	1	He does NOS more implicitly and thinks it comes out around the games. His reason for ignoring NOS is they do not need to connect science teaching to NGSS.		Paradigm shift Importance of evidence Induction Social context Controversial issues

Difficulties of the Course Mentioned by the Instructors

It seems this course is not an easy course to teach. On the one hand, the nature of course, which is a course in the liberal arts, is new for students and they have resistance to it. On the other hand, the proper person for teaching this course should have enough background in the history and philosophy of science and mathematics and writing lesson plans, who is difficult to find. As a result, instructors mentioned parts which were difficult and challenging for them, and based on that, suggested ways overcome these difficulties. In addition, both science and mathematics teacher candidates are taking this course, that creates another challenge to instructors. Table 4.7 summarizes challenging part of the course from instructors' point of view. The most challenging part for instructors is having science and math students together in this class. Most instructors think materials for teaching history of math are not as rich as materials for teaching history of science. Another challenge for instructors who have history and philosophy backgrounds is helping their students to develop 5E lesson plans. Instructors suggest UTeach should provide an instructional manual or website as a guideline for writing 5E lesson plans. In addition, instructors suggested that UTeach ask instructors to share their history of math materials on the website. Table 4.8 briefly mentions their suggestions to overcome part of these problems.

Table 4. 7. The part of teaching the course that is challenging and difficult for instructors and their opinion about having science and mathematics students together in this class.

Site Number and Instructor ID		Difficulties of the Course	Instructors' Views about an Integrated Class Between Science and Mathematics Students
1	1	There are more sources related to the history of science compared with the history of mathematics. There is not a good textbook about history and philosophy of science written especially for science teachers. Students' resistance to taking the class because they feel this is not a useful class for them. Lack of a model for students to integrate history into their teaching. Lack of emphasizing on the history of science by politics, tests, and standards.	"There are not that many things to tell about pure mathematics, but when it is integrated, the class makes sense to both groups."
	2	Teaching mathematic part is difficult.	It is not difficult with inquiry model in which students find the history of their field themselves.
2	1	It's a required course for the UTeach students, so, they are not excited to come into it. Mathematics part is difficult to teach.	Doing the mathematic part is difficult but it is good for both groups to learn something about the other group.
3	1	This mix class (math and science students together) is a challenge but it is useful.	It a little difficult because mathematics students are less historically orientated compare with science students, but he thinks it is useful they know mathematics has history too and it is good they know mathematics is not separate from science.
	2	The culture of students from science and mathematics is different from students in liberal art, and this difference should be overcome between teacher and students. This course is a required one and students are not satisfied with that. Some instructors fear mathematics, so it is difficult for them to teach this part.	He thinks teacher candidates have a fear of math and its teaching and he does not want them to transfer this feeling to their students. He wants teachers to be able to convince their students that they can make the rules of math.
	3	Checking 5E lesson plans Dealing with the use of technology	Mathematics students really need it, they should be able to offer alternative methods of solving problems to their students.
	4	5E lesson plans	Having science and mathematics students together is difficult but it helps to overcome the division between science and math teachers. A separate class would be easier, not better. She emphasizes integration of mathematics and science instead of talking about different nature of them, which is more philosophical debate

Table 4.7. (cont'd.)

Site Number and Instructor ID		Difficulties of the Course	Instructors' Views about an Integrated Class Between Science and Mathematics Students
4	1	5E lesson plans	
	2	Keep track of UTeach assignments Communicate effectively across disciplines	He thinks it would certainly be easier if it was just science students.
5	1	The number of objectives for this course is too many, so, it is difficult to keep track of them.	
6	1	Doing historical experiments, because they are narrow and so localized to a particular content and he is not interested in teaching content.	It is useful to: Use mathematics as a vehicle to show differences between these two disciplines. Show how mathematics and science integrated, how they serve each other and how they are part of the society and how society had impact on them
7	1	Since he does it in his way, he does not have any challenges.	There is a different class for perspectives in mathematics
8	1	Design 5E lesson plans or teaching science and mathematics are kind of challenges from his perspective, but he thinks they can be handled. Both the instructor and a student should move to other directions of his/ her expertise.	He believes the fact that science and mathematics teachers are in the same class is a challenge but still an opportunity to help them realize how the nature of two disciplines are different. The fact that the science students say they hate math, and mathematics students don't see why they need to learn science is exactly why we shouldn't separate this course. He thinks we should help them to see the relevance.
9	1	Students lack knowledge in the content of their field. Students need to be learning the history, the content, and the issues of science and mathematics rather than trying to talk about how that would be presented to middle school kids.	It is good to have two students from science and mathematics both coming in because many of them brought their own experience into the class.
10	1	Classroom demonstration of the lesson plans takes up a lot of class time. Due to lack of background, covering history and philosophy of mathematics is difficult.	It is more problematic than useful because there are many students in the class. It is good if they hear from each other, and if they separate them, it is difficult to find materials for one semester to support mathematics students.
11	1	Lack of background knowledge in students. Lesson-plan writing is very challenging.	He covers little of the mathematics part, so he prefers a separate course.

Table 4. 8 . Instructors' suggestions for the Improvement of the UTeach *Perspectives* class

Site Number and Instructor ID		Instructors' General Suggestions for Course Improvement
1	1	Talk explicitly about "challenges, problems, and possibilities" and try to find a model for teachers to help them to overcome this problem. State standards should be written in a way that values teaching science in the context of history. He thinks to improve curriculum, it should be more inquiry based, and it would make the course less challenging for students and instructor.
	2	His suggestion for UTeach is to provide more information on how mathematics changed over time.
2	1	No suggestion.
3	1	No suggestion.
	2	Update information on the website.
	3	He suggests adding labs and keeping the mathematics lesson plans from the model curriculum.
	4	Her suggestion for UTeach is creating a website to teach students how to do research in the history of science, which resources to use, and how put the results in the 5E lesson plan model.
4	1	No suggestions.
	2	Starting a collaborative document for people who have taught the course before to give input. Having one person from each background in the team of authors to make sure that certain areas are not overrepresented. Including discussion of the atomic Golden Age and the importance of it on the development of philosophy.
5	1	Adding historical experiments and field trips.
6	1	Emphasize on NOS and NOM.
7	1	Realize the main idea of the course is NOS and move away from a history of science class.
8	1	He thinks updating the information that is on the website is necessary to reflect the way the course is really taught in the different places. Co-teaching class with a mathematician.
9	1	Adding more science content to the curriculum.
10	1	Providing more support for the history and philosophy of mathematics.
11	1	Using "Reacting to the Past" game.

Instructors' Rationales for Having a Course in the History, Philosophy, and Nature of Science in a Science Teacher Preparation Program

Many reasons are mentioned in the literature about the necessity of offering a course in the history, philosophy, and nature of science to preservice teachers. From looking instructors' syllabi, and their answers to the survey, a long list of rationales can be provided, but in table 4.9 I just mentioned the rationales from their interview that caused me to conclude that is/are their main rationale(s); the table also shows their reasons about importance of the course.

Table 4. 9.The importance of the course and rationale for teaching this course from instructors' point of view.

Site Number and Instructor ID		Importance of the Course	Rationale for Teaching this Course
1	1	It gives a more encompassing view on science and mathematics. It improves critical thinking and the ability to analyze resources. It connects science, mathematics, technology, society, and culture.	In the context of reading and activities, helping students to recognize the importance of integrating HOS in their classroom. Showing science is a part of society and changes over time. Cultures are the central factor in science.
	2	It helps students to understand how their perspectives change over time regarding science and mathematics. It helps to tell the story, and telling the story would make the topic more intriguing and interesting to students. How the scientific ideas have developed during the history, and help students to develop their own ideas. Learn how people come to understand science and mathematics and how the process of development is the same.	Science and math have stories, and they should be integrated into classrooms. Science is embedded in the culture and society.
2	1	Students should learn how they should talk to the public as a science teacher to communicate a correct picture of science.	Learn how to think about mathematics and science "from the outside." Learn to ask questions about what scientists and mathematicians do, and why. Become aware that many prominent scientists, and even mathematicians, have often disagreed with one another.
3	1	Broaden students' perspectives and their appreciation. Students understand better the subject matter they will be teaching as whole science and mathematics. When they become a teacher eventually, they will be better engaged with the wide range of the students who maybe are not inherently interested in science and mathematics, but who are interested in historical development.	Broaden students' perspectives on the subject they are teaching, to be able to go beyond the subject.
	2	"What history of science captures very nicely is the process instead of just giving rules and asking students to memorize them. This course is defined because science educators not only should be connected to science departments but also to liberal arts. They should be familiar with their history and enjoy it."	Students see science as a process. Students realize science is embedded in culture and society. Students see there is disagreement in science. Students can recognize misconceptions in textbooks and overcome them. Students need to be able to dig into the history of every topic and know how to do research in history.
	3	Teachers should be able to answer their students' questions about origins of some ideas or about why we should do some problems in a certain way and not another way. Learning about history helps students to see everything from a different angle of view and later teach it that way.	Students feel confident using primary documents and finding history. Students find the ability to suggest alternative solutions to their students.
	4	It is an important course in giving an overall picture of topics, providing liberal arts, and humanity view.	Being able to think critically, analyzing resources, analyzing information, and connecting information and science and mathematics together.

Table 4.9. (cont'd.)

Site Number and Instructor ID		Importance of the Course	Rationale for Teaching this Course
4	1	Increase student motivation. Help students develop better attitudes toward science/mathematics.	
	2	This class gives students a chance to understand a lot of the larger conceptual and even political issues that undergird the history and philosophy of their fields. It helps they realize why something happens in the first place and what led to this point.	Students should learn to question the philosophical bases or foundations of different fields.
5	1	It provides students with a more integrated understanding of science and mathematics to not keep teaching it as an insulated or solitary subject. Increase students' creativity in teaching.	Increase admiration for scientists/mathematicians. Humanize the sciences/mathematics. Make instruction more challenging and thus enhance reasoning.
6	1	It helps students to gain an informed perspective of science and `mathematics disciplines. Science and math should provide students with the ability to speak by reason. Try to explain and use data to make reasonable decisions. Adding some history and context to mathematics makes it more relevant to students' lives and gives a better picture of math instead of a mechanical picture.	Develop a perspective of the nature of mathematics and science through reading, discussion, reflection, and writing, taking into account the philosophical bases, assumptions, strengths, and limitations.
7	1	The nature of science and this idea of how science works, both at the large macro level and the small micro level, is something they should learn.	Make students think about science and engineering practices. Help students to learn about NOS and how science works.
8	1	It brings humanities approach and critical thinking skills. Science teachers teach in a paradigm, but they need to realize the difference between real science's characteristics and what they do as educators. It provides future teachers with the ability to look critically at science.	Giving "more historically accurate picture."
9	1	It's very valuable to know where the content you are teaching came from. Showing struggles of mathematicians and scientists depicts the human aspects of science. History makes topics more interesting by telling a story. It opens students' eyes to other disciplines. In order to be a good teacher, students need to be provided broader knowledge. This course shows the human part of science to students and shows that there were struggles until we reached this point.	The course should show the interaction of mathematics and science and culture.

Table 4.9. (cont'd.)

Site Number and Instructor ID		Importance of the Course	Rationale for Teaching this Course
10	1	It is a valuable and a very helpful course.	Understanding that science and math are very human activity. Science is a matter of culture like art or music.
11	1	History is very important to STEM majors to give them a sense of humanity.	Improve intellectual and academic skills.

I need to explain here that since each instructor's syllabus contains several objectives, and they choose a list of objectives in the survey, I had the possibility of asking about the objectives they mentioned in these two documents and discussing them in interviews. I focused on objectives that repeated in the interview.

Rationales and objectives that UTeach has for this course based on their model curriculum can be found in the model syllabus provided on the website.

> This course explores a selection of topics and episodes in the history of science and mathematics. It has four interlocking goals: 1) to provide an overview of the history of science and math (for general education and to better comprehend subjects that you may eventually teach); 2) to enable you to put these historical perspectives and context to work in pedagogy; 3) to sharpen your independence of thought; and 4) to improve your writing skills.

Besides some objectives mentioned by the author of the curriculum as his points of focus in the course. He mentioned the course should show students:

5) Science is a process not a collection of memorize-able rules; 6) science is embedded in the culture of society ; 7) there are disagreements in the science ; 8) part of what they hear from media or read in the books are not correct, and they should increase their awareness to be able to overcome this misconception and give an accurate picture of science to students; 9) they are able to dig into the history and find interesting and informative information from it and share it with their students.

As it can be seen from these objectives, some of these 9 objectives are related to aims of every HOS classes and some of them are with pedagogy concerns

Methods, assignments, and resources used by instructors for teaching Perspectives

Since most of the instructors are not following the UTeach model and at least made some changes, it seems necessary and informative to summarize the methods they used, their reasons for using these methods, and kind of assignments they defined for their students. Th information is summarized in Table 4.10. In addition, instructors are using different resources for the course which mentioned in Table 4.11. There are lots of articles included in the instructors' syllabi, so I have not mentioned them due to space limitation.

Table 4. 10. Methods of teaching and assignments used by instructors for teaching the "Perspective" and advantages of their method from their point of view.

Site Number and Instructor ID		**Instructors' Method**	**Assignments**	**Advantages of Method from the Instructor's View**
1	1	Lecture and discussion about articles. Inquiry-based learning in which students step-by-step find the history of a topic, cultural context of it, and people involved in it and integrate it into their lesson plans and improve it with getting feedback.	Umbrella project (it is both a big part of method and an assignment). Reflection of each week's reading, including a summary of the reading, an analysis of the reading, and an opinion of the reading.	Students unconsciously bring their culture to the classroom with choosing people from their history, and topics because of their personal interest. With access to other students' lesson plans, students have an archive to refer to it in the future.
	2	Same as the previous instructor.	Historical Inquiry into non-Western-white-male contributions to the development of mathematics and science. Reflection of each week's reading including a summary of the reading, an analysis of the reading, and an opinion of the reading. A 5E Lesson plan.	He wants students to choosequestions of their own interest and find information out and use them.
2	1	Lecture for 15 minutes, then a discussion based on a question she asked. Activities about topics they are covering, like Newton's light experiment.	A historical and analytical paper on some aspect of the history of science or mathematics. A 5E lesson plan, which integrates a historical perspective into a science, math, or technology lesson and presents it.	

Table 4.10. (cont'd.)

Site Number and Instructor ID		Instructors' Method	Assignments	Advantages of Method from the Instructor's View
3	1	Lecturing Discussion Exercises Field trips around the campus	Three short papers on a topic of students' choice. Preparation and presentation of a history-based lesson plan.	
	2	Lectures Discussions Some activities	Two 5E Lesson Plans (he gives previous students lesson plans and asks students to improve it for one of them).	Students see the creative process of science, but without them, the science process for them is just applying rules.
	3	Historical experiments Discussion Field trip to libraries with primary resources	Written biographies containing at least five quality sources on the topic of the lesson plan students are supposed to write. 5E lesson plan integrating a historical topic into a science or math lesson, and present it.	Even less motivated students like to engage in doing lab.
	4	Activities Role-playing Few lectures Lab	Reading comprehension/ reflection questions. Two essays about method, innovation, and argumentation. Annotated bibliography 5E Lesson Plan and its presentation.	
4	1	She has not taught the class.		
	2	The students analyze dimensions of the history of science using group activities, often where each group focuses on a particular topic. The students compare and contrast the difference codes of ethics with drawing Van diagram. A philosophical dialogue with a friend. Students discuss a broad question every week in a group and then they come together to discuss it as a class.	Five philosophical exercises A research paper which requires students to compare and contrast the United States' education model with models from other countries. A 5E lesson plan	
5	1	Lecture Discussion Field trips Historical experiments	Flexible with students choice: Writing historical experiment Writing a dialog Writing a research paper writing a lesson plan	
6	1	Using activities that present ideas and then through discussion and debriefing, they extract the meaning of those lessons. The process, product, technology model for specifically talking about NOS. Analyzing a radio program called Engines of Our Ingenuity.	Summary paper for 3 textbooks. Prepare & deliver four Presentations: Engines of Our Ingenuity, Famous Scientist or Mathematician, A Big Idea, and Myth buster Busting. View a documentary and determine if it is science or pseudoscience with a written submission.	

Table 4.10. (cont'd.)

Site Number and Instructor ID		Instructors' Method	Assignments	Advantages of Method from the Instructor's View
6	1	Using activities that present ideas and then through discussion and debriefing, they extract the meaning of those lessons. The process, product, technology model for specifically talking about NOS. Analyzing a radio program called Engines of Our Ingenuity.	Summary paper for 3 textbooks. Prepare & deliver four Presentations: Engines of Our Ingenuity, Famous Scientist or Mathematician, A Big Idea, and Myth buster Busting. View a documentary and determine if it is science or pseudoscience with a written submission.	
7	1	Lecture Large and small group Discussion Readings Presentations and personal Reflection. Students read the paper and the autobiography of one of the scientists in the same time to see differences between how we really do science vs. scientific method.	Defining nature of science in context paper Science-in-action report Science case study Scientific practice presentation Students choose a book in the beginning of the semester and lead a 20 min class discussion about it.	Half of the class is very academic and second half is practice and usage of it in the classroom. Students realize the role of the sociology of science in the practice turn in science education that has led to the NGSS.
8	1	Students in his class should read primary sources in the head of the class and come to class and have discussions about them.		He thinks his background in philosophy is extremely helpful for students because philosophers take specific kinds of questions seriously, which may not be taken seriously in other disciplines. Scientists sometimes take an idea and ignore others but philosophers are more open to see different sides.
9	1	Very science-content based. Opens discussions and activities.	A 5E lesson plan. A historical and analytical paper.	
10	1	Field trips to museums Lecture Discussion Some activities	Short writings, which answer a question about that week's readings. A historical and analytical paper.	
11	1	Using the scientific careers of Galileo and Darwin as case studies in the context of the game. A role-playing kind of approach with playing a game called "reacting to the past." For playing the game, students must present some scientific theories and have some background knowledge.	"Reacting game," in which winning and losing are defined according to the quality of written and oral argumentation. 5E lesson plans.	.

Table 4. 11. Key Resources used by Course Instructors

Site Number and Instructor ID		Textbooks	Other Resources
1	1	**Math students:** Berlinghoff, W. P., & Gouvea, F. Q. (2004). Math through the Ages: A Gentle History for Teachers and Others, A Joint Publication of Oxton House Publishers and The Mathematical Association of America **Science students:** Joy Hakim (2007). The Story of Science: Einstein Adds a New Dimension, Published in Association with the National Science Teachers Association, Smithsonian Books, Washington and New York.	Katz, V. J., & Michalowicz, K. D. (2004), *Historical Modules for the Teaching and Learning of Mathematics* (contains historical modules (lessons) for teaching and learning of mathematics or science.)
	2	Same with the previous one.	Same with the previous one.
2	1	Natural Science in Western History (Complete) by Frederick Gregory	Online resources: Electron discovery: https://www.aip.org/history/exhibits/electron/ Curie: https://www.aip.org/history/curie/ Radium from American Institute of Physics: Craze: http://museumofquackery.com/devices/radium.htm
3	1	Galileo Galilei, The Essential Galileo (ed. and trans. Maurice Finocchiaro) James D. Watson, The Double Helix (Norton Critical Edition, ed. Gunther Stent),	Additional weekly materials (no more information in the syllabus).
	2	The Cult of Pythagoras*(*(University of Pittsburgh Press, 2012) Science Secrets: The Truth About Darwin's Finches, Einstein's Wife, and Other Myths (University of Pittsburgh Press, 2011).	Lots of weekly articles. For example: Galileo Galilei, The Assayer (1623), reissued in Discoveries and Opinions of Galileo, translated by Stillman Drake (New York: Anchor Books/Random House, 1957), pp. 237-238. Thoren, V. E. (1990). *The lord of Uraniborg: a biography of Tycho Brahe*. Cambridge University Press. Cambridge, University Press Online source: Van Helden, Albert, The Galileo Project (authoritative website: http://galileo.rice.edu/)
	3	Newton and the Culture of Newtonianism by Dobbs, Betty Jo Teeter, and Margaret Jacob. New York: Humanity Books, 1994. Scientists: A History of Science Told through the Lives of Its Greatest Inventors by Gribbin, John. The New York: Random House, 2004. For lab: God Created the Integers: The Mathematical Breakthroughs That Changed History	Lab resources Different universities' resources Art museums Some of the math lesson plans which are on the website.
	4	Math Through the Ages: A Gentle History for Teachers and Others by Berlinghoff, William P., and Fernando Q. Gouvêa. A History of Science in Society: From Philosophy to Utility by Ede, Andrew, and Lesley B. Cormack.	An online resource for research in the history: Rael, Patrick. Reading, Writing, and Researching for History: A Guide for College Students. Brunswick, ME: Bowdoin College, 2004. http://www.bowdoin.edu/ writing-guides.

Table 4.10. (cont'd.)

Site Number and Instructor ID		Textbooks	Other Resources
4	1	She does not teach the course	
	2	There are no required textbooks for this course	Readings are given to students usually as PDF files that are organized around the general themes. For example: dberg, D. C. (2010). The Mathematical Sciences in Antiquity in, *The beginnings of Western science: The European scientific tradition in philosophical, religious, and institutional context, prehistory to AD 1450* (pp. 89-110). University of Chicago Press. Lindberg, D. C. (2010). Science in Islam in, *The beginnings of Western science: The European scientific tradition in philosophical, religious, and institutional context, prehistory to AD 1450* (pp. 161-182). University of Chicago Press. Goldstein, T. (1980). Art and Science in the Renaissance in, Dawn of modern science: From the Arabs to Leonardo da Vinci. Henry, J. (2008). Renaissance and Revolution in, *The scientific revolution and the origins of modern science*. Palgrave Macmillan.
5	1	Bauer, S. W. (2007). The history of the ancient world: From the earliest accounts to the fall of Rome. New York: WW Norton & Company. A chapter from: Galilei, G., & Finocchiaro, M. A. (2008). *The Essential Galileo*. Hackett Publishing.	University of Oklahoma's online materials: https://libraries.ou.edu/hsci The big history project sponsored by Bill Gates: https://school.bighistoryproject.com/bhplive
6	1	The Story of Math, Rooney, 2009 The Rough Guide to Evolution (Pallen, 2009) The Mismeasure of Man (Gould, 1981),	There is a list of articles for each of following titles in the syllabus. The Nature of Mathematics and Science Reference Books. For example: Adler, A. (1991). Mathematics and creativity. In T. Ferris (Ed.), The world of treasury of Physics, astronomy, and mathematics (pp. 435-446). Boston: Little Brown. The Nature of Mathematics References Books: For example: Berlinghoff, W. P., & Gouvea, F. Q. (2004). Math through the ages: A gentle history for teachers and others. Washington, DC: The Mathematical Association of America and Farmington, Maine: Oxton House Publishers The Nature of Science References Books: For example: McComas, W. F. (Ed.). (1998). The nature of science in science education. Boston: Kluwer Academic Publishers.
7	1	Grinnell, F.(2008). Everyday practice of science: Where intuition and passion meet objectivity and logic. Oxford University Press.	Lots of short articles Newspapers Magazines For example: Koerth-Baker, M. (2011). The scientist who studies scientists—An interview with Harry Collins. Boing Boing. Chapter 4 & 2 from Ben-Ari, M. (2005). *Just a theory: Exploring the nature of science*. Prometheus Books.

Table 4.10. (cont'd.)

Site Number and Instructor ID		Textbooks	Other Resources
8	1	Lindberg, D. C. (2010). *The beginnings of Western science: The European scientific tradition in philosophical, religious, and institutional context, prehistory to AD 1450*. University of Chicago Press.	Extra readings: Westfall, R. S. (1971). *The construction of modern science: Mechanisms and mechanics*. Cambridge University Press. Hankins, T. L. (1985). *Science and the Enlightenment*. Cambridge University Press. Coleman, W. (1971). *Biology in the nineteenth century: problems of form, function and transformation* (Vol. 1). Cambridge University Press. Martinez, A. A. (2012). *The Cult of Pythagoras*. University of Pittsburgh Press. Kuhn, T. S., & Hawkins, D. (1963). The structure of scientific revolutions. *American Journal of Physics*, *31*(7), 554-555.
9	1	Bronowski, J. (2011). *The ascent of man*. BBC Books, Random House.	Online resources (no more information)
10	1	Benjamin, J. R. (2015). *A student's guide to history*. Macmillan Higher Education. Thirteen Edition. Gregory, F. (2008). *Natural science in western history*. Houghton Mifflin. Hatton, J., & Plouffe, P. B. (Eds.). (1999). Science and Its Ways of Knowing. Addison-Wesley; First Edition Darwin, C. (1967). On the origin of species: a facsimile of the first edition with an introduction by Ernst Mayr. New York: Atheneum.	Supplemental Readings such as: Galilei, G. Letter to the Grand Duchess Christina of Tuscany. *Published online at Modern History Sourcebook.* Galilei, G. (1967). *Dialogue concerning the two chief world systems* (p. 185). Berkeley: University of California Press.
11	1	Linder, D. O. Trial of Galileo Galilei. Dunn, E. E., & Siems, D. (2009). *Charles Darwin, the Copley Medal, and the Rise of Naturalism 1862-1864*. Pearson College Division	Online game webpage: http://reacting.barnard.edu

Instructors' background and the possible effect on their approach

I was interested to see whether instructors' backgrounds and the science standards in the state have an effect in their approaches with the course. Data for the theme are summarized in Table 4.12.

Table 4.12. Instructors' Background, Main emphasizes of the course and Science Standards in the region

Site and Instructor Number		Instructors' Background	Main Emphasize of the Course	Science Standards in the Region
1	1	Science education	HOS	State standards
	2	History of science	HOS	State standards
2	1	Chemistry & Biochemistry	HOS	"Texas essential knowledge and skills"
3	1	History	HOS	"Texas essential knowledge and skills"
	2	History of Science	HOS-HOM-POS-POM	"Texas essential knowledge and skills"
	3	History, Radiation Physics, and History of Science		"Texas essential knowledge and skills"
	4	History of science	HOS	"Texas essential knowledge and skills"
4	1	Science education	-	"Texas essential knowledge and skills"
	2	Graduate student in philosophy	POS	"Texas essential knowledge and skills"
5	1	Education (Science)	HOS	"Texas essential knowledge and skills"
6	1	Education (Science)	NOS-NOM-POS	"Texas essential knowledge and skills" He uses Nature of Science from the National Science Teacher's Association Standards for Science Teacher Preparation
7	1	Science education	NOS	State standards
8	1	Philosophy	POS-HOS	"Texas essential knowledge and skills"
9	1	Education (Math)	HOS-HOM	NGSS
10	1	history	HOS	State standards
11	1	history	HOS	State standards

As can be seen, most of the sites are using Texas essential knowledge and skills standards, which place special emphasis on teaching the history of science and math.

This chapter provided 11 case studies and several themes that came from cross-case studies analysis. The themes include instructor's view about the model curriculum and using it, instructional methods and resources used in each site, rationales for teaching history of science, and challenges of teaching this course and suggestions for improving it. The data used in chapter V answers the research questions.

Chapter V

Conclusions, Discussion and Recommendations

Introduction

It is vital that science teachers understand something of the nature of the discipline if they are to engage, inform and empower their students with an appreciation for how knowledge is created and validated in the scientific enterprise (McComas, 2004). This understanding is an important aspect of scientific literacy (NRC, 2012; NGSS /Achieve, 2013). The challenge within science teacher education is on how this understanding can be communicated to those who will become teachers and, in turn to their students.

Certainly, one recommendation is that preservice teachers have an experience in the nature of science (NOS) designed to transmit information and pedagogical practices. However, another potential method for sharing this information resides in the domain of the history of science (HOS). The use of HOS in science teaching is recommended vastly beginning with comments to the British Association for the Advancement of Science in 1855 (in Matthews, 1992) to more recent support from Eichman (1996), Sherratt (1982, 1983), Matthews (1994), Rutherford (2001) and Hodson (2008). However, despite these recommendations, there is little inclusion of the history of science either in textbooks or in classroom discourse. In fact, there are many rationales for including the HOS in science teacher education and ultimately in the science curricula (McComas, 2008, 2010; Schiffer and Guerra, 2014; Clough, 2006). However, in additional to including history of science as a destination in its own right, HOS can be both a vehicle to convey important lessons about NOS (Clough 2010, Adúriz-Bravo, Izquierdo-Aymerich, 2009).

Given my interests in the teaching of HOS/NOS I was pleased to find that the UTeach program. UTeach is a national science and math teacher preparation model started at the University of Texas, Austin. Itincludes a required class that explicitly focuses on HOS and may include NOS although teaching about NOS is not among objectives of this program. It seems this course started being more fit to Texas standards that has emphasize on HOS, not NOS, but now the program is used nationally. UTeach correctly recognized the importance of including a HOS class among other core courses for their teacher candidates in science and math. It seems critical for each program to be evaluated after implementing, to see if aims and objectives of it are met. This project started to provide a clear picture of UTeach's HOS class called "Perspectives on Science and Mathematics" (herein called *Perspective*) at various sites around the U.S. where the program has been adopted.

UTeach introduced a model curriculum for *Perspectives* and prefers that the instructors keep their classes as close as possible to this initial version, especially the first time that a new site offers the course. At the same time, UTeach is flexible in letting the instructors bring their ideas and background to the course. In the study reported here, I wanted to learn about different sites' approaches with *Perspectives,* including the instructors' backgrounds, their instructional methods and resources, and their objectives. In addition, the model curriculum's implementation fidelity was important for me.

I obtained information from 11 sites via 16 instructor interviews, syllabi and other course materials, and surveys. I wrote and analyzed 11 case studies to answer the research questions qualitatively. The survey was consisting of 10 questions and sent to instructors via email. Interviews were semi-structured and questions prepared for each instructor based on their answers to survey questions and their syllabus. Via looking at the model curriculum and interviewing with its author objectives of UTeach for this course extracted, and its consistency with literature suggestions analyzed; this earned picture helped me to investigate 11 sites of UTeach implementation of the course, and their cases are summarized in Chapter 4 with more complete case records include in Appendices C through M.

Discussion of Findings

Research Q1: The Nature of the Model Science Lessons Provided by UTeach

The first research question addressed relates to the nature of the content and instructional methods that exist in the UTeach Model Curriculum for the "*Perspectives on Science and Mathematics*" class provided by the UTeach. This model curriculum is provided on the UTeah's website, unfortunately, I am not able to include the model. As a result, the answer to question one is longer than other questions, therefore there are data tables in this chapter.

According to the literature, generally in a history of science class several different objectives are included, and "learning about the history of scientific disciplines and knowledge might be viewed as an end rather than a means to achieving other goals". (Abd-El-Khalick, Lederman, 2000, p. 1087). Research emphasize using history of science as a vehicle for teaching NOS (McComas, 2010, Adúriz-Bravo, Izquierdo-Aymerich, 2009). This course, *Perspectives,* is essentially a history of science class with some philosophy of science frequently included but not specified in the model curriculum.

For reasons that are not made clear, the instructor's guidelines for the course, mentions that "this is not a nature of science course"; however, regarding the importance of NOS and the possibility of using HOS for teaching it, and recommendation of literature, it does not seem a good idea to ignore NOS in the *Perspectives*. Although research shows that preservice teachers' knowledge of NOS can be increased slightly even with just a HOS course, in order to obtain a better knowledge of NOS, its elements should be discussed explicitly and reflectively in classrooms (Abd-El-Khalick, Lederman, 2000).

Given the science focus in this study I did not examine the mathematics lessons but an analysis of the eight science lesson plans appears next guided by the following questions:

- Are course content topics relevant to secondary science and math teaching?
- Is the topic recommended by the literature related to HOS?
- What is the likely outcome of having students study this topic?
- Which objectives of NOS might be an outcome of this topic?
- How might the lesson be improved to offer more coverage of NOS?

The analysis of each lesson is accompanied by a summary of that lesson and the responses to the question asked above. At the end of each lesson plan analysis, I mention possible NOS elements that could be included with little effort in future versions of the lesson even though the focus of this course is HOS not NOS. In keeping with the HOS focus, I evaluated the lesson plans as if they were recommended by the HOS literature. Table 5.1 shows Next Generation Science Standards

’ (NGSS) Appendix H about NOS categories which I referred to analyze lesson plans.

Table 5. 1. NOS Categories in Appendix H of the NGSS (p.430-436).

	NOS Categories in Appendix H of the NGSS
I	Scientific Investigations Use a Variety of Methods
II	Scientific Knowledge is based on Empirical Evidence
III	Scientific Knowledge is Open to Revision in Light of New Evidence
IV	Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena
V	Science is a Way of Knowing
VI	Scientific Knowledge Assumes Order & Consistency in Natural Systems
VII	Science is a Human Endeavor
VIII	Science Addresses Questions about the Natural and Material World

Perspectives Model Lesson Plan #1) *What Is Science? What Is Mathematics?*

Summary by the author as provided on the UTeach Web Site:

> This topic deals with ambiguities and disagreements about what counts as science and as mathematics. Students look at survey results from the last class related to this question, explain their own opinions, and consider those of others. After facilitating this discussion among the students, the instructor provides an overview of the expansion and development of the field of mathematics and offers his or her own opinion about its status as a science. [Should mathematic consider as science or not]

As is clear, this lesson plan focuses on the question of “what is science?” To address this question, a list of 22 subjects (e.g. physics, accounting, mathematics, philosophy, is provided to students and they are supposed to choose which are and which are not science...). The topic seems quite relevant for starting this course. Many articles have been written about “what is science?” (Brush, 2000; Wolpert, 1992; Lindberg, 1992). This shows the importance of the topic;

besides, to start to work in any discipline it seems necessary to be familiar with definitions and borders that define the discipline. In addition, even some method classes' instructors start their class by talking about what is science (Nouri, 2016). And obviously, when the name of a course includes the label *Perspectives*, it should be designed to provide the background of the topic to students.

Students talk about different disciplines and whether they are science. This provides students with an opportunity to think deeply about each discipline and try to find a framework themselves. Although the course is designed to be a HOS course and ignores using this opportunely explicitly, this can prepare the proper framework for students to learn about nature of science. Elements of NOS from table 5.1 that can explicitly be debated in this session are science is a way of knowing (V), science addresses questions about the natural and material world (VIII), scientific knowledge is based on empirical evidence (II) and scientific knowledge is open to revision in light of new evidence (III).

The natural outcome of this lesson is that the preservice teachers will realize there are limitations about the label scientific for each discipline or even each claim. Knowing this is critical for preservice teachers since it helps them in their future life to judge what they hear more critically and with having some criteria in mind and it is what we want them to transfer to their future students.

This lesson plan is a very good lesson for a HOS class, and my suggestion is limited to thoughts about how to include NOS. Preservice teachers should experience strategies that will enable them to work effectively with their future students, so we should design activities and lesson plans with this objective in the mind. This should be coupled with discussion about the educational theories behind that particular lesson plan. This lesson is no exception. Our audiences are future teachers. They should know the connection of each lesson plan to students and what society expects them to do. With this introduction, I think in the end of this lesson plan, an instructor could mention NOS explicitly with discussing it with s preservice teachers and connect all the debates in the class to the area called NOS. Then, the instructor can show the mentioned elements in the NGSS. NOS is mentioned both in the appendix H and inside this document.

This part not only helps preservice teachers to get a better understanding from topic but also provides them more motivation for learning it. Generally, people learn better and pay more attention if they feel the current topic will help them in fulfilling a part of the expectations of their career.

One of the concerns of science education was due to lack of a national standard and due to lack of emphasis on elements of scientific literacy, our students perform weakly in international tests. Todays, with introducing NGSS, and in the condition that states decided to adapt it there is a hope for having a national standard. Moreover, NGSS includes NOS as the fourth dimension of its standards, at a low level, but not as high of a level as would be ideal. It seems it is time to take advantage of these opportunities, but a good standard is a tool in the hand of teachers. Teachers should be prepared effectively to implement these standards.

Perspectives Model Lesson Plan #2) *Revolutions in Astronomy.*

Science Focus: Physics

Summary by the author extracted from the UTeach Web Site:

> This topic focuses on the development and acceptance of new theories in astronomy, particularly on how observable evidence changed the human understanding of the earth's motion and its place in the universe. As a primary example, students consider how recognition of the stellar parallax phenomenon led to the acceptance of a heliocentric model of the solar system. Alternative models of stellar and planetary motion are also discussed, as well as the conflicts between astronomical observations and religious teachings of the time. This topic requires at least two class sessions. Day 1, prior to the reading assignment, should include a discussion of the evidence available to Aristotle and Copernicus when they constructed their models of the heavens. On Day 2, students take a brief reading confirmation quiz before discussing the contributions of later astronomers (namely Digges, Brahe, Rothamm, Kepler, and Galileo).

Lavach (1969) designed an inservice program and used history of science to teach a group of teachers, and astronomy was one of these topics. The references and the discussions are very useful. For example, instructor asks students for evidence that proves the Earth moves, and for each answer they discuss whether the proof is valid. Using observation as a scientific method can help preservice teachers to realize there are different methods for doing science. This lesson plan provides a proper context for talking about the role of society in science, societies' pressures on scientists, and even disagreement among them. Empirical evidence that supports each claim helps preservice teachers to realize why science changes over time; besides, it helps them to realize what kinds of evidence are accepted in the field of science.

There is time allocated for doing experiments in the class, the experiments which helps preservice teachers with more practical learning habit to get interested in the topic. There are different uses of the history of science in this lesson plan, for example, autobiography and letters of Galileo and dialogs of his is used besides other historical readings. Discussions in class help preservice teachers to be more interested and to raise their curiosity. The idea that there is not any pre-reading is great to open discussions, because it helps preservice teachers reveal their naïve ideas and misconceptions.

This topic is in the standards for the content (both in the National Science Standards, and NGSS); so, there is an increased chance that preservice teachers will use it in their future classes. To teach the astronomy lesson plan an instructor needs some background in the topic but martials include references for additional review and preparation.

There are many myths regarding Copernicus's model with respect to the one proposed by Ptolemy. Talking about these helps preservice teachers realize that they should not believe easily everything they hear or think they know and they should do a deeper search in historical documents; this realization highlights the aim of this course for them. Some of the myths can still be found in textbooks. There are misconceptions in the textbooks and preservice teachers should be prepared enough to not rely on just textbooks. Another topic which is interesting is talking about the position of religion. Galileo was a religious person, but he realized correctly that science and religion are two different topics. This is crucial for preservice teachers for realizing and helping their students to understand. This awareness can overcome some uncertainty among teachers about teaching topic like evolution. This is a useful quote from this lesson plan in the model curriculum.

> Students who are going to become science teachers should try to anticipate how science education can create or foster the illusion that there is an essential conflict between science and any particular religion. Perhaps they need not raise it directly in their classrooms, but it may be discussed in the Perspectives setting. Thus, historical examples that rightly portray certain scientists as deeply religious can go a long way towards letting students know that scientists are very diverse in religions and philosophical outlooks.

This lesson plan is written perfectly; again, the only suggestion is to connect it to these elements in NOS: scientific knowledge is open to revision in light of new evidence (III); science addresses questions about the natural and material world (VIII); scientific investigations use a variety of methods (I); science is a human endeavor (VII); scientific knowledge is based on empirical evidence (II) from NGSS; and the role of creativity in developing science

Perspectives Model Lesson Plan #3) *Species, Monsters, and Things in Between*

Science Focus: Biology

Summary by the author extracted from the UTeach Web Site:

> Students discuss problems in the usual definition of species: "a group of organisms that breed to produce fertile offspring." They first become acquainted with some of the historical roots of the definitions of species and ponder different ways in which hybrids have been traditionally viewed. They learn that hybrids suggest the possibility of an evolutionary relationship between parent species, that categories such as "mammal" have historical and conventional origins, and that evolution predicts the existence of transitional forms. This lesson is written up for students as an example of a 5E lesson plan that focuses on a Perspectives topic.

The topic is relevant because the discussion of species is within the content standards (Both in NGSS and national science standards). Besides, since previous lesson plan was related to physics, it is good that this topic is related to biology.

The lesson plan is about stories from ancient scientists and their attempts to categorize animals. It shows preservice teachers another kind of scientific method. They experience with this lesson plan how much collecting facts helps scientists, and maybe here there is a potential for talking about induction. The lesson plan also can show students how scientists in the 1700s explained something in a way that may differ from our current view but was valid at that time. Their explanations and improvement in technology helped the scientists that followed to build a new knowledge. This helps preservice teachers to learn about the tentative nature of science.

Discussion of the disagreement between Plato and Buffon and an examination of why Buffon's idea was more successful has potential to open a conversation about disagreement in science generally. Doing this is suggested by the literature (for example see Bagdonas, & Silva, 2015).

In addition, Buffon used imagination to categorize animals and this provides another opportunity for talking about the role of imagination and creativity in science. The fact that a scientific idea should be able to predict other ideas is another topic that can be debated, due to Buffon's theory of degeneration. Preservice teachers can discuss why it was a theory and what characteristics a theory has. Such a discussion can be a perfect outcome of this lesson plan, which is written in the 5E model to help preservice teachers practice writing and teaching it. Moreover, for instructors who are not so familiar with 5E, this activity can present an opportunity.

The views of nature of science questionnaire (VNOS), one of the main instruments to measure understanding of NOS (Abd-El-Khalick, Lederman, Bell, & Schwartz, 2002), has a question related to species which shows the importance of the topic. Abd-El-Khalick and Lederman (2000) reported preservice teachers who took the history of science courses and did not have any discussion about species were not able to answer NOS questions related to them.

Elements of NOS that could be incorporated in this lesson include the following: scientific knowledge is open to revision in light of new evidence (III); scientific investigations use a variety of methods (I); science is a human endeavor (VII); scientific knowledge is based on empirical evidence (II); and the role of imagination and creativity in science.

Perspectives Model Lesson Plan #4) *Darwin's Path to Evolution*

Science Focus: Biology

Summary by the author from the UTeach Web Site:

> This topic examines the development of Darwin's theory of natural selection as the driving process of evolution. Students are introduced to a selection of background concepts and events and review the kinds of evidence Darwin collected to analyze and evaluate his conclusions:

I provided more background for this lesson plan because the topic is in common for both this lesson plan and lesson plan 5. A historical timeline is provided for preservice teachers in this lesson plan that helps them to get enough background knowledge of society and other scientists' views before reaching Darwin. The lesson plan benefits from a proper activity that allows preservice teachers to see Darwin's position and reach the conclusion he reached.

In addition, learning about philosophical issue is important in the *Perspectives* class, and the topic of evolution according to Rudolph, and Stewart (1998) is a proper topic to show philosophical differences between Biology, geology and paleontology, and Physics.

> Philosophers of biology have recently begun to make key distinctions between physics and the foundation of biology, evolutionary theory. One crucial distinction, described by Sober, is that which Darwin implied in the standards he used to judge his own work. Whereas physics concerns itself primarily with the identification of universal laws of matter, evolutionary biology focuses more on the specific patterns and particularities in nature, the plays, and outcome of the game rather than the rules, so to speak. p.1076

According to Abd-El-Khalick and Lederman (2000) science teachers tend to approach historical narratives with the framework they obtained from their own science classes and

> These frameworks are mainly incongruent with current conceptions of NOS. HOS is viewed from within these conceptual frameworks. Then… HOS is not viewed or interpreted as being a repository for the active attempts of earlier scientists to understand the natural world from within certain sets of culturally and cosmologically embedded conceptual tools. HOS is rather read from within the spectacles of present scientific ideas and indiscriminately judged from the viewpoint of present-day knowledge. As such, the subtleties of the historical narrative are often lost and ``lessons" about NOS are disregarded. p.1061

One of the positive points of this lesson plan is providing enough background knowledge for preservice teachers. This helps preservice teachers to come a little closer to what Butterfield (1965) called "putting on a different kind of thinking cap" (p.13), but as Abd-El-Khalick and Lederman (2000) pointed out:

> This might not be enough. To perceive the associated "lessons" about NOS, students should be able to "step back" to the present and discern the relevance of the historical narrative to the nature of current scientific knowledge and practice. This second conceptual shift might be as difficult for students as the first one is anticipated to be.p.1086

Clearly, this lesson plan is concerned about teaching preservice teachers about evolution and convincing them that it is scientific, and, authentic. Also, this lesson shows the role of gathering evidence in science and depicts how science is a process. One characteristic of a scientific work is it is repeatable by others and this characteristic can be talked about in class. Moreover, the role of humanity in science is very clear in this lesson plan when Richard Owen with similar evidence reached a conclusion different than Darwin's.

An element of NOS—that science laws and theories are different but both worthy and important --can be debated in this lesson plan. Evolution is a theory but has characteristics of a law, so it can help preservice teachers to distinguish between these two. This writer of the lesson plan emphasizes the difference by saying that teachers should "Highlight the distinction between Darwin's realization that evolution is happening and his subsequent struggle to understand the how-or-why, the process/mechanism that produces such changes." In the "case of simultaneous discovery in science," the story about Wallace and Darwin can be use and is interesting. The pressure of society and religious backgrounds of families is another opportunity to open discussions that can add to students' knowledge of NOS.

According to Farber (2003), "it is necessary that those teaching evolution (or any science) have an adequate conception of the nature of science if they expect to teach their students effectively" (p. 351). Regarding NOS this lesson plan has potential to debate these topics from Table 5.1 explicitly: Scientific Investigations Use a Variety of Methods (I) ; Scientific Knowledge is based on Empirical Evidence (II); Scientific Knowledge is Open to Revision in Light of New Evidence

(III); Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena (IV); Scientific Knowledge Assumes an Order and Consistency in Natural Systems (VI); Science is a Human Endeavor (VII); Science Addresses Questions about the Natural and Material World (VIII).

A course in the history of evolution along with two other HOS courses were considered by Abd-El-Khalick and Lederman (2000) who showed that the evolution course was more successful in increasing students' knowledge of NOS. The aspects of NOS that were explicitly emphasized by the instructor of the evolution class were: The tentativeness of scientific theories and their explanatory function; The nature of theoretical testing; The considerations associated with the use of the term "prove"; The role of scientific theories in guiding research; Science is a human enterprise and scientists are a self-conscious group; Important Role of logical considerations, professional and sociological factors as well as practical concerns, in the generation and validation of scientific knowledge; The social and cultural embeddedness of science, noting that scientists are part of a larger societal and cultural context and are indoctrinated into that context's assumptions. McComas and Kampourakis (2015), in a practical article, explained to teachers how they can use this topic to show creative aspects of science, as well as historical, cultural, political, and social conditions of science.

Farber (2003) suggests using historical case studies with an emphasis on scientific problems for teaching evolution. Doing this means focusing on the questions: what are they, how did they come about, and what answers have been suggested? This can then be applied to Darwin's theories, encouraging students to look at the process of question and answer. Because Darwin is often viewed as the quintessential scientist, students may be encouraged to see his process as of the NOS.

The potential aspects of NOS from Farber (2003)'s perspective include: the dynamic nature of science; science has levels of generality based on why the theory of evolution has "to be presented as a theory" (p. 353); discussion about proof and certainty; scientific method (there are different methods in evolutionary biologist's work. Such as: experimental, observational or comparative, and creative); the importance of cultural context (Darwin's work took place in industrial England).

In addition, Rudolph and Stewart (1998) mentioned

> Research in the teaching and learning of evolutionary biology has revealed persistent difficulties in student understanding of fundamental Darwinian concepts. These difficulties may be traced, in part, to science instruction that is based on philosophical conceptions of science that are no longer viewed as adequately characterizing the diverse nature of scientific practice, especially in evolutionary biology. This mismatch between evolution as practiced and the nature of science as perceived by researchers and educators has a long history extending back to the publication of Darwin's theory of natural selection (p. 1070).

McComas (2012), used the story of Pangenesis to talk about some aspects of science; including the importance of evidence, inductive reasoning, creativity, inferences, , the effect of society and different between theory-law. Although this topic is not a part of this lesson plan, because the idea of Pangenesis was introduced by Darwin it can be added to the lesson plan to improve it.

In addition, Bloom (1989) showed that teachers' understanding of NOS can help them to teach evolution better. This means these two (knowing evolution, and knowing NOS) are a good supporter of together.

Perspectives Model Lesson Plan #5) *Questions and Evidence on Evolution*

Science Focus: Biology

Summary by the author extracted from the UTeach Web Site:

> This topic emphasizes often overlooked types of evidence that are in fact useful in teaching evolution to high school students, particularly in response to typical questions they might ask. Students also review how evolution is presented in a selection of secondary biology textbooks and discuss how the textbooks might be improved. The instructor concludes by summarizing historical opposition to and acceptance of Darwin's theory.

This lesson plan supports the evolution lesson plan and attempts to make sure students understand the topic completely. In order to do these 10 questions for discussion are given to students, these questions help preservice teachers to connect what they learned about evolution to context of teaching it in high school. One example of these questions is, “In my other biology class, I learned that animals are in balance with their environment. So why would any animals evolve, if they already fit pretty well with their environment?” In addition, two questions ask about NOS explicitly. The difference between law and theory and the fact that we cannot prove something in science are the topics of NOS that will be discussed in class to answer these two questions.

In addition, students will analyze high school textbooks to see how they present history and supportive evidence regarding evolution. This is a useful assignment since it helps them learn to look at high school textbooks critically and realize they should always use them carefully and know that there are lots of things a teacher should add to the textbook to help students get a better understanding.

Scholars emphasize the importance of a textbook both because students read it and teachers use it (Valverde, Bianchi, Schmidt, McKnight, & Wolfe, 2002). Some research has been done to check elements of NOS and HOS in textbooks. Alshamrani (2008) examined the included NOS aspects, and their accuracy of NOS inclusion in physics textbooks. The results show most textbooks have aspects of NOS, but in 84.5% they are included implicitly through the main texts.

Abd-El-Khalick, Waters, & Le, (2008) examined chemistry textbooks for their inclusion of NOS and concluded none of them has a representation of all 10 elements of NOS, which were emphasized in national reform documents in science education including AAAS, 1993; NRC, 1996; NSTA, 2000. Niaz (1998) analyzed chemistry textbooks for their inclusion of historical aspects of the atomic model and concluded many useful aspects are missed. Fuselier, Jackson, & Stoiko (2016) checked the representation of NOS in college evolution textbooks, and they mentioned even in the case of writing about social influence on science fields, there is no explicit connection to NOS. Blachowiccz (2009) reported only 16% of textbooks talk about the historical origins of science.

These results support the importance of checking textbooks; if teachers can see for themselves the lack of HOS and NOS in the textbooks, they may feel a responsibility to fill the gap.

Perspectives Model Lesson Plan #6) *Secrets of the Alchemists*

Science Focus: Chemistry

Summary by the author extracted from the UTeach Web Site:

> This topic delves into the history of alchemy, showing how it contributed to the development of modern chemistry. Students learn how certain alchemical symbols designated actual chemical reactions. Students reflect on how to improve chemistry classes by incorporating aspects from its origins in alchemy

The lesson plan is about alchemy, and the way that it is written is both fun and educational for students. Students use alchemical symbols to understand the meaning of some of old pictures. Text and pictures came from a book: The Twelve Keys of Basil Valentine, published in 1599. It is explained in the lesson plan that “Valentine's book is a treatise in alchemy, but it does not explain the meaning of its symbols. However, given various other texts and alchemical traditions, the meaning of some of its symbols are common and have been deciphered." Valentine key activity shows the basics of chemistry in ancient times. Some of the findings are similar to today. The lesson compares modern science with very old science to open a discussion about how science changed over time and why.

The fact that alchemy integrated matter science, religion, astronomy, and botany provides an opportunity to talk about why science is not done in the same way today. Going back to an ancient time, it can be important to show "pairing, both medieval and early modern, of the terms theoretical and practical." (Dear, 2005, p. 393). The pairing was important to the early modern mathematical and natural sciences. The topic depicts beautifully how a failure from people's view in that time led to future success in science. Some scholars emphasize talking about failures at the same time as successes in science to show students a failure is a part of science (Ben-Zvi, Genut, 1998).

Although scholars emphasize integrating history with the content of science (Monak & Osborne, 1997), the topic featured in this lesson plan has potential to be taught in high school chemistry class independently, but it should be taught carefully to prevent misconceptions about science and creating a misunderstanding of borders between science and non-science.

In this lesson plan, there is a part about Newton's activities in alchemy. I think mentioning Newton's fascination with and participation in activities outside what we consider today to be science can be tricky. According to Cunningham, and Williams (1993) the fact that a hero like Newton used theology, mysticism, alchemy, and Biblical chronology may give a scientific appearance to ancient belief, but it is different from modern science. These changes in time should be clarified precisely if we are to teach this lesson plan to students.

> Isaac Newton's activities included work in various mathematical sciences, in theology and biblical chronology, in alchemy, in parliamentary politics, and in running the Royal Mint. As arguments for the imperviousness of the boundaries between those areas of activity have become increasingly less convincing to many historians, a corresponding tendency has arisen to incorporate them into broader and more complete accounts of Newton and the meaning of what he did. That tendency and similar ones in other topical areas have made the history of science, especially for early modern Europe, resemble other kinds of sociocultural history. As our history has in many respects become better, it has also become less identifiable as being specifically the "history of science. (Dear, 2005, p. 391).

Alchemy is historically important in another way. According to Oakley (1998), the experimental method of the 17th century was connected to alchemy as a mixture of mystery and science.

The elements of NOS can be covered in this lesson are: scientific knowledge is open to revision in light of new evidence (III); science is a human endeavor (VII); science addresses questions about the natural and material world (VIII).

Perspectives Model Lesson Plan #7) *Impossible Chemistry*

Science Focus: Chemistry

Summary by the author extracted from the UTeach Web Site:

> This topic examines the discovery of radioactivity to illustrate how scientists are often compelled to change previously held notions about what is possible for the detection of surprising, seemingly incredible, phenomena. Students begin by contemplating how the alchemists might have wished to change properties of metals. This leads to a discussion of the contributions of Marie Curie in identifying radioactive properties of certain metals and the impact this had on society at that time.

This lesson plan is about properties of matter and the discovery of radium. The topic is one of the important topics in chemistry and can be discussed in teaching the periodic table, properties of matter, and radioactivity, so it has potential. The periodic table itself has an interesting story; Mendeleev's attempt to describe a law, and later the discovery of atomic theory, which explained the law can use to teach the distinctions between law and theories to students (McComas and Kampourakis, 2015).

Adúriz-Bravo and Izquierdo-Aymerich (2009) showed students a Madam Curie movie to generate discussion about issues like the distinction between 'discovering' and 'inventing'; scientific modeling via abduction. The discovery of radium by Marie Curie has several points related to NOS which can be discussed in the class. First of all, it shows a woman as a scientist, and students can realize the context of society at that time was against women working in science. In the same time, they can see how Madam Curie was able to overcome these obstacles. Giving this picture is essential to our students to encourage them to believe in girls' potential for being scientists.

The fact that chemists at the time were not convinced by Curie's claim about radium shows the role of society, peers, and importance of providing evidence in science.

Since in this lesson plan there is a discussion of benefits and dangers of radium, students can debate if scientists are responsible for their outcomes and the way society uses them and if we should stop doing parts of science that we feel will be dangerous. This means the lesson has the potential for discussing socio-scientific issues.

Henri Becquerel's experiment which is discussed in this lesson plan, can be used to open a discussion about how some scientific findings happen by accident despite the fact that science is theory-driven.

Talking about the evolution of matter can help teachers to talk about cross-cutting concepts in NGSS. Using a video documentary, in addition to narrative and readings of history demonstrates a way to vary methods of teaching the history of science to students. In addition, reading what was written by Eve Curie, about Marie and Pierre Curie which is part of the readings for the course for using autobiography and biography in the classroom. Cakici and Bayir (2012) used life stories of Isaac Newton and Marie Curie to help students learn about NOS by role playing. Madam Curie failed hundreds of times but she continued to fight for her ideas, and this shows failure, as well as success is a part of science.

Elements of NOS from NGSS that can be discussed are: scientific knowledge is based on empirical evidence (II); science models, laws, mechanisms, and theories explain natural phenomena (IV); science is a human endeavor (VII); in addition, the theory-leaden nature of science.

As it can be followed, in all of these lesson plans there are several connections to the nature of science. These components can be discussed explicitly in the class with preservice teachers. Students should have possibility to tell their thoughts and get reflection on their opinion. Preservice teachers' attention should be attracted to these elements as characteristics of science. Research supports this explicit and reflective discussion is the only way that increases the possibility of learning about NOS (Abd-El-Khalick, Lederman, 2000).

A Summary of Findings Regarding a Review of the Model Lessons Reviewed

Based on the information provided in this section, details related to the first question can be summarized as follows:

- The science content of all the lesson plans reviewed is included in Next Generation Science Standards (NGSS), but not inspired by NGSS.

Science teachers will teach based on the standards. If we decide to approach this course with the lens of HOS, it is better to choose topics teachers feel more connected to them because topics are in the standards. Clough (2006) recommends using topics that parallel classroom science, so this can be considered a positive point for the model curriculum.

- There are examples of different branches of science in the curriculum

History of most branches of science including physics, chemistry, biology, geology, and astronomy are covered by lessons in the model curriculum. This supports McComas's (2008) suggestion related to using examples of different disciplines to give a broader view to students and to show that some themes both of HOS and NOS cross the boundaries of the disciplines.

- All of the content is recommended by the literature for having potential for including HOS

The literature recommends some topics as having more potential for teaching HOS. Most of the time these topics are proper for converting broader objectives rather than just telling a story. Topics in the model curriculum were based on the recommendations of the literature, for example, atomics models recommended by Justi and Gilbert (2000), discovery of radium recommended by Adúriz-Bravo and Izquierdo-Aymerich (2009), evolution recommended by McComas (2008)

- The model curriculum is written in a way that corrects some of the students' misconceptions

The author of the model curriculum tried hard to help students to see an accurate picture of HOS and overcome some myth about it. This seems the highlight point of the model curriculum and is supported by Allchin (2003) who argues HOS lesson plans should be written in a way that prevents the possibility of converting history to myths.

- The lesson plans show controversial issues, failures, and critics in the history of science

The author of the model curriculum tried to give a detailed picture of time by depicting competing perspectives that were dominant. Both Allchin (2013) and Ben-Zvi, and Genut (1998) emphasize the importance of showing setbacks in the HOS.

- All the lessons have a high potential for explicitly including NOS, but in none of the lesson plans is there a mention of NOS.

As mentioned several times in this document, HOS should be a vehicle for converting a higher message which is NOS (Matthews 1994, Clough 2010). It seems very irrational if there is an opportunity to teach a class in HOS and not to use this opportunity for discussing NOS. Unfortunately, this misuse happened in the model curriculum, and although the lesson plans are written professionally, there is a lack of connection to NOS. This situation is happening even though the NSTA Preservice science standards (2012) emphasized that teachers' lesson plans should reflect the nature of science.

Although as Clough (2010) asked, unless these lesson plans are written in a way that draws attention to NOS, there is no guarantee that students who have no knowledge of NOS will be able to receive the hints.

- The only instructional method used is lecture/discussion

Although there are a variety of methods to teach HOS (McComas, 2010), the lesson plans, are written based on lecture and discussion with only a few activities: one lesson involves watching a movie. Methods such as role planning (Cakici, Bayir, 2012), using historical experiments (Chang, 2011), and other more active methods do not appear as options in the curriculum provided.

- The model curriculum does not consider the needs of diverse groups of students

Not only is there a chance that teacher candidates are from different cultures, races, genders, and nationalities but their future students may also be highly diverse. Providing these candidates with the possibility of experiencing lesson plans written based on needs of different students is vital. Fouad, Masters, and Akerson (2015) emphasize considering the importance of students' cultural background.

- The lesson plans rarely mention the last 50 years of science history.

While Clough (2010) suggests presenting past and present together to avoid depicting a wrong picture of science by mentioning only a view of science that has now been updated, the lesson plans provided by UTeach do not have a deliberate connection to the present.

Research Q2: The Relationship of the Various Versions of the *Perspectives* Class when Compared with the Model Curriculum: An Evaluation of Implementation Fidelity

Implementation fidelity is defined as “the degree to which a particular program follows an original program model” (Hasson, Blomberg & Dunér, 2012, p.2). In this case, the model curriculum for *Perspectives* was written by a highly-experienced instructor of this class, is posted on the UTeach website and featured in the in-person workshops hosted by the UTinstitute. “Analysis of the implementation process and its fidelity is important in order to understand what specific reasons caused an intervention to succeed or fail”) Hassan, et.al 2012, p.2).

According to O’Donnell (2008), the fidelity of implementation can be measured based on five criteria. (a) adherence—whether the components of the intervention are being delivered as designed; (b) duration—the number, length, or frequency of sessions implemented; (c) quality of delivery— the manner in which the implementer delivers the program using the techniques, processes, or methods prescribed; (d) participant responsiveness—the extent to which participants are engaged by and involved in the activities and content of the program; and (e) program differentiation—whether critical features that distinguish the program from the comparison condition are present or absent during implementation (p.34).

One or more than one of five criteria could be the focus used to evaluate a program’s implementation fidelity. In this case, adherence -- whether the components of the intervention are being delivered as designed- -- is the criterion used in this study. Items b, c, and d in this criterion need access to information that can be provided either by interviewing with preservice teachers who took the class or with observing classroom practices. Lloyd’s (1999) noticed “curriculum implementation consists of a dynamic relation between teachers and particular curricular features” (p. 244).

I gauged adherence to the model program by talking with instructors and asking them directly if they are using the model curriculum or not, and considering the instructors' syllabi, and their answers to survey items (specifically items # 7-10 in Appendix B) about using the model curriculum. Relevant data about curriculum use is found in Table 4.5, with data regarding rationales and instructional methods included in Tables 4.9 and 4.10 respectively.

Some data obtained from interviews are different than data obtained from the survey. In the survey, many instructors chose a variety of lesson plans provided by the UTeach Institute and developed their own, but after talking with the instructors, I recognized they included similar topics but didn't use the same lessons to covey these topics. For example, inclusion of a lesson plan about Darwin and evolution is common to all the sites studied.

An intervention cannot always be implemented fully according to the program model, and researchers argue that sometimes the local adoption even is good and improves the outcomes (Blakely, Mayer, Gottschalk, Schmitt, Davidson, Roitman, & Emshoff, 1987). From a consideration of all the data, I can make a judgement about implementation fidelity at each site into one of four groups as follows:

1) High fidelity in implementation: Sites that are using all or most of the lesson plans from the model curriculum. This is level 3 in Table 4.5. Since none of the sites (except the author of the model curriculum in Site 3, Case E) investigated in this research used all the lesson plans or most of them without changes, so this category does not have any subgroups.

1) Medium fidelity in implementation: Sites that are using the model curriculum with medium dosage. Instructors in these sites use some of the lesson plans, and follow the same objectives. This is level 2 in Table 4.5.

2) Low fidelity in implementation: These sites are using some parts of the model curriculum. For example, they follow same objectives and few lesson plans but the method of instruction is different. This is Level 1 in Table 4.5.
3) Lack of fidelity in implementation: These sites do not have the same objectives for the course, so they ignored the model and have their own version of the class. In some cases, they use some assignments or readings from the model but the general approach is different. I should clarify since using 5E lesson plan is a core component in UTeach model and it is not related to the model curriculum, having it does not count as using the model curriculum. This is Level 0 in Table 4.5.

Sites with Medium Implementation Fidelity

These sites have the same posted objectives as in the UTeach model curriculum, they use some of the lesson plans and activities, and include writing a 5E lesson plan as the main assignment for students. A review of the data indicates that two instructors at two sites implement the model curriculum in their classrooms with high fidelity.

The first example of this level of fidelity is represented by a scientist who taught the course for four times (Case 2, Appendix D). She does not have a background in the history of science and uses the model curriculum in teaching the course. Besides a commitment to the stated rationales for the *Perspectives* class she tries to help her students learn about NOS. As a scientist, showing the tentative nature of science, the influence of culture and society, and the important role of communications are highlighted in her class. She wants preservice teachers to think from outside of their field and communicate an accurate picture of science to the public. The objectives she has in common with the author of the curriculum is showing disagreements in science, science as a process, and showing that science/math have a history. Her assignments and her method of teaching (lecture, discussion) are completely fit to the model. So generally, I can say she implements part of the model curriculum and adds something from her background as a scientist to it (e.g. talking about the kind of questions science can answer).

The second example of high program fidelity is the class taught by a historian (Case 10, Appendix L) who has previous experience teaching HOS but not to preservice teachers. Although the course has offered five times, he has taught it for the first time. He uses parts of the model curriculum which fit to his strengths. This means that he uses most of the science lesson plans. He wants preservice teachers to see science as a human endeavor and part of cultures. Assignments include lesson planning and writing answer to questions posed based on weekly readings. Some of these readings are from the model and some are new. Preservice teachers write an analytical paper too. He added field trips to methods of the model curriculum.

Sites with low Fidelity of Implementation

Some sites follow the same rationales and assignments that UTeach defined, occasionally use lesson plans from the model curriculum, but they teach the course with their own resources and methods.

At the main site (Case 3, Appendix E), I talked with 4 instructors including one who is the author of the curriculum, I do not consider this person. One of them was the first person who taught the course and when the model came out, he had his own materials, so he continued using them. The two other instructors had their own materials from other classes and preferred their versions of the course. The point is they all follow same rationales and objectives for the course and all ask student to create 5E lesson plans. Having students dig into history and doing research for them is priority. The nature of science is of important only for one, in part. So, I can say they may not follow the same route, but their destination is same. In addition, they mentioned they use a few mathematics lesson plans from the model curriculum.

At Kappa State University (Case 9 Appendix K), a math educator teaches the course, he had his own version of a history of math class and when asked to teach this course, he used his own math lesson plans and some since lesson plans from the model curriculum. The main difference is that he strongly believes preservice teachers should learn about content in this class as well, so he included a lot of it. 5E lesson planning is an important part of his class.

At Delta State University (Case 5 Appendix G) a historian of science use some resources and readings from the model curriculum. He mentioned the first time he taught the course he used some lesson plans, but now he just uses one or two. He uses historical experiments and field trips strongly and does not use the 5E lesson planning instead preservice teacher are free to choose from list of possibilities.

Sites with lack of implementation fidelity

Several sites were judged to have low fidelity in implementing the UTeach model, but such a finding should not connote anything negative. Some sites follow certain objectives for the course and after the initial review by UTeach is done, they define their own version of the course. Fortunately, UTeach institute is open to this revision. Among sites, there are two that their instructors (both science educators) who strongly against the UTeach model (case 6 Appendix H, and case7 Appendix I). Both believe the outcome for this class should focus on helping preservice teachers learn about NOS and recognize how science works and how to teach these concepts to students. As a result of this belief, all class time is allocated to discussing elements of NOS and all assignments support this goal. They believe that if preservice teachers see what the outcomes of the class were for them, they will try it in their own classrooms. One instructor told me that because they are not part of UTeach anymore, there is no problem following their own path (Case 6) The second one convinced UTeach to continue his method, interestingly he mentioned that many people asked him to send a copy of his instructional plan after he presented it in one of the UTeach workshops (Case 7).

SW State University (Case 1 Appendix C), was a bit of a puzzle. In the survey, one of the instructors said that he uses six lesson plan from the model curriculum but in the interview and syllabus it is clear that he does not actually use them. The second instructor mentioned in the survey that he did not look at the model curriculum. At this site, both instructors use the same curriculum, resources, and assignments. In this site writing lesson plans and presenting them is a huge part of the class. They do it with doing research in the history and integrating it in lesson plans. The difference is here even the research does not seem deep like historian of science classes. Emphasizing teaching history and trying to provide preservice teachers with the ability to do that is the main instructional goal of this site. It seems that this site meets UTeach's criteria superficially.

There are two other sites, both taught by philosophers of science (Case 4 Appendix F, and case 8 Appendix J), with class goals that are different and I could not find any use of the model curriculum lesson plans. Instructors care about philosophical questions and asking the origin of thinks. Nature of science is part of their class but not with this title. Although both instructors have 5E lesson plan, a master teacher takes responsibility for it. One of them does not care about having students write lesson plans, but the second one thinks lesson plan writing is one of the strongest elements of this course.

A historian of science is another instructor who is not using the model either (case 11 Appendix M). He uses a role-playing game without any use of the model curriculum's lesson plans or resources. Even he uses his own version of lesson planning which includes more argumentation. He used to have this game in his previous history of science class in history department and just repeat it.

In conclusion, if I look each instructor' use of the model curriculum according to table 4.5, it is clear that 9 instructors are not using the model provided. Not surprisingly, the author of the model curriculum uses it completely, 2 instructors use most of the lesson plans, and 4 use the model partially or get ideas from it. Considering this on a site-by-site basic, 6 (55%) sites not using the model, 3 (27%) use it partially and two sites (18 %)with medium rate have adopted the model. Reasons for not using the model will be discussed as part of the response to the next research questions.

This analysis of the model curriculum that has been examined, reconceptualized and field-tested by educators across the nation provided a unique opportunity to examine a curriculum adoption, and suggests UTeach should reconsider objectives of this course. The dose of program fidelity is not something that UTeach can count on it. The important part is most instructors' problem is with outcomes they want from the course and it is a danger alarm that putting a different version of the model curriculum without changes in the bigger picture cannot help UTeach. If this class and its model curriculum truly have been shown to produce more informed and effective science teachers, then objectives related to nature of science which is the concern of many instructors should be added to objectives.

Research Question 3: Factors Involved in the Implementation of the Model Curriculum

Not surprisingly, there are many different versions of the commonly-titled class called *Perspectives* created for many reasons at the various sites. There are distinct reasons stated for omitting, modifying, or adding components to the recommended content of this program. Here readers should refer to Table 4.5 which included categorized reasons provided by the instructor for their use of the model curriculum. These reasons will be discussed further here.

Different expected outcomes for the course (having different objective/objectives)

There are different rationales for teaching HOS. These rationales define the teacher's approach. According to Remillard (2005), teachers' goals for a class are an important factor in the level of enacting that curriculum. Therefore, it is no surprise that instructors with their varying backgrounds and individual goals for the class would have produced differing versions of the course.

In this case, when the instructor has the same rationales (the instructors' goals are the same as those in the model) for the course, the possibility of implementing it increases. In this study, two instructors changed the course completely because they believed NOS rather than HOS should be the important outcome of this class. In addition, lack of emphasis in philosophical view is mentioned by two other instructors. They think this philosophical view is necessary for asking kind of questions scientists and historians do not ask. The instructor at Alpha State University (Cae 4 Appendix F) told me "Understanding philosophical points makes more sense than knowing a history of a topic" (personal communication, November 21, 2016).

There is another instructor who thinks that teacher candidates need more background information in the content in this course, so a big part of his class is allocated to teaching preservice teachers the content of science (e.g. modern science). Finally, yet another instructor believed the author of the model curriculum may be more interested in correcting misconceptions about science history itself but her emphasis is on science and society, so she connects history to socio-scientific issues. For example, the history of climate change is one of her favorite topics. The use of socio-scientific issues in the context of HOS is suggested by Gray & Bryce (2006).

Different methods for teaching the course

While there are potentially seven methods for teaching HOS suggested by the literature as summarized by McComas (2010, Table 2.4), the main method used by the model curriculum is lecture and discussion with some activities included. These are not the approaches that some of the instructors prefer. The instructor in cade 6 told, “I am science educator, not a lecturer, I cannot stand in front of the class and just lecture [for most of the class time]” (personal communication, May 4, 2016). This led the instructors to make changes to the class. Three used constructivist and inquiry approaches, guiding the preservice teachers to find a topic of their interest and bring that information for discussion to class. These instructors believe this technique brings the culture of preservice teachers into the class (for example, girls are more likely to choose a woman scientist), and makes learning more meaningful. Allchin, Andersen, & Nielsen (2014) support this method. They used inquiry, historical cases, and contemporary cases for helping experienced upper secondary science teachers, involved in short-term professional development, to make sense of NOS. Three started doing historical experiments and believed it made preservice teachers more engaged. They learn the language of ancient time and realized the importance of the culture and society. Chang (2011) supported the use of historical experiments as an effective method in HOS classes to engage students.

Another instructor used a role-playing game which requires background knowledge in HOS and believes that preservice teachers will invest more in learning because they want to win. Cskici and Bayir (2012) supported role playing as a method that increases preservice teachers' knowledge about the scientific method. Furthermore, instructors said there are better resources outside of the model curriculum to use such as great books, lab resources, different universities' resources, art museums. Lack of science and engineering practice was another reason mentioned by one instructor.

The Differing Background of these Instructors

Remillard (2005) suggested that the teacher and the curriculum are two important aspects that have major impacts on the way a curriculum is enacted. Among factors that define a teacher's effect in enacting a curriculum, he mentioned teacher's pedagogical content knowledge, subject matter knowledge, and pedagogical design capacity. Data gathered in the present study support this claim.

In this group of 16 instructors from whom data were drawn in this study, there are five distinct discipline backgrounds present: (1) historians (some expert in the history of science), (2) philosopher of science, (3) science educators, (4) math educators and (5) scientists. As a group the instructors have a broad range of approaches to teaching the course, which does not seem surprising considering their different backgrounds. In the next section, I briefly discuss how instructors from each background approach teaching the course.

1) Historians (some of whom are experts in the history of science). Among the 16 instructors with whom I talked, seven are historians and experts in the history of science.

Their objectives for the course are similar. They want preservice teachers to know that science and mathematics has a historical component, are human endeavors, and depend on society and culture. In addition, they want preservice teachers to be able to do research in the history and find accurate information about it. These instructors think preservice teachers need to know the history of science and mathematics to broaden their horizon and perspectives; to develop higher order thinking, to be able to suggest alternative approaches to their students, and to help them to recognize mistakes and misconceptions are not odd. As a result, the instructors follow the UTeach model which was written with the same objectives, but they do not generally duplicate the model curriculum's lesson plans because they have their own version brought from their HOS classes. Instructor number 4 from Mega State University (Case 3 Appendix E) told "I'm a trained historian of science and drew on my own training and teaching style instead [of using the model curriculum]. I used a few activity ideas from it" (personal communication, May 13, 2016). Historians think the language that science educators use is different and it is good for preservice teachers to hear the experts' language in this course. One instructor is an exception, he uses most of the lesson plans, but does not have expertise in the history of science.

2) Philosophers of Science. There are two philosophers of science among the 16 instructors. These individuals obviously are most knowledgeable and care most deeply about philosophical questions and think such issues are more important than a model curriculum focus solely on historical views. As a result of their distinct background, they have more philosophical approach to the course. This group cares more about NOS compared to the previous group.

3) Science Educators. There are four science educators among the group that I interviewed. Three have strong background in the history and philosophy of science, one does not. Interestingly these three people emphasize NOS, and present an accurate picture of science

using history. The most interesting part is none of them ask preservice teachers to write 5E lesson plans, while writing 5E lesson plans is not a challenge for science educators like it is for other instructors from different backgrounds. The fact that they are not demanding 5E lesson plan shows they believed that changing their preservice teachers' perspective and giving them an accurate language of science to use is more important.

By contrast, another science educator, put all the emphasis on writing the lesson plans. He believes the entire idea of the class is helping preservice teachers in an inquiry-based process to write a lesson plan.

4) Math Educator. The only math educator in the group takes a different approach to the course compared with other instructors. He talks in the first half of the semester about math in ancient times and in the second half about the history of science. His rationale is that in ancient times most inquiries conducted in mathematics until development in science speed up. Therefore, he divides his class to reflect reality. In addition, this approach helps math preservice teachers see the importance of math in science and gives them confidence and a better feeling about both mathematics and science. Meanwhile, science preservice teachers realize they should invest more in learning math. Secondly, he covers lots of content from various branches of science and math in his class, since he thinks preservice teachers need to learn about multiple disciplines' important ideas to have a broader picture. He is not implementing the model curriculum.

5) Scientists. The only scientist in the group is neither an expert in the history of science nor in pedagogy, so she relies on the model curriculum for teaching. Beyond the model curriculum, this instructor tries to communicate ideas of nature of science in her class. For example, she emphasizes that although science changes over time, but it does not mean we cannot rely on it.

Instructors' Teaching Experiences and the Implied Impact on Decisions

Instructors' experience and skills play a very important role in adopting the model curriculum (Remillard, 2005). All of the instructors who have previous experience of teaching a class in the history of science or nature of science preferred to use their own version of the class sometimes with a small modification to make it fit the UTeach objectives. For example, the instructor at Zeta State University (Case 7 Appendix I) said, "I had a graduate level course and when I compared my materials with the model, I decided to keep mine" (personal communication, October 31, 2016).

In contrast, the instructors' who are novices in teaching this class rely more on the model curriculum, and even in doing it, they use the lesson plans that are fit to their background. For example, one instructor (Case 10 Appendix L) said "I picked the ones which spoke to my strengths and did not try the rest" (personal communication, May 25, 2016). It shows instructors confidence about using materials written by another person, plays a role in adapting a curriculum. This is the same with the importance of a teacher's tolerance for discomfort in implementing a curriculum introduced by Rimillard (2005).

These results are aligned with the research that claims in educational programs teachers are a very important factor in implementing a program. According to Woolley and his colleagues, the characteristics of teachers which have an effect on implementation fidelity are: 1) Teachers' perceptions of the intervention 2) their beliefs about the need for the intervention 3) teachers' self-efficacy 4) their teaching experience and skill competence (novice teachers are more flexible regarding new programs compared with experienced ones) 5) teachers' confidence about using the intervention (Woolley, Rose, Mercado, Orthner, 2013).

Instructors Opinions about the Use of the Model Curriculum

Durlak and DuPre (2008) identified three factors which influence the implementation failure: factors related to the community (such as politics, funding, and policy), the provider (such as potential benefits of the innovation) and the characteristics of the intervention (such as adaptability and compatibility). Most of the instructors implied that because the model is written from just one person's point of view it is not as creative as they would like it to be. Each instructor, based on their background, thinks some important objectives are ignored in the model curriculum. Lack of philosophical view, lack of NOS knowledge, and lack of educational views in the model curriculum are three important critiques. One instructor thinks the model is too "stagnant" and another one believes it lacks logic and jumps from one topic to another one. Remillard (2005) mentions the teachers' perception of a curriculum as a factor that influences enacting a curriculum and the data from this study confirm this.

The majority of these instructors stated implicitly or explicitly that they do not feel right using another person's material. They think the model is an example of what could be done, and is not meant to be simply reproduced, but everyone agrees having a model is great to get ideas and perhaps to get started.

Local conditions of each Site

Local conditions are characteristics of each sites. The standards of the state in which the site operates, and the department the instructor comes from are examples of local conditions. According to Carroll and colleagues, some adoptions in programs are due to "local conditions" (Carroll, Patterson, Wood, Booth, Rick, & Balain, 2007, p.5). Sometimes, the changes in the intervention based on local conditions can improve it, "as long as the essential elements of an intervention are implemented with high fidelity" (Hasson, et.al, 2012, p.2). The data gather in the study reported here confirms that local conditions have an effect in the adoption of the UTeach model curriculum.

In many sites, an instructor is put in the situation of teaching the course at the last minutes. In this condition, if they already have taught a similar course they have replicated it and never even look at the curriculum to find strong points in it. Otherwise, when they were novice in teaching these kinds of course, they have adopted the model without thinking about its weaknesses. In some sites, there are two different classes for *Perspectives* in science and mathematics. Therefore, instructors feel freer in acting in their own way. In addition, how many science and how many mathematics preservice teachers are in the class is another issue that has an effect in the instructors' approach. For example, if most students in the class are science preservice teachers, the instructors were likely to focus more on the history of science compared with history of mathematics.

The Standards Guiding Preparation of Teachers (this is one of the local conditions but because of its importance, it is included separately)

Texas, where the UTeach model was first developed, uses "Texas essential knowledge and skills" as its standards for teacher preparation. In this document, there are many references to HOS, but none to NOS. Therefore, we should not be surprised to note that the class *Perspectives* has a HOS not a NOS focus. According to one of the instructors, this fact was very important when they defined the course to be an HOS course and writing the model curriculum. The same pattern was found through communication with instructors. The standards they use, plays a key role in their approach because it is a tool in their hand to convince their students about the importance of the course. In Texas, they tell their students that as future science teachers you have to connect your teaching to HOS based standards. In another state, they have NGSS, which there is not any connection to HOS in it, but there are connections to NOS, therefore, they highlight NOS to convince their preservice teachers. I told one of the instructors (case 11) to emphasize on NOS in NGSS and he answered, “and we do not use NGSS”. (Personal communication, December 5, 2016). Probably, this problem is result of sharing a class developed in Texas with the entire nation without reconsidering objectives to make it fit to a national standard.

Woolley, Rose, Mercado, Orthner, (2013) determined that program, individual and school-community factors play a role in treatment fidelity. I found different expected outcomes for the course, methods for teaching the course, different backgrounds of the instructors, instructors’ teaching experiences, instructors’ opinion about intervention, local conditions, and standards as important factors in the final design of an individual version of the *Perspectives* class at a given site even initially.

Research Question 4: Suggestions might enhance the Model curriculum for a HOS/NOS class for preservice science teachers

The goal of this question was to take what I have learned from a review of the literature and from an examination of 16 different version of a HOS class (with NOS potential) and highlight the suggestions and best practices.

For answering this question, I summarized rationales, methods used by different instructors, position of NOS in their curriculum, and instructors’ suggestions for improving the course to offer what is the best approach from my perspective.

A summary of different rationales for offering this class to preservice teachers

From reviewing rationales and objectives, instructors have for this course, listed in Table 4.9, I can summarize these instructors want preservice teachers to realize science and math have a story and are human endeavors. Everyone believes it supports higher level thinking with helping preservice teachers to come out from their own area of knowledge (science or math) and broadens preservice teachers' horizons.

In most of the sites (6-11 including Cases C, E, F, J, L, M), learning to include history in the pedagogy with writing 5E lesson plans is a major focus. In two sites, it is included but is not the main assignment. In three sites, lesson plan writing is not the instructor's concern at all.

Three instructors are interested in helping preservice teachers to overcome misconceptions related to history. In addition, three instructors want preservice teachers to see disagreements in science, to find the ability to suggest alternative solutions to their future students, and to realize failures and disagreements are parts of doing science. In on site, the main one, instructors want preservice teachers to be able to do research in the HOS professionally. In the other words, they want to teach the preservice teachers the method of digging in the history of science, not the result of it. Two instructors' focus is on helping preservice teachers learn about NOS

Summary of different methods used by instructors

Instructors of this course used a variety of methods for teaching. I can tell lecture and discussion is the more common methods used by most of the instructors, but still there were other interesting methods involved. Table 5.2 summarized the methods used by instructors for teaching this course.

Table 5. 2. A Summary of instructional methods used by the instructors of the Perspectives class

	Instructional Methods Used by the Instructors
1	Lecture and discussion about topics found in articles and textbooks. There are different topics that instructors chose as a theme of one week. For example, “what have we learned from the philosophy of science, and how does this strengthen or limit our current thinking?” “How has the work of the philosophy, history, and the science studies communities been translated to the K-12 context?”
2	Inquiry based learning in which preservice teachers find a topic in the history of science, and examine its cultural context and the people involved and use this information to develop a lesson plan. For example, history of force and motion, and people who involved on it used in writing a lesson plan for teaching force and motion. Instructor, in this method, is facilitator during the semester. As a result, in the end of the semester, preservice teachers have prepared lesson plans for several topics.
3	Activities that clarify some points or ideas. For example, Nature of Math (NOM) Cube Activity in which students observe the qualitative and quantitative relationships depicted on five faces of a cube and then predict the contents of the hidden sixth face.
4	Recreate and/or reenact historical experiments. For example, Newton’s work with color and like to demonstrate the nature of experimentation and discuss the role of scientific communities in the development of scientific knowledge.
5	Field trips to libraries, and museums primarily to work with actual objects or to explore primary resources. Students read primary and secondary sources ahead of the class and come to class and have discussions about them.
6	Philosophical discussions in which preservice teachers talk about a philosophical topic with a partner and later within the entire class. For example, investigating professional codes of ethics, and reflecting on teaching philosophy are two topics that preservice teachers discuss about them.
7	A role-playing kind of approach with playing a game called “reacting to the past”. The game consists of elaborate games, set in the past, in which students are assigned roles informed by classic texts in the history of ideas. Students are asked to take a side and after reading background information, support their side.
8	Analyzing POD cases and web-based resources about HOS such as *Engines of Our Ingenuity*. Each preservice teacher selects one EOI episode from the web-based archive and prepares/presents a 10-15 slide PowerPoint that (1) communicates the main events of the episode and (2) communicates the NOS/NOM significance.
9	Students read a paper and the biography or autobiography of one of the scientists at the same time to see differences between how we really do science vs. scientific method.
10	Case studies, narratives, science stories. Lots of case studies and stories is written to communicate HOS/NOS. Some of them even are supplemented by rationales for using them. For example, (http://library.buffalo.edu/libraries/projects/cases/case.html)
11	Writing a 5E lesson plan is common on all the classes in which students should use history of science as context to teaching a specific science content. Students present their lesson plans in the classroom and get feedback, as a result some hours of each instructor’s class allocated to these presentations.

The potential of including NOS in the *Perspectives* class

I have summarized instructors' view about nature of science in Table 4.6. The table shows whether elements of NOS were part of the instructor's classroom explicitly or implicitly. Based on this data we can divide instructors to three categories.

Instructors who believe the main outcome of a class like this should be NOS. This view which prevails at two sites (Case 6 Appendix H, Case 7 Appendix I). The instructors introduce HOS as a vehicle for teaching NOS, and all of the activities, assignments, and discussions are to support this idea. In addition to NOS, other objectives of the class are met in these two sites, and this shows putting NOS as an outcome not only does not harm to other objectives but also supports them. All most all elements of NOS are covered on these sites and even in one of them, each week's theme is one element of NOS.

Historians, philosophers, and science educators support this approach and introduce the use of the history of science as a source to develop knowledge of NOS (e.g., Matthews 1994). Integrating history of science is one of the suggested methods for contextual NOS instruction (McComas, 2010; Clough, 2006; Hodson, 2009).

Instructors believe that NOS is important but other objectives are more important. This group which consists of five instructors, occasionally, highlighted some aspects of NOS in their classroom and discuss them with preservice teachers. The numbers of elements are not too much; science is embedded in society and culture, science is a human endeavor, the existence of more than one scientific method, and science is open to change and makes mistakes are popular elements that are discussed in their classrooms.

Some researchers believe using history of science increases knowledge about science content (Galili & Hazen, 2000), in addition to NOS concepts (Kolsto, 2008; Clough, 2006; Irwin, 2000), and helps students to create connection between science content and other disciplines (Matthews, 1994) which highlights the social side of science (Allchin, 2013). The point is, instructors who focus in the NOS do not miss other objectives, but researchers show focusing on the other objectives do not result in the understanding NOS (Abd-El-Khalick and Lederman 2000).

Instructors who believe the NOS comes automatically from readings and activities

Five instructors think they do not need to discuss elements of NOS in class because it comes simultaneously and naturally when you teach HOS. Consider this quote from instructor Number 1 in Case 1 “Connecting to NOS/NOM comes from their reading and activities. Preservice teachers write reading reflections and it [knowledge of NOS] naturally happens through them” (personal communication, May 2, 2016). When these instructors talk about what objectives they follow or what is going on in their classroom, some elements of NOS can be found, but they never highlight them in the class. Several empirical studies have been conducted to investigate the impact of using HOS in understanding NOS (Abd-El-Khalick and Lederman 2000; Lin and Chen 2002; Rudge, Cassidy, Fulford, & Howe, 2014; Khishfe, 2013), all of them support it is not going to happen without opening direct discussion.

Instructors who believe the NOS is not the aim of this class or even not know about it. Three instructors including the author of the curriculum, seriously reject NOS as an aim of such a course, but it seems more sensitivity to the word than what the word brings. This claim is clear from my answer to question one that shows lots of potential NOS elements in the model curriculum. This sensitivity is because they believe “Nature of Science never became a profession." Many of instructors were not familiar with the term NOS and I have to explain what it means, but one instructor even after my explanations said that he does not have any idea what I am telling and how it is connected to this class.

As it was explained, nature of science is much highlighted in two instructors' class and partly can be found in five instructors' class explicitly. Some elements of NOS more or less can be found in all the instructors' curriculum implicitly. The point is based on the literature, implicit mention to it is not useful and does not have an effect. It seems unreasonable when the model curriculum has elements of NOS implicitly inside, this potential is lost by ignoring to discuss it in a more explicit way.

Unfortunately, nature of science is not a highlighted outcome of this course, although research and expert opinion support its inclusion in teacher education classes. The result of this research shows this happens because NOS is not in the standards that are used in the Texas and because the directors of UTeach in the beginning were not a supporter of it. The model curriculum which is written by a historian of science, with a look to NOS as unnecessary topic, gave this deficiency more credit. Although even on the scale of Texas this view is problematic and against suggestions of literature, with the widespread use of UTeach in all the country these days this problem need to be solved. Especially, now that NGSS is out and many states have adopted it, and this document introduced NOS as an important component of teaching science, UTeach should move to focus on NOS as an important outcome of this course perhaps in addition to HOS.

Highlights from the instructor's best practices as a basis for improving UTeach's model curriculum or suggesting a new one

It will be no surprise that generally I believe the focus in class such as *Perspectives* should be on NOS primarily with support from HOS. This is much more in line with the options of science educators and the expectations of guiding documents like NGSS. With that in mind, there are positive points in the model curriculum that are parallel with the recommendation of literature and should be kept:

Overcoming misconceptions is one highlight component of the model curriculum. A HOS class should help preservice teachers to have enough knowledge to recognize misconceptions and myths in the textbooks and complete faulty picture that they depict from science. Postman (1994) criticize textbooks with telling:

> There is no sense of the frailty or ambiguity of human judgment, no hint of the possibilities of error. Knowledge is presented as a commodity to be acquired, never as a human struggle to understand, to overcome falsity, to stumble toward the truth (p.116).

In addition, according to literature, HOS lesson plans should be written in a way that closes possibility of converting history to myth (Allchin, 2003). This is one of the main objectives for the author of curriculum which is very highlighted in his textbook "Science Secrets".

Another highlight point in the model curriculum is talking about failures in the science and Allchin (2003) confirm it by telling HOS classes should show failures and critiques and explain errors at the same time with celebrating successes (Allchin, 2003).

Based on reviewing the literature and collecting information from instructors I have some suggestion for UTeach for improving this course. Some of these suggestions are offered by instructors.

1) As mentioned, nature of science is an important missed part of this course. As much as I am happy that UTeach correctly recognized the importance of having a course in the liberal art, for preservice science teachers, I feel pity that NOS is missed in this important decision. It happened in the condition that analyzing the model curriculum shows the potential of including it, many instructors are doing it, and it neither hurts objectives of the course nor needs lots of time. NOS just needs to be highlighted by instructors in their HOS class and probability of happening it decreases when it is not emphasized by UTeach. Ignoring NOS is like having a fruit tree but ignoring its fruits and just using other benefits a tree can bring for us.

This suggestion mentioned by four instructors of the course and by literature that says HOS lesson plans should both illustrate the development of fundamental science ideas and should communicate important NOS ideas (Metz et al. 2007; Clough, 2007). It should have components that open discussion about NOS and has potential to draw students' attention to NOS (Clough, 2010).

2) HOS lesson plans should be written in a way that follow some rationales and convert science content to students, only telling stories is not useful. Helibron (2002) highlights this point by stating:

> Finally, wherever possible the case studies should carry epistemological or methodological lessons and dangle ties to humanistic subject matter. But never should the primary purpose of the cases be the teaching of history. (p. 330)

Unfortunately, this happened in some instructors' classes when the whole idea is just teaching history without any special expected outcomes. This should be redirected to teaching HOS for special objectives and should emphasize by UTeach. As an example, according to literature a HOS lesson plan should help preservice teachers to depict a correct and accurate picture of what scientists do with the students' mind. Eccles (2005), concluded that we do not give a good picture of scientist to our students and they see scientists as an “eccentric old men”. He thinks to show social and human picture of scientists is very necessary if we want women in science. In addition, it should not portray scientists larger or more complex than they are (Allchin, 2003). In some sites, providing an accurate picture of science and scientists is not the main focus of the instructors.

3) Clough (2010) emphasized, students should receive information about how science had been done in the Past and how it has been going on present to avoid dismissing accurate NOS ideas. In two sites, this comparison is highlighted by comparing autobiography of ancient scientists and new scientists, I feel this is a useful component which can be added to resources of the course.

4) One of the instructors asked the preservice teachers to read the autobiography of one scientist for one special finding and then preservice teachers read the article which is the outcome of this work. I find this very helpful in helping the preservice teachers to gain an accurate picture of science, and language of communicating it. In addition, Words of scientists should be used to provide authenticity to the NOS ideas (Clough, 2010).

5) Many instructors, including the author of the curriculum, suggested that UTeach update their website and get the necessary copyright for some of the supplementary pictures and documents which are not included due to this problem. For example, even the name of one of the books which introduced as a textbook by the author has changed but the wrong information remains on the website.

6) The fact that the method of teaching this class is limited to lecture and discussions is one of the problems of this curriculum. Historical experiments, field trips, and game “Reacting to the Past”, suggested with one of the instructors, can be introduced as new methods.

7) Instructors suggested UTeach to prepare and provide a handbook for doing historical experiments. Lavach (1969) used historical lectures and experiments in some concepts like astronomy, mechanics, chemistry, heat, and electricity and teachers in the experimental group showed a significantly better understanding of NOS.

8) Several instructors suggested that those who teach this class including those with expertise in history, philosophy, and science education background should sit together and write a curriculum for this course to provide a document which is rich. In addition, some instructors asked for the interactive website in which instructors can share ideas and put their resources.

Areas for Further Study

With direct observation of these instructors' classroom, or conducting several follow up interviews this research can answer more questions in depth. In addition, interviewing with UTeach directors, can add to clarity of UTeach's opinion about the course. Preservice teachers who took the course are another valuable resource; interviewing with them helps a clearer picture of instructors' classroom practice obtain.

This research can be extended with interviewing the preservice teachers who are taking the course to realize how many preservice teachers find such a course useful for their future. It is not common in teacher precreation programs to offer a course in HOS/NOS. Preservice teachers' satisfaction with this course and learning about their experience, can provide program coordinators with motivation to offer such a class. In addition, by talking with such students, we might find which method of instruction of HOS/NOS is more effective and enjoyable. In this research, we recognized different instructors have different approaches with the course, interviewing preservice teacher provides of us with more effective methods. For example, between doing historical experiments and role playing which one is more engaging and informative for preservice teachers?

The graduates of UTeach – all of whom would have had some version of the *Perspectives* class, could be observed in their classroom to see how much HOS/HOM/NOS they are communicating in their teaching compared with teachers with same years of experience who did not take such a class. Besides, it helps to realize which kind of teaching approach from instructors of UTeach had a better effect on preservice teachers' performance on their classes. In addition, the objectives, and methods of this class can be compared with other HOS courses for preservice teachers.

In addition, preservice teachers' knowledge of NOS can be investigated before and after taking this class with questioners and interviews. The data can help a researcher to recognize if a specific approach with teaching this class was effective in improving students' knowledge of NOS. Comparing different data cross sites, can provide information about the kind of instructional approaches that is more effective in helping students in understanding NOS. The research in the area of increasing preservice instructors' knowledge of NOS have done with small samples without comparing several instructional approaches and conducting such a research can add to literature. In addition, implementation fidelity, dosage of instructors' commitments to UTeach's model, and classroom practice of instructors can be examined for other core courses offered by UTeach.

Final Thoughts

This research has focused on analyzing a course called *Perspectives on Science and Math,* developed as part of the national UTeach program for the education of preserve math and science teachers. As written, this course has a very strong focus on the history of science but there is much potential for the inclusion of nature of science. To understand this course, I analyzed the model curriculum provided to program-adopters on the UTeach Institute website, collected syllabi and interviewed with 16 instructors who are teaching this course at 11 sites across the U.S.

I learned from this research that this course has been offered by instructors with differing backgrounds including historians of science, philosophers of science, science educators and even occasionally by scientist, math educators, and historians. As a result, instructors approach with the course comes from three main resources: expectations of UTeach communicated to the instructor via the model curriculum and workshops, instructors own background and experiences, and leading standards in the state.

The prevailing view is approaching this course like very typical HOS course in the liberal art department that give an accurate picture of HOS to preservice teachers, help them to do research in history, and overcome their misconceptions and myths in the history. This typical view is not searching to provide an accurate picture of science or at least it is not highlighted on it. Kolsto (2008) warns, superficially going through history in the classroom may "reinforce a naïve positivistic view of science" (p. 995), which occasionally can be seen in the instructors' approach with the course.

In the same time, some instructors around the country, who are with high chance science educators with studies in the area of history and philosophy of science, correctly recognize this kind of approach is a necessary condition. They communicate ideas related to NOS to their students as highly recommended by researchers (Clough, 2006; Hodson, 2009; Matthews 1994; McComas, 2010).

Looking to methods instructors use, lecturing and discussions besides some activities are a most common method in this course. Some instructors, show more variety in the methods they used like using historical experiment, going to field trips, and playing games. These shows possibilities for teaching this class as supported by researchers (McComas, 2010; Paraskevopoulou & Koliopoulos 2011; Schiffer and Guerra, 2014; Rudge, Cassidy, Fulford., & Howe, 2014; Allchin, Andersen, & Nielsen, 2014). Whether science standard of the state demands connecting science to NOS or HOS is very important in instructor's approach.

Teaching the course for instructors is not without challenges. Having science and mathematics students together is a big challenge for them both for lack of materials and lack of students' interest in a mixed class. The point is in the end all of the instructors see this challenge an opportunity for both groups of students. They think they should realize how much their fields are interconnected. They should see differences among these two courses too. The other challenge for them is finding materials for math students. The model curriculum's math lesson plans solved this problem somewhat but they asked for more.

5E lesson plans are not very popular among instructors. Most of them feel they are time-consuming and difficult to handle. A complete prepared guideline for writing 5E lesson plan is another request of instructors because many of them do not have an educational background. One suggestion from instructors was allocating an extra time to writing a lesson plan and presenting it outside the normal class time which a master teacher controlling it.

The UTeach Institute needs to reconsider the objectives of this course to make it more connected to the national standards (NGSS) especially NOS part of it because 18 states, along with the District of Columbia, have adopted this standard for teaching science. UTeach is a national program and it is crucial for it to follow national standards. This course has high potential to be changed to a very useful course for preservice teachers. The data provided in chapter IV of this research can be useful for people who wants to teach a course in the history of science to see kind of resources other use, kind of assignment they define, and their general approach to this course. UTeach and other teacher preparation programs can take advantages of instructors' suggestions and challenges they had to improve the course. UTeach is able to provide a list of different methods and resources that instructors use in the website with the contact information of the person recommending those methods to help communication and sharing ideas.

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Appendix

Appendix A:

Survey questions

1. How many times have you taught Perspectives (or a class like Perspectives)?

2. Which of the following is your primary department or college?

Other

3. Think about these big topics. How much time (in percent) do you spend on each in the course? (For example, 25% for history of Math)

1- History of Math

2- History of Science

3- Philosophy of Science

4- Philosophy of Math

4. From this list of activities that might be used in a class like "Perspectives,", which have you used in your version of the class? (Choose all that apply)

- ☐ I have students read original works (or selections) in the history of science
- ☐ In class I use case studies, stories and other similar illustrations of the history of science
- ☐ I verbally share many examples of anecdotes/short stories from the history of science
- ☐ Students read biographies and/or autobiographies of scientists and their discoveries
- ☐ Students read an entire book on some aspect of the history of science
- ☐ In class students engage in role playing and related activities with respect to historical personages or events in science
- ☐ We engage in experimental reenactments (repeating historical experiments) and other "hands-on" approaches to explore the history of science
- ☐ In class I have students watch a film (video) about some aspect of the history of science

In the space below, please tell us about any other ways (beyond lecture-discuss) that you use to communicate aspects of the history of science with students

5. From the following list, please choose your top 5 rationales which you would associate with the teaching of history of science and/or mathematics in a class like "Perspectives".

- [ ] Increase student motivation
- [ ] Increase admiration for scientists/mathematicians
- [ ] Help students develop better attitudes toward science / mathematics
- [ ] Humanize the sciences / mathematics
- [ ] Demonstrate that science / mathematics has a history
- [ ] Assist students in understanding and appreciating the interaction between science / mathematics and society
- [ ] Provide authentic illustrations for the way science/ mathematics actually functions
- [ ] Reveal both the link and distinction between science and mathematics
- [ ] Help to connect the various science disciplines by showing the commonalities between them
- [ ] Make instruction more challenging and thus will enhance reasoning
- [ ] Provide opportunities for the development of higher order thinking skills
- [ ] Contribute to a fuller understanding of basic science / mathematics content
- [ ] Help to reveal and dispel classic science misconceptions (this rationale is linked to what is called historical recapitulation in which some learners are seen to proceed through stages of misconceptions that are occasionally linked to incorrect ideas held by scientists in the past)
- [ ] Help to reveal and dispel classic science misconceptions
- [ ] Provide an interdisciplinary link between science / mathematics and other school
- [ ] Improving science and mathematics teachers' knowledge about content of science and math

Other

6. This is a list of nature of science topics that might be included in a class like "Perspectives." Which of the

4. From this list of activities that

5. From the following list, please choose your top 5 rationales which you would associate with the teaching of history of science and/or mathematics in a class like “Perspectives”.

☐ Increase student motivation

☐ Increase admiration for scientists/mathematicians

☐ Help students develop better attitudes toward science / mathematics

☐ Humanize the sciences / mathematics

☐ Demonstrate that science / mathematics has a history

☐ Assist students in understanding and appreciating the interaction between science / mathematics and society

☐ Provide authentic illustrations for the way science/ mathematics actually functions

☐ Reveal both the link and distinction between science and mathematics

☐ Help to connect the various science disciplines by showing the commonalities between them

☐ Make instruction more challenging and thus will enhance reasoning

☐ Provide opportunities for the development of higher order thinking skills

☐ Contribute to a fuller understanding of basic science / mathematics content

☐ Help to reveal and dispel classic science misconceptions (this rationale is linked to what is called historical recapitulation in which some learners are seen to proceed through stages of misconceptions that are occasionally linked to incorrect ideas held by scientists in the past)

☐ Help to reveal and dispel classic science misconceptions

☐ Provide an interdisciplinary link between science / mathematics and other school

☐ Improving science and mathematics teachers' knowledge about content of science and math

Other

6. This is a list of nature of science topics that might be included in a class like "Perspectives." Which of the following do you include in your class? (Choose all that apply)

☐ Science produces, demands, and relies on empirical evidence.

☐ Knowledge production in science shares many common factors: shared habits of mind, norm, logical thinking, and methods such as careful observation and data recording, truthfulness in reporting, etc.

☐ Laws and theories are related but are different types of scientific knowledge.

☐ Science has a creative component.

☐ Scientific observation, ideas, and conclusions are not entirely objective and are directed, in part, by ones prior conceptions.

☐ Historical, cultural, and social influences impact the practice and direction of science.

☐ Science, technology and engineering impact each other but are not the same.

☐ Scientific knowledge is tentative, durable, yet is self-correcting. (this means that science cannot prove anything except that scientific conclusions are valuable and long lasting because of the way in which they are developed; errors will be discovered and corrected as a standardize part of the scientific process).

☐ Science and its methods cannot answer all questions. In other words, there are limits on the kinds of questions that can and should be asked within a scientific framework.

Other

7. To what extent are you familiar with the model curriculum for the Perspectives class provided on the UTeach website? (Choose from menu)

8. How did you learn about the UTeach model Perspectives curriculum?

○ Via attending a workshop

○ Via a previous instructor

○ Via program coordinator

○ Via attending a UTeach conference

○ I do not use the UTeach model curriculum

Other

9. If you have never used the model Perspectives curriculum, what is your reason for it?

10. The following is a list of lessons from the model Perspectives curriculum. Which of the following have you used in your version of the class? (Choose all that apply)

- ☐ Plato's Philosophy of Mathematics
- ☐ Revolutions in Astronomy
- ☐ Paradoxes of Division
- ☐ Minus Times Minus is What?
- ☐ Radical Puzzles
- ☐ Species, Monsters, and Things in Between
- ☐ Darwin's Path to Evolution
- ☐ Questions and Evidence on Evolution
- ☐ Secrets of the Alchemists
- ☐ Impossible Chemistry
- ☐ Discovery of the Electron
- ☐ Infinitely Small
- ☐ Prisoners of Probability
- ☐ The Age of the Earth
- ☐ Non-Euclidean Geometry
- ☐ Philosophies of Mathematics – Choose or Sleepwalk

Appendix B

Guiding Questions for interviews

These questions are general questions that I have asked all of the instructors, but I asked some questions that were specific to each instructor and I asked them based on the person's answer to survey or some points in his/her syllabus.

Interview questions for instructors of course

How long have you been teaching "perspective" for UTeach?

How many times have you taught this course?

Which department are you from? What is your background?
From which department are you?

What resources do you use for this course?

What do you think about the curriculum?

What part of the curriculum is your favorite and why?

What suggestions do you have to improve the curriculum?

What are the objectives of this course, and what should they be?

To what extent does the curriculum meet these objectives?

If somebody asks you to change the curriculum, what will you do?

Who is the best person to teach this course from your point of view?

What have been the benefits of teaching this course for you?

As a person from Philosophy/History/Education which part of curriculum is challenging for you to teach?

And what perspectives does your background add to the curriculum?

Where is the position of the nature of science in this course? How much are you as an instructor of course care about it?

How do you interpret nature of science from the Philosophical Educational lens versus historical lens?

Do these assignments help the student understand the history/philosophy/nature of science?

What elements in “perspective” are aligned with a nature of science class from your point of view?

Do you co-teach this course with any other professor? If yes, which parts do you teach?

How did you learn about the curriculum’s materials? (How did you train? (From attending a workshop/from a previous instructor/ looking into materials?

What is your experience working this curriculum with students?

What is your feeling about teaching this course?

What are the benefits of this course for students? How is it related to their future job?

How much do you find this course related to NOS?

Appendix C

Case Study 1: SW State University

This site, SW State University, is a public research university with a student population of almost 17 thousand. The SW State site offered Perspectives since 2012, for six times. For this time, the *Perspectives* class has been taught by two instructors, both from the education department, with the same syllabus prepared by the first instructor. This class meets once a week for a total of three hours per week. The first instructor has taught the course 6 times when the second one just taught it once. After the program coordinator provided me with first instructor's email, I could contact him for requesting her syllabus and sending the survey link; later I interviewed him by phone. Later I send an email to UTeach's *Perspective* list serve and asked if there is an instructor that I have not contact and has the desire to participate. The second instructor answered and I send him the survey and asked for his syllabus, and later interviewed him by phone.

The Importance of the Course

The emphasis in this class is on the history of science and history of mathematics with a little explicit focus on the philosophy of science. The first instructor thinks *Perspectives* is an important course because it gives students a "bigger view of science and mathematics and at the same time provides opportunities for critical thinking, analyzing resources, connecting science, mathematics, technology, society, and culture." Although this quote is from his interview, the similar sentences can be found in his syllabus. Instructors want to show that science is a part of society and is affected by culture, and science changes over time are the central factors. From the Umbrella project that they defined which asks the student to dig into history to find changes over time and conditions of time, they meet this rational somewhat. They believe by developing, preparing, and teaching mathematics and science lessons at the intermediate and secondary school settings in historical contexts, preservice teachers will have a better appreciation of teaching profession. Furthermore, they believe that the course recognizes and celebrates the contributions of women and non-European cultures to mathematics and science. They claim it because students for their project can chose a scientist that is not a white man and is from their own culture.

The second instructor added that it is very important for science and mathematics teachers to know some history about their subject area to understand how these ideas have changed and how we look at science and mathematics over the years. He thinks that telling the historical story would make the topic more intriguing and interesting to students once these preservice teachers are in their own classrooms.

Resources for the Course

As I mentioned both instructors use a same syllabus which is complete. In the syllabus, the course objectives and students learning outcomes are mentioned. There are a few sentences that explaining each assignment, the rubric for each assignment is included. There are short paragraphs about each textbook he uses. A tentative list of topics and readings for each week is included.

Preservice teachers enrolled in their class feature two textbooks. One textbook for the math students[1] and another for the science students[2]. I syllabus these books are described as:

> The main part of the mathematics textbook consists of a collection of 25 short historical sketches. Each sketch focuses on a particular mathematical topic (i.e., The

[1] Berlinghoff, W. P., & Gouvea, F. Q. (2004). *Math through the Ages: A Gentle History for Teachers and Others,* A Joint Publication of Oxton House Publishers and The Mathematical Association of America

[2] Joy Hakim (2007). *The Story of Science: Einstein Adds a New Dimension***,** Published in Association with the National Science Teachers Association, Smithsonian Books, Washington and New York.

> Story of Zero, The Story of Pi, The non-Euclidean geometries), and illustrates the origins of the topic, including key people associated with its development. The science textbook pairs with a gripping narrative style with informative sidebars; hundreds of charts, maps, and diagrams; suggestions for further reading; and excerpts from the writings of great scientists.

In addition, a CD[3] is provided and contains historical modules (lessons) for teaching and learning of mathematics or science. In the course outline, in each week the name of the articles that students will read for the next session and pages of the textbook that they should read are mentioned. These articles are on the course website and students can download them weekly.

Instructional Method: An Overview

The first instructor's method for teaching *Perspective*s is starting with asking students to write their answers to these 3 questions:

- What is your background in teaching science in the context of history?
- Do you think is important
- What are benefits of teaching history to students?"

Then, during the semester in the context of reading and activities, they reach the conclusion that history is important. Then the students write a reflection at the end of the semester and these reflections show they reached to the point that it is important to include history.

Their instructional method is basically to provide lectures about weekly articles (since the textbooks are separated, they do not discuss them in the class and students write a reflection on it). Each week students read a chapter from their textbook along with extra articles provided by the instructors. Instructors give lectures in the class about articles and open a discussion. Students write weekly reflections on their reading from their textbook. As stated in the syllabus, "each entry reflection

3 Katz, V. J., & Michalowicz, K. D. (2004), Historical Modules for the Teaching and Learning of Mathematics

should include . . . a summary of a chapter of the textbook, an analysis of the reading, and an opinion of the reading”. Both instructors emphasize their role in helping students to engage in inquiry through something called they call the “Umbrella Project” which I will discuss in greater detail later in the case. Both instructors believe since students find everything related to their topic themselves, their class is inquiry base. For me, it is difficult to see the course inquiry base, because instructors’ method is lecturing. The second instructor emphasizes “We keep telling students to use inquiry, but in none of our courses we use it ourselves”. So, he wants students to find their topic of their interest and extract the history of the topic.

Challenges of the Course

The first instructor thinks there are more sources related to the history of science compared with the history of mathematics. He believes there are not good textbooks about history and philosophy of science for science teachers. His students’ sometimes are resistant to taking the class and feel it is not useful because they feel due to lack of resources and time, they are not able to teach history in their future science class. “Even if students are convinced they should use history in their classrooms, there are not a good source for them to refer it and do it.” He remarked that it may e take and entire semester to convince students that using history is important for them. This strategy works for many of them, but at the end of the day, they do not know how. He emphasized that we need a model for students to integrate history into their teaching. For example, if they want to teach algebra, they should be able to refer to some place and find suggestions for teaching it from a historical basis. Even if we convince them of the value of history, we then send them to classrooms and think they will be able to teach it.

He also blames politics and tests and common core for not including an emphasize on the history of science and believes it is very natural that with the lack of support from schools even teachers who confirm its importance may not include it in their classroom practice. Rather, they teach in ways that tests force them to teach. He thinks we need to talk explicitly about “challenges, problems, and possibilities” and try to find a model for teachers to help them to overcome these problems and State standards should be written in a way that value teaching science in the context of history.

Instructors’ View about the Model Curriculum

The first instructor is not using the model curriculum; he uses his own model which is history, culture, and mathematics. “I got the general ideas from it but I want my students to get the big picture and would be able to perform it in their own classroom.”

Second instructor’s class was an additional section that added at the last minute, so he did not have that much time to prepare for the class and based his class directly on that of the other instructor. He says the main reason for not using the model curriculum is the time limitation he had, so he looked at some parts of it, but due to lack of logic and inquiry decided to not use it. He believes if he had time the class was more inquiry base.

Class Assignments

The “Umbrella Project” is the main assignment of the course. In the first week, the instructor introduces the project and ask students to find a partner and identify a topic from science/ mathematics content that they like. The topic should target the standards for a high school such as electricity and atomic models. The project requires four people in a group working in pairs within that group. One student pair works on one topic and another pair on another topic. In our example. One pair works on the history of electricity and another pair work on the history of atomic models. In the first phase of the project, both pairs investigate the history and cultural context for their topic and write a four-page paper. Then, in the class, these two pairs read each other’s paper, debate it and critique it. In the second phase, they find historical people who have contributed to their topic and write about them and again review it together, in the last part they should put what they learn from the history of their topic in the context of a classroom teaching for 45 minutes and write a 5E lesson plan. For example, the pair that chooses the physics idea of electricity would write a lesson plan for teaching the concept in class when they included the history of it and people involved in the developing the idea in their teaching; another pair does the same thing for atomic models. They should present it in the class for 45 minutes. In this stage, everyone writes a review for them. The pair of students writes a pre and post critique for their lesson plan. The instructor thinks in this method students unconsciously bring their culture to the classroom. They choose people from the history (or math or science) based on their interests.

NOS Connections

Regarding NOS, the first instructor did not talk explicitly about it in his class, but he thinks connecting to NOS/NOM comes from their reading and activities. “Students write reflections on their reading and it naturally happens via them that they learn something about science. It is naturalistic inquiry without pre-structure. I move with students and facilitate their learning.” In our interview, the second instructor remarked that he is not sure he connected his lesson plans to NOS because his main rationale for this course is for students to realize that mathematics and science have a story and to be able to use these stories in classrooms.

Suggestions for Improving the Course

The second instructor thinks to improve curriculum, it should be more inquiry base, and it makes the course less challenging for students and instructor. His suggestion for UTeach is providing more information on how mathematics changed over time.

Appendix D

Case Study 2: Beta State University

This site, Beta State University, is a public master university with a student population of almost 8 thousand. The Beta State site offered Perspectives once a year since 2010, which means it was being taught for the sixth time at the time of the interview. This class meets three times per week for a total of three hours per week. The instructor I interviewed by phone is from the Department of Chemistry & Biochemistry and has taught the course four times.

The instructor tells me that she enjoys teaching the course and it is one of her favorites. The person who was teaching the course, before her, moved into an administrative position and was no longer teaching the class so she was assigned to teach it in an emergency one semester because they didn’t have anyone else available. She explained that she sometimes feels unqualified to teach the class, because she does not have a professional training in the history of science. She used to refer to aspects of history of science in her physical chemistry class. For example, she used to introduce a “scientist of the day”; related to the concept that they are looking at in the class for that day. She believes her physical chemistry class’s students responded positively to this assignment and believe this was the reason UTeach contacted her for teaching *Perspectives* class. They needed somebody to teach the *Perspective*s class and she received good student reviews after teaching it for first time, so UTeach asked her to continue teaching the class in the following semesters.

The Importance of the Course

The instructor explains that the course has four broad goals: to provide an overview of the history of science and mathematics; to put these historical perspectives to work in pedagogy; to promote intellectual curiosity and sharpen students critical thinking skills; and improve preservice teachers' presentation and writing skills.

Resources for the Course

In the syllabus, the instructor provided a general description of the course, the course objectives and students learning outcomes. There are a few sentences that explaining each assignment. The name of textbook is mentioned. A tentative list of topics is included, but readings for each week is not clear.

Her textbook[4] has been the required book for the last few years but this year the cost of that book became high, so she did not require it. She did use some readings out of that book and then she also used some readings out of David Lindberg's book [5]so, she kind of selectively pulled some essays or chapters out of those books and then she also used a couple of readings articles recommended in the model curriculum.

The instructor had to be out from the town of a week this semester so she created several online lessons for the students and she used some current articles to compare them with ancients to show we still work on some issues. In addition, she uses some online sources, for example, American Institute of Physics interactive gallery which has exhibits and other online resources for history of science. She used the discovery of electrons from their website (https://www.aip.org/history/exhibits/electron/) and have built timeline based on the gallery. They have an interactive gallery on Madam Curie as well (https:// www.aip.org/history/ curie/).

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[4] Gregory, F. (2008). *Natural science in western history*. Houghton Mifflin.
[5] Lindberg, D. C. (2010). *The beginnings of Western science: The European scientific tradition in philosophical, religious, and institutional context, prehistory to AD 1450*. University of Chicago Press.

Radium Craze (http://museumofquackery.com/devices/radium.htm) is another source and she described it by telling

> We talk about Pierre Curie strapping a sample of radium to his arm and some other crazy stuff. It seems to cement the idea that our knowledge is always changing. I ask them to reflect on what things do we accept as safe today which might not view that way 100 years from now.

The resources that she mentioned in the interview were provided in the syllabus as well. Her answers to the survey agree with those from her interview and syllabus regarding her rationale for the course or method she used.

Instructors' View about the Model Curriculum

That first year that she taught it she relied extensively on the model curriculum. She had about two weeks between the time she was asked to teach the class and its start. She had no idea what she was doing so she used that modern curriculum quite heavily. The previous instructor had used a little bit of it but no a whole of it so she just pulled a few things that the previous instructor had done and then relied on that modern curriculum to figure out what it was.

> I taught it, I really didn't even have a good feeling for what the purpose of the class was or what I was supposed to do, so, I used the model curriculum. In the subsequent years, I still use it and I still do follow some of the lesson plans that are in there and are kind of supplemented and altered and added some of my own stuff as well. Well, I'm extremely lazy, so the ones that I (picked) or some that I already had some familiarity with so coming from chemistry background e.g. radiation.

She also takes the few of them from areas she does not know, such as math lesson plans. She intentionally grabbed some of those math ones so that gave her some math guidance about some things that she had to learn to target her own knowledge so she came up to speed very quickly. She chose some lesson plans and then as she got more experience changed what she used from years to years, sort of based on what the students bring in my class. As an example, she mentioned this year, which included one chemistry student and 4 or 5 biology students and then many math students, she added more math lesson plans.

Instructional Method: An Overview

Mostly she lectures in the class but what she tries to do is to give a lecture at maybe 15 minutes and then she poses a specific question related to main idea of lecture and try to initiate a discussion and then that discussion takes the class and then comes back again to maybe 5 to 10 minutes of some additional information and then asking another question to see if she can get again some more discussion going with that. In addition, she does some kind of hands-on activity to make students be involved with the activity.

I asked about example and she said,

> Well, for example, we talk about Newton with students and bring in and explain that module with Newton so I bring in some light sources and some prisms and we just do and it's maybe 10 or 15 minutes long where they shine a light source through the prism and then we look at it. … you know this makes sense to us and of course, we know that there are all different colors of light in the white light but that time Newton did it, this was a very different and this was revolutionary people didn’t know that yet.

She talked about Valentine's key activity from the model curriculum as an example of a topic that students love. (In this lesson plan students use Alchemical symbols to understand the meaning of some key Valentin’s pictures which are provided in the lesson plan along with some texts). She told this lesson plan opens discussion about alchemy as crazy, superstitious or whatever side of science and certainly some of the people who like that, some of them are kind of more serious and she asks preservice teachers to be thinking about the difference between how we are scientists or teachers of math and science to view math and science and how general public might view that and what are the responsibilities when we are talking about math and science. So, in alchemy she does an experiment where she takes a clean copper penny and coats zinc on to the penny and then heats the zinc and the penny turns gold, (not a real gold, it is just bright), it looks like she just turned the penny into gold so she uses that to talk about it doesn't mean it really happens or not, we can trick public. So, it is important how as a scientist or a teacher we talk to the public.

One of the other things she tries to do throughout the course is just to come up with different things. She showed them, the videos from a French group that took the picture of particle waves last year.

> I showed students the picture of particle waves and told them but we don't know how does that work, what does that mean, some part is particle some part is a wave. Then, I say here's 2015 paper where these guys finally sort of proved this idea of particle waves together like 100 years or not quit 100 years later. Here's what we finally got! You know to this idea and I try to stay on top of some of the current literature to throw some more stuff out periodically to discuss.

Class Assignments

Regarding assignments, in the class students are asked to write one historical and analytical paper on some aspect of the history of science or mathematics. In addition, students should write a 5E lesson plan and integrate a historical perspective into a science, math, or technology lesson and present it in the class.

Challenges of the Course

She believes that the required nature of the class within UTeach may cause students not to be excited to come into it. So, she starts the class with telling what they are going to do in the course and this is her goal to convince students to be (these things) by the end of the course.

NOS Connections

In the survey, she provided a list of nature of science topics that might be included in a class like *Perspectives* included all the list and she explained she thinks all of them are important. In the interview, she answered student will learn about characteristics of science via explanations and readings and sometimes she discusses them but she focuses on the history of science. Generally, from her explanation, it seems there are refers to the nature of science in her class.

Suggestions for Improving the Course

She did not provide any suggestions for UTeach regarding *Perspectives* because she likes it this way. I generally, see her class useful for preservice teachers.

Appendix E

Case Study 3: Mega State University

This site which I will call Mega State University is important because it is the home of the overall national program and of the author of the model curriculum. The Mega State site is a very large public research university with a student population of almost 51 thousand. The *Perspectives* class has been taught by several instructors, all from the History department, each using different syllabi. This class meets three times per week for a total of three hours per week. I interviewed four instructors from this site including him. One of them was the first instructor of the course and taught the course five times, the author of the curriculum taught the course 17 times, the other two were current instructors alternatively teach the course in the spring and fall and each has taught the course two times and six times respectively. I interviewed face to face with instructors 2 and 3 during the UTeach' workshop for the course. I interviewed both instructor 1 and 4 by phone.

All of the instructors are from the history department which seems a tradition at this site and makes sense given the history orientation of the class. Each of them has developed an individual syllabus, but the method of instruction and main topics are very similar. None of them use the model curriculum; they prefer to use their own materials that they have from previous similar classes. All instructors' classes consist mainly of the history of science. The first instructor spends 75% of the history of science and 15% in the philosophy of science and 25% in History and Philosophy of math (interestingly more than 100% according his survey). The second instructor (the author of the model curriculum) says he has 25% for each of history of science/mathematics, philosophy of science/ mathematics. The third instructor spends 80% on the history of science and math and 20% on philosophy. Instructor number 4 believes she spends about 65% of class time on the history of science, 10% on the philosophy of science and 25% on history and philosophy of math.

Importance of the Course

Answering the question about why the UTeach program decided to have such a course, the first instructor told he was not directly involved in planning, but he heard the following from those who were:

> [There was] a sense that it [the course] would broaden students' perspectives, and their apparition. They will understand better the subject matter they will be teaching as whole science and mathematics. And when they turned to be a teacher eventually, they will be better engaged with the wide range of the students who maybe are not inherently interested in science and math but they are interested in historical development. And, as the title says giving students' perspectives about topics, to instead of just teaching topic from the book, doing it in a way to engage students.

The author of the curriculum commented that this course was established because science educators not only should be connected to science departments but also to the liberal arts; they should become familiar with the history of the discipline and enjoy it. "What I decided that I would take the course as an introduction to students about how scientists/sometimes disagree with scientists." He believes if we do not show these disagreements to students we are hiding the process.

The curriculum author thinks history of science depicts a process of developing facts, theories and laws in the science and science teachers should learn to use this process to help their students learn science from ways distinct from memorization. Perhaps learning what helped Darwin could also help students to learn better and teacher students should have this ability in their hand. From his perspective, even if the discovery process is a mess, there is a benefit in talking about it.

The third instructor mentioned that learning about history helps preservice teachers see everything from a different angle of view and later teach it that way. As an example, he mentioned that one of his students had a problem with algebra and after he showed his student Newton's approach, he liked that.

From the first instructors' perspective, the class was first more taught by the historian of science but now recently philosophers of science teach it. The first instructor was engaged in planning what to put in the course, and they wanted to do it flexible that every instructor can teach it in their own way. The first version of the class included three case studies including something from the Scientific Revolution from 17^{th} century, something about Darwin and history of evolution, and something from the 20^{th} century such as the history of atomic bomb and history of DNA.

Instructors' views about the model curriculum

The first instructor reminded me that he was not involved in putting together the model curriculum. He will teach the course again in the spring 2017 and he thinks because he had his own ideas and course elements, he will use them again, but he thinks it is a good model for people who are teaching it for the first time. He says in the History Department they recommend that instructors teach the course in the way they like. "The materials are provided for people to use it if they want, but there is not a rigid structure for what they need to do."

For the first instructor, the model curriculum therefore is just a resource, a starting point, and example for people who want to start it. "UTeach wants it taught by the historian of science but now everybody teaches it because some places these people [historians] are not available so science and math faculty or science educators or philosophers are teaching the course." He thinks the main concern is an important function of the course can be lost if it does not teach by people who have a real suitable background in the history of science. He thinks because most of the historian of science does not experience teaching it to preservice teachers the model curriculum can help them to get the idea.

The instructor number 4 at this site thinks that having a model is great to get the idea, but it does not feel right to use another person's material. Instructor number 3 said the model curriculum is written perfectly and he wishes he was the author.

The author of the model curriculum likes his material and believes it is the result of much feedback and subsequent change, but at the same time is very open to any changes other instructors decide to implement. He knows that there are several versions of "Perspective" and his version is just one of them. His belief is the mathematics part is written better and feedback from students has confirmed this belief for him. He feels that the reason is that the math lesson plans are better representations of what happens in a class. As an example, he says many of the pictures necessary for the Darwin lesson plan are not on the website due to copyright problems, so the lesson plan is not complete for those who may want to replicate it. I found this odd for a model lesson plan to be incomplete.

The author of curriculum mentioned disagreements and different perspectives in the history of science and mathematics are the focus of his curriculum and his class. For example, Newton and Leibniz were not in the same page so each created his own model for mathematics.

> What is interesting about disagreement? It is not just about one group is right and another one is wrong. It is about how these disagreements are productive and there is creativity there and I think that is an important part of math should be taught. then you have a child in that classroom having difficulty doing something such as extracting square root of negative numbers that puzzle opens a window to the historical moment when people debate it.

He believes that if we do not show these disagreements to students we are hiding the process. Removing misconceptions is another main effort. He thinks teachers have a fear of math and its teaching and he does not want them to transfer this feeling to their students.

> I want them to impress their students with the attitude that they can do something that some real mathematician did because many of great rare mathematician are just normal people, and they just try to do things a little differently.

Resources for the Course

Instructor 1 focuses his class on four units: Galileo & the Scientific Revolution, Darwin and Evolution by Natural Selection, The Atomic Bomb, Genetics and DNA. There are field trips[6], movies[7], workshops[8] involved in each unit. He has the students purchase a textbook[9] and provided additional articles on a website for the class. The second instructor has a package of readings including books[10] [11]. Each week includes articles and some selections from the book.

Instructor 3 requires four textbooks[12]. In syllabus, there is a theme for each week and there are extra articles for readings for each week. They have field trips to museums and libraries to use

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[6] To an archive, library and museum at the University of Texas at Austin
7 'The Day After Trinity'
[8] Workshop on researching and writing history papers and history-based lesson plans
[9] Galileo Galilei, The Essential Galileo (ed. and trans. Maurice Finocchiaro), James D. Watson, The Double Helix (Norton Critical Edition, ed. Gunther Stent),
10 Martinez, A. A. (2012). *The Cult of Pythagoras. University of Pittsburgh Press.*
11 Martinez, A. A. (2011). *Science secrets: the truth about Darwin's finches, Einstein's wife, and other myths. University of Pittsburgh Press.*
[12] 1. Gribbin, John. *The Scientists: A History of Science Told through the Lives of Its Greatest Inventors*. New York: Random House, 2004.
2. Kuhn, Thomas S. *The Structure of Scientific Revolutions*. 4th edition. Chicago: University of Chicago Press, 2012.
3. Sobel, Dava. A More Perfect Heaven: *How Copernicus Revolutionized the Cosmos*. New York: Walker, 2011.
4. MacKenzie, Dana. *The Universe in Zero Words: The Story of Mathematics as Told through Equations*. Princeton: Princeton University Press, ND.

original and primary documents to investigate. For example, there is a worksheet is called Darwin's Evidence and in which the instructor explains

> On the following pages, I have provided quotes from Darwin's origin. Illustrating four of his several main lines of evidence. Read these quotes and find examples in the museum that illustrate this type of evidence. The final question asks you for ideas about how you could the museum in teaching.

Instructor 4 uses a textbook[13] and there are additional required primary and secondary source readings listed in the schedule which posted by the instructor on the website for the course. For example, week two's theme is Textbook Histories of Math and Science and the readings are supporting this theme[14].

Instructional Method: An Overview

Generally, all instructors at this university state a desire that preservice teachers learn to find events by digging into the actual history, and they think in this way, they find the ability to overcome misconceptions in students' minds.

The classes at this site are oriented around lecture, discussion, and completing of various activities. Some lectures are used to give background and discussion around readings, writing papers and lesson plans. The students are usually paired in groups to do lesson plans which are about putting a historical topic related to content in the typical Uteach 5E structure. Students also have field trips around the campus. There are some small differences among instructors' teaching methods. Instructor 3 allocates half of his class doing historical experiments. One of these

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[13] Ede, Andrew, and Lesley B. Cormack. *A History of Science in Society: From Philosophy to U4lity.* 2nd ed. Toronto: University of Toronto Press, 2012.

[14] Matthews, M. R. (1994). Chapters 1 and 6 in *Science teaching: The role of history and philosophy of science*. Psychology Press.
Berlinghoff, W. P., & Gouvêa, F. Q. (2004). "History in the mathema>cs classroom" and "The history of mathemacs in a large nutshell." *Math through the ages: A gentle history for teachers and others*.(1-31) MAA.

experiments is Theories of Light and Color which is recreation of Newton's color spectrum. A handout with historical background and details of the experiment is given to the students. Instruction is included in the handout:

> In this lab, you are to recreate Newton's experiments with prisms, which he reported to the Royal Society in 1671. Newton used these experiments to investigate the nature of light on colors. Our primary purpose, however, will be to examine the nature of experimentation itself, as well as the role of scientific communities in the development of scientific knowledge.

The instructor 3 uses many different resources for teaching the course such as lab resources, different resources at the university such as the art museum, and some of the math lesson plans written by the author of the model curriculum. Instructor Number 4 has more activities about science content. Her emphasis is on science and society, so she connects history to socio-scientific issues. For example, the history of climate change is one of her favorite topics. She believes the author of the model curriculum is more interested in correcting misconceptions.

The third instructor is trying to develop a "lab book" because students seem to like historical experiments lab, and even less motivated students like to engage in doing labs. He suggests adding discussion and lab sessions to the course as extra time or at least a certain day of the week is necessary to spend time on discussions and recreating historical labs. He thinks since labs are hands-on activities and so may open the door for students with a practical learning style. He used to do several labs with Stephen hawking's book[15] and he had students to compare ideas to see conceptual description but then he realized there are similar lesson plans in the model curriculum, and even more consciously than his materials, and he started to use them in the lab.

[15] Hawking, S. (2007). *God created the integers: The mathematical breakthroughs that changed history*. Running Press.

The author of curriculum believes that his book “*Science Secrets*” came from his efforts in teaching this class. While finding resources, he noticed there are many possibilities, and some sources give teachers mistaken ideas. He decided to provide teachers with a reliable book to help them overcome many of the myths of science and mathematics. He thinks some of what teachers transfer to their students came from cartoons, and they are not correct. For example, the systems of Ptolemy and Copernicus are equally complicated but people often think the first one was rejected because of this complication. He mentioned that the name of his published book (“*Science Secrets*”) is different from its name referenced in the model curriculum (“*Secret and Myth in Science and Math”),* and he believes this is one of the points that makes instructors confused.

Instructor 3 uses some of the math lesson plans from the model curriculum, but he criticized the book “Science Secrets: The Truth About Darwin's Finches, Einstein's Wife, and Other Myths” because “myth is a philosophically loaded term and students do not really understand what myth means”. He thinks that even an accurate story (lesson plan) in the “myth” book may give students a “wrong philosophical impression”. He is a very strong supporter of re-enacting historical labs and his suggestion to UTeach is to add that part. He thinks since labs are hands-on activities and are useful for students with practical learning style. He says he got good feedbacks from students about it.

Class Assignments

The first instructor’s main assignments are three short papers, a 6–8 pages paper on the history of the topic of students’ choice, preparation and the presentation of a history-based lesson plan.

In second instructor's class, students design and prepare two 5E Lesson Plans. They select the subject of these lesson plans from a variety of options. For the second lesson plan, he gave them previous students lesson plans and they should improve it.

Instructor number three's assignments are three to five pages written biographies, A bibliography containing at least five quality sources on the topic of the lesson plan students are supposed to write, working in pairs, students prepare and revise one 5E Lesson Plan integrating a historical topic into a science or math lesson, and present it.

Instructor number 4 syllabus is 2 pages including brief mention to assignments, a tentative schedule and name of the text book. the list of assignments include reading comprehension/reflection questions, two essays one about the method, innovation, and argumentation, and another one textbook histories; annotated bibliography and topic proposal; 5E Lesson plan and its presentation. Unfortunately, there is not more information about these assignments.

Challenges of the Course

The first author says he was surprised to find so many math students in the class and it makes it a little difficult because they are less historically orientated compare with science students, but he thinks it is useful they know mathematics has history too and it is good they know math is not separate of science (something that some of the math teachers think), so he thinks this mixed class is a challenge and need to add something relevant for these students, but it is useful.

They think it is not easy to have science and math students together, but it helps to overcome the division between science and math teachers. A separate class would be easier but not better, Instructor 3 said. He thinks the course is even more important for math teachers because, with the lack of knowledge of the history of math, they were not able to answer students' questions about origins of some ideas or about why we should do some problems in a certain way and not another way.

The author of the model curriculum mentioned he had two sources of discomfort that he had to overcome: First, the culture of students from science and math is different from students in liberal arts. He feels this difference should be overcome between teacher and students, and "it should be a professor's responsibility to walk most of the distance rather than insult students that they are not ready and they are not interested and serious". Second, this course is a requirement and students are not satisfied with that. He believes overcoming these difficulties took him several semesters and much effort until in 2011 materials were ready to go to the website.

In Texas, they have "Texas essential knowledge and skills", in which there are lists of everything students should know related to each grade and there are many connections to the history of science (not to the history of math). The instructors can talk about this standard with their students as elements that they are supposed to teach. Many students show resistance to this course because it is required, but after showing them that they are teaching them materials that they are expected and required to teach, they are more open to it.

NOS Connections

Regarding NOS, there is an obvious sensitivity about the word among those interviewed. The first instructor of the course told me that the first director of the UTeach criticized NOS and this influenced the way the course was orientated. The instructors believe the word is created by science educators and it does not make sense to have a list of characteristics of science. All of them separately told me historians of science and science educators have a different language.

The first instructor's words demonstrate the misconception about NOS among historians of science. When he said:

> I got to say my attitude is rather than defining the term NOS and it is more useful to look actual examples, work of science has been done in the past and students pick on some characteristic of it, rather than trying to boil it down to list of characteristics of nature of science. We try to bring up aspects of how science have been done and how it works, how it be organized. Instead of making some major points of this is NOS.

The author of curriculum's first reaction to word nature of science was:

> Rather than talking abstractly about something called a scientific method which is very common in the nature of science course, we talk about scientific method plural. Instead of talking abstractly we are talking historically.

Then, later when all other comments were about humanizing science via history, showing creativity role, showing society role, and the position of experiment and observations, I asked him for his response to the idea that from the science educators' view, everything he mentioned is nature of science and nature of mathematics; why then, say that this is not a nature of science course. His answer was that it is "a disciplinary difference". He added

> What happened is within the field of education, they developed a movement that became the nature of science, they were people who were interested in not teaching science itself but its procedure its methods…um…they were interested in analyzing the process and talking about it, talking about hypothesis talking about methods. Meanwhile, there was a certain community, the community was scientists who wanted to find out the history of their discipline, you see there are two different questions.

After I tried to clarify one element of the nature of science is science uses different methods, he told me it is not just about it.

> let me clarify this in this way someone in the nature of science is using history of science[yes] but they are not conducting research in history of science, the way we conduct research in history of science would be{pause}suppose you want to write about Galileo we read original words in Latin and Italian, ….., the kind of words that nobody else if knows that exist and then when you are preparing an article or a book or something and you

> publish your findings you literally are a historian you discover things that happened and nobody else knows what happened.

The author of the curriculum thinks that since nature of science people are not able to dig deeply into the history, they believe what they hear and there are more chance that they transfer wrong information to students. He believes that what a historian of science tells students is unique and with giving context of society and culture of that time. He believes this course should be something different from other courses in the department of education.

Instructor 4 is familiar with nature of science via reading articles in the journal *Science & Education*. She also is familiar with Michael Matthew's work. She hopes when she talks history, she communicates them implicitly. In addition, she talks about testability and publishing. In the survey, she has chosen all the elements of NOS.

Instructor 3 believes that nature of science is all over the course. He says we talk about observation, scientific methods, and other things, but NOS is a very philosophical topic and more advanced compared to the goals of this course. He believes that history of science is a subset of NOS.

The scientific method, metaphysics, commitments, and paradigms are the topics the third instructor mentioned he is covering as NOS and he told they always have discussions about things happening. His reaction to the teacher's guideline statement against NOS was "I have not seen that. It can be bothersome. Everything we do is the NOS. Even in a philosophy class, we were concern about NOS. it should be omitted from the website." He adds "a nature of science course would be an advanced discussion of elements that emerge from this course." He says "I consider the history of science a subset of NOS because NOS is history, philosophy, society all of that."

They think the main value of the course is going to to be lost when someone outside of the history of science is teaching it and having a model curriculum is at least a guide for these people, but the model curriculum is just a sample.

Suggestions for Course Improvement

They have some struggles with lesson plan part. Thus, instructor number four suggested UTeach to have a website to teach students how to do research in the history, which resources to use and how put the results in the 5E lesson plan model.

Obviously. Instructor 2(the author of the curriculum) suggests other instructor at least use the model 1 time. Instructor 3, suggested adding historical experiments to the curriculum.

Appendix F

Case Study 4: Alpha State University

This site, Alpha State University, is a large public research university with a student population of almost 37 thousand. Alpha State site has offered the *Perspectiv*es class since 2010. The *Perspectives* class has been taught by philosophy graduate students; each instructor develops a personal syllabus but expectations are the same with just some readings and expectations changed. I talked with one of the instructor-students and a master teacher who monitors those teaching this course. The master teacher has a bachelor degree in chemistry, master's degree in education leadership and a Ph.D. in chemistry with an emphasis in the education. Some of these graduate students taught the course several times and two of them taught it just one time. The graduate student who I interviewed has taught the course just one time. This class meets two times per week for a total of three hours per week.

The course was started at Alpha State University by a philosopher of science and later he handed the class to graduate students as instructors but he supervises them in teaching the class but they are free to teach it in their own way. The master teacher provides instruction in the 5E lesson plans' writing in the class. The graduate student with whom I talked, told me the emphasis of this class was in philosophy. He believes he covers more philosophy of science (40%), history of science (25%), and then philosophy of math (20%), and history of math (15%). Of course, this is quite different from many of the other sites where the focus is clearly more on the history of science.

Importance of the Course

The instructor interviewed thinks we should question the philosophical basis and foundations of different fields. He said that the history of science just covers the facts as they exist without realizing that lots of the assumptions of different scientific disciplines are open to question and critique,. He thinks questioning history and philosophy of these things are important for practicing science and failing to do it can lead to either errors or maybe even dangers and certain patterns, so it is his rationale for the course. He added that he thinks it is critical for a teacher to understand why this happened in the first place and what led to this point. For example, knowing a debate between Newton and Leibniz and their philosophical differences is very important in understanding Calculus.

Resources for the Course

In syllabus, the course objectives and students learning outcomes are mentioned. There are a few sentences that explaining each assignment and criteria for grading. It is mentioned that there is no specific textbook; each week's readings are uploaded on the course website, from weekly assignment it is clear that most of them are book chapters. A tentative list of topics and readings for each week is included. The positive point is there is a complete reference to each week's readings.

Each week has a special theme. For example, Global History of Mathematics, the Islamic Golden Age, and the Renaissance is one week theme. In this week, students are supposed to read our chapters from three different books[16]. As it can be seen in the previous example, there is a reasonable readings in mathematics too.

Instructional Method: An Overview

The master teacher told me that the class is focused on lectures, discussions, and presentations by students. Their students should do 5E lesson plans just one time and with a partner. It is explained in the syllabus as "this lesson plan will have philosophical and/or historical learning objectives and incorporate the historical and/or philosophical aspects of the topic in the lesson." According to master teacher, the curriculum used by the instructors is close to the model curriculum but not an exact version, depending on the personal interest of instructors. This was not match with what the instructor told me that at least half of his class is philosophical debates and nature of science. She says the history of math is a larger part of their curriculum because they have many math students compared with those in science. She thinks there is not a single model curriculum for this course because it depends on which department would teach it.

The instructor often introduces a basic concept or question at the beginning of the class like "what is philosophy" and have students break into groups of two or three to generate an response

[16] Lindberg, D. C. (2010). The Mathematical Sciences in Antiquity in, *The beginnings of Western science: The European scientific tradition in philosophical, religious, and institutional context, prehistory to AD 1450* (pp. 89-110). University of Chicago Press.
Lindberg, D. C. (2010). Science in Islam in, *The beginnings of Western science: The European scientific tradition in philosophical, religious, and institutional context, prehistory to AD 1450* (pp. 161-182). University of Chicago Press.
Goldstein, T. (1980). Art and Science in the Renaissance in, Dawn of modern science: From the Arabs to Leonardo da Vinci.
Henry, J. (2008). Renaissance and Revolution in, *The scientific revolution and the origins of modern science*. Palgrave Macmillan.

to the question, then they come together and discuss each of their answers from the group and the instructor provides a broad answer.

The instructor gets students to question the role of values in science especially in the earlier twentieth century with certain scientific groups and philosophers of science (for example, the effect a group of logical positivists had in Vienna in the early twentieth century), and he gets students to critique it, because it appears when people examine it they see science is embedded with value.

> [science] is not something that is separate from values but the way in which experiments are constructed, the kinds of questions that people are asking, the topics that they choose to pursue or not to pursue, and then all of the questions why the use of human and animal subjects in research and ethical issues in science-- isn't that … a value? Again, just like other human endeavors [it] doesn't necessarily mean that we have to reject science, we just have to understand that it is value-laden, and then we can understand and we can examine the values that are present or absent within scientific practice.

He selects readings[17] that ask questions about values in science, then in the class discussion, he brings those questions out explicitly.

Class Assignments

In each session of the class, students work together to answer a question or a series of questions, and then they come together as a class to discuss and make sense of information. One assignment, which is unique to this site, is called philosophical exercises and students should do a variety of them. Students would have ideas that they would go to explore on their own and then they had to engage in philosophical dialogue with a friend about it and provide a report. In one of

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[17] Briggle, A., & Mitcham, C. (2012). Science and Its Norms in, Ethics and science: An introduction (pp. 66-86). Cambridge University Press.
Rollin, B. E. (2006). Scientific Ideology and 'Value Free' Science in, *Science and ethics* (pp. 11-30). Cambridge University Press.

them, students must reflect on the different questions regarding professional codes of ethics. In another one, they had to reflect on different aspects of their lesson plan and reflect on their teaching philosophy. Since this is a unique assignment I bring more explanation from the syllabus

> These exercises are designed to be thoughtful moments where you are able to reflect on the concepts in math and science that are normally overlooked when we focus on the 'nuts and bolts' of the subjects. Specific instructions will be provided the week before each assignment is due and will be available on Blackboard. Each philosophical exercise is worth 3 points.
>
> Exercise #1. Ethics: Investigating Professional Codes of Ethics
> Exercise #2. Inquiry: Philosophical Dialogue with a Friend
> Exercise #3. Natural Philosophy: Reflection on the Natural World
> Exercise #4. Social, Political and Ethical Aspects of Topic in Lesson Plan
> Exercise #5. Reflecting on your Teaching Philosophy

The research paper is another assignment called Education Investigation and requires students to compare and contrast the United States' education model with models from other countries. The paper must incorporate news and journal articles, quantifiable data from studies, and critical comparison should provide by the student. Like most of the other sites, design of a 5E lesson plan and its presentation is another assignment. According to the syllabus “this lesson plan will have philosophical and/or historical learning objectives and incorporate the historical and/or philosophical aspects of the topic in the lesson.”

Seven unannonced quizzes about week’s readings and a midterm (it covers the assigned content and readings from the first half of the semester) are also included in the students’ grade.

Instructors' View about the Model Curriculum

The instructor said, when he wanted to teach the course he looked through other instructors' materials from earlier semesters and talked with people who taught the course before but he was not directly consulting any documents from the program.

He said some of the people who taught the course before him copied some part of the class from the model. So, he thinks they use a combination. They implemented a lot of class activities throughout the semester, some long-term projects like the lesson plans from the model curriculum, and some shorter project, and they have lots of dialogues about each day's topic.

He looked at the syllabus of past people who have taught in his university and used a lot of what had been done before, and then he altered few things to suit his own tastes or experience just based on what he thought should be emphasized. So, he thinks that having a model is important because some level of standardization is important, but it should be left open to modifications by the instructors.

NOS Connections

The instructor mentioned that several areas related to NOS should emphasized including the ideas that 1) science/math are not just something that exist already constructed, they are things that humans engage with, so understanding science as a human endeavor is very important. 2) Saying "scientific method" is like calling something a salad, meaning that we have different ways of doing science. 3) Science is also political because it's a human endeavor, so the kind of research is defined by where the money comes from, so the role of society is important. These elements are included in readings, and class discussions. For example, there is a reading[18] related to scientific method.

Suggestions for improving the course

My contact at this site suggests that there should be a collaborative document that people can share and modify with their own ideas about the course. He thinks that having a diverse group of people who are working collaboratively on a model for the course would be best just to make sure that the model does not represent just one person's ideas. Certain areas aren't overwhelmed.

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[18] Henry, J. (2008). The Scientific Method in *The scientific revolution and the origins of modern science*. Palgrave Macmillan. (pp. 14-27)

Appendix G

Case Study 5: Delta State University

This site, Delta State University, is a large public research university with a student population of almost 23 thousand. The Delta state has offered the *Perspectives* class every academic semester since 2010, which means it had been taught ten time at the time of the interview. In addition to the survey and a review of the syllabus, I interviewed an instructor from education who has taught the course five times and is currently only instructor of the site. He has degrees in both science and the history of science making him quite unique among those teaching this class. This class meets one time per week for a total of three hours per week. I was able to interview him during the UTeach's workshop for Perspective; later I emailed him the link of the survey and asked for his syllabus.

The Importance of the Course

The instructor's background is in biology but he has graduate degrees in theology as well as the history of science. He is from science and math education department and he is a full-time high school teacher in biology as well and works in the university as adjunct. He believes he spends 80% of history and philosophy of science and 20% for math. He thinks this course is very important today due to the STEM movement. As he said,

> The importance of the course for future teachers especially, in the STEM movement is that they can provide [their] students with a more integrated understanding of science and math and not keep teaching it as an insulated or solitary subject. I think this will lead to better innovation integrated thinking and possible creativity for the students."

And regarding history it can help since,

> Science and math are human endeavors . . . only humans do but if the students don't understand that it's a human thing then they won't enter in it themselves so the history of science is placed that role.

Resources for the Course

There is a short course description in the syllabus, but there are not any objective or students learning outcome included.

> This course explores understandings of the natural world from antiquity to the 18th century. We will explore what people in the past knew about nature as well as why they were interested in nature. Throughout we will ask: What are the different ways that people in the past understood the natural world? How did they explain such phenomena as the motions of the planets, the growth of plants and the workings of the human body? And what motivated people to investigate the natural world?

There are a few sentences that explaining each assignment. The name of the textbook he uses is mentioned. A tentative list of topics and readings for each week is included. There are big questions for each week in his syllabus for example: These include "What you think we should ask when studying the past and why?" "Where to begin the study of history and why?"

The instructor mentioned many personal resources he uses for the course. He strongly recommends the University of Oklahoma (UO) materials[19] available from the library, one of the strongest in the nation documenting the history of science. UO has digitized all of their collections online and provide them for free. In the website, I found extra information:

> The History of Science Collections, located on the 5th floor of Bizzell Memorial Library, is a premier research collection in its field. Holdings of nearly 100,000 volumes from every field and subject area of science, technology and medicine range chronologically from Hrabanus Maurus, *Opus de universo* (1467) to current publications in the history of science. The Darwin collection consists of all of Darwin's works in their first editions and several autographed letters, as well as hundreds of subsequent editions and translations.

[19] https://libraries.ou.edu/hsci

He has also utilized the Big History project[20], an online course sponsored by Bill Gates. Most recently, his favorite textbook to use is Susan Wise Bauer's *The Story of Science* book[21].

Instructional Method: An Overview

As mentioned in the survey, interview and syllabus, the instrucors uses lectures, discussions, field trips and performing historical experiments. For filed trip, He and his students went to the University of Oklahoma library to see their collection which features many first editions of actual works. Students get to see, touch and even hold them. He thinks students feel more connected with the document in this case compared with online resources.

He suggested that he does not spend class time having students watch videos but has them engage in primary research with an optional creative expression/demonstration related to the integration of science and mathematics to humanities. In explaining his method he said

> I'm more prone to some discussion and as well as I do lecture but it's also lead that to the point so we can have a discussion. And then I spend half of the class doing repeating historical experiments.

As an example of one week, according syllabus, he Lectures about The Copernican Revolution, students read chapter seven and eight of their text book and a book chapter[22], then their topic for discussion is "Astronomy and the Bible in the 17th Century".

[20] https://school.bighistoryproject.com/bhplive
[21] Bauer, S. W. (2007). The history of the ancient world: From the earliest accounts to the fall of Rome. New York: WW Norton & Company.
[22] Galilei, G., & Finocchiaro, M. A. (2008). *The Essential Galileo*. Hackett Publishing.

Instructor's view about the model curriculum

This instructor began by attending a workshop on the model curriculum where he took everything they had because he was asked to replicate the class. Then, step by step, he brought new materials and ideas he had from OU and this changed the nature of instruction

> It's very good it's (cut) some mistakes that need to be edited for spelling mistakes, grammar mistakes but it's a good document to use and it saves the kids from buying a book, and then other than that there are number of articles that I like just from the history of science. I don't buy a lot of books, don't use big books. The other stuff in the "UTeach" course which is about the curriculum stuff there's lot of (prepared) questions, short phrases, I don't find those really useful but they're not bad.

He thinks the books and other resources that are introduced in the model curriculum are good, and some of the lesson plans can be used to get ideas.

Challenges of the Course

The instructor with whom I spoke believes that a person should have enough knowledge of science, history of science and education to be able to teaching the *Perspectives* class and these qualities are hard to find.

He thinks that trying to simplify a complex topic like history in a way that it does not lose its importance is a real challenge for the instructor of this course, but when it happens the instructor will benefit as well. There is not a clear plan that will guarantee that this happens.

> There are no book about the historical experiments for teaching history of science, there is no real curriculum or lessons for teaching it, so they are very few resources for teaching history of science. Most teachers do not want to include the history of science because they do not know enough about the subject or they do not know what they should say about it. In my experience, most teacher start with a date like 1917 and as soon as they do, students lost their interest immediately.

He mentioned an article called “Should the History of Science be Rated X” and pointed out that teachers do not like to talk about the history of science because it shows it as a human endeavor and as such it makes mistakes, so some might say this portrays science as a weak subject.

He thinks teaching math and the history of chemistry are challenging parts of the class for him because he does not have experience with math and chemistry particularly has a strange history that’s hard to teach it.

NOS Connections

This instructor believes that nature, philosophy, and definitions of science are raised directly out of the study of the history of science, so aspects of the nature of science are a direct outcome of this class. He said that even with the high school students he talks about issues like humanities explicitly in the class. He said that by “human activity” he means that science is limited, makes mistakes, self-correcting, and has a certain context. He believes that the nature of science is infected by human nature, because for example in ancient time people insist the earth is flat just because it helped the church to keep its power.

When I mentioned that in addition to humanity there are other elements in the model curriculum which are related to NOS such as different methods for doing science he added that scientists do scientific work with different methods but when they want to communicate it, they explain it in order because they want everyone to understand it and this same method of communication miss lead people that there is just one scientific method.

Class Assignments

He suggested that there are many possibilities for assignments that can be more useful and transferable to kids than just 5E lesson plans.

> I have some teachers writing articles for high school kids. I have some teachers, they're doing canvas paintings of science concepts but it comes with an biography or description like (would be) in a museum. Some teachers are doing . . . DBQs (documents based questionnaires) where they have the kids read extracts from primary documents then there are certain questions that the students have to ask or answer about those documents.

He thinks students can move through some documents to a point of "aha" moment in that they are able to realize what conditions led the scientists to this especial point.

> I have other teachers writing historical experiments so in the same way, you'd write a modern experiment with the materials, the procedure and analysis questions they're doing the same thing, but other experiments that are 500 years old or 200 years old, right? And it's meant to define the atom or (vacuum) or what Darwin saw --- or what he didn't see, so the writing experiments like a science teacher should are their historical experiments.

Moreover, he allows students to try other related things if they like.

> I have one guy writing a dialogue. He wants to mimic Galileo's dialogues, so he's writing a screenplay which is incredibly difficult. He has come up with characters that interact, he [wants] to have a debate about a science concept that ---- would do that. Galileo could write a dialog a screenplay. It's classically great!

The syllabus makes it clear that the writing reflection for each week's readings is obligatory but the final is a project of the student's choosing, which confirm information from interview

Suggestions for Improving the Course

He suggests repeating historical experiments . . .

> We'll take an experiment from an old book from chemistry or physics. We'll get all materials and rebuild it or it's kind of --- simple. It's all repetitive. We make Galileo's drop and repeat it. We make oils, vacuum chamber so we spend about the second half of the class, which is about an hour and a half, repeating that.

He agrees with the instructor of a workshop about doing a historical experiment and teaching the history of science through such re-enactments because it is more fun for students so students learn better. The interesting point about this experiments is that students should do it with using the language of the time, so it needs their awareness of background information regarding society and culture. He thinks that the lack of historical experiments is a weakness in the UTeach model curriculum and should be included.

He thinks a number of objectives for this course is too much, so it is difficult to keep track of them.

> I reduce the number of objectives to about maybe it's just 2 or 3. The students that you teach are not going to be historians; they're not going to be probably doctoral candidates, maybe a few will. They're going to be teachers and they have to work on "how do I transfer knowledge?" How do I make a concept transferable to a younger mind?" so --- they need to be doing is about communication of complex ideas so to me, that's an objective."

Appendix H

Case Study 6: Zeta State University

This site, Zeta State University, is a public university with highest research activity with a population of almost 50 thousand students. Zeta state has offered the Perspectives class twice a year since 2010. It was taught for the eighteenth time when the interview took place because it is typically taught twice each semester. The instructor who taught the course 12 times was from the education department. He mentioned that they are not a part of UTeach anymore, but he did not provide any further explanation. Since he mentioned his method was the same when they were part of program, I kept this site as part of the overall data set for this study. This class meets twice a week for a total of three hours per week.

The Importance of the Course

The instructor lists the following objectives for the course in the syllabus: First to assist prospective mathematics and science teachers to gain a clear perspective of their disciplines (science and math), so, using that they might provide their students with an authentic and rich form of mathematics and science. Such a perspective increases students' desire to understand these human enterprises and to use them in their daily and professional lives. The second objective is to help learners develop a view of the nature of mathematics and science through reading, discussions, and writing reflections in which philosophical bases, assumptions, strengths, and limitations of mathematics and science are included. These objectives were all mentioned in the interview, syllabus and the survey.

Resources for the Course

In the syllabus, the instructor provided a general description of course objectives and students learning outcomes are mentioned. There is a list of standards relevant to this course for teaching science and mathematics in the syllabus. For example, “students should know algebra includes contributions from diverse cultures” from math standards, and “students should understand the historical and cultural development of science and the evolution of knowledge in their Discipline” from the National Science Teachers’ Association Standards for Science Teacher Preparation. There are a few sentences that explaining each assignment. Regarding to resources that he uses to teach, there are a good explanation in his syllabus but the syllabus does not have any weekly schedule. There are only a list of assignments but explanation for each is not provided. He sent me a description of the teaching activities he used in class.

The instructor has provided his students with a comprehensive list of books and references that they may use as resources. For example, “The Nature of Mathematics and Science[23]”, “The Nature of Mathematics[24]”, “The Nature of Science[25]”, and some articles in the syllabus[26]. Due to lack of a weekly schedule in the syllabus, I do not know how he uses these resources and how students have access to them. He has also provided some online resources such as a podcast of a radio program called “Engines of Our Ingenuity.”

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[23] For example: Adler, A. (1991). Mathematics and creativity. In T. Ferris (Ed.), The world of treasury of Physics, astronomy, and mathematics (pp. 435-446). Boston: Little Brown.

[24] For example: Berlinghoff, W. P., & Gouvea, F. Q. (2004). Math through the ages: A gentle history for teachers and others. Washington, DC: The Mathematical Association of America and Farmington, Maine: Oxton House Publishers

[25] For example: McComas, W. F. (Ed.). (1998). The nature of science in science education. Boston: Kluwer Academic Publishers.

[26] Benjamin, A. T. (2007). *The joy of mathematics*. [Two DVD Set]. Chantilly, VA: The Teaching Company.

Instructor's View about The Model Curriculum

The instructor believes that UTeach model curriculum is stagnant but thinks it is reasonable for UTeach to present such a model. He says that UTeach has its own vision, but instructors modify it to show their specific views, focus and styles. He believes that instructors make choices because of fears. In other words, if we fear doing something we avoid that, so if there is a part in a model curriculum that we do not feel confidence about teaching it, we ignore it. He added, one of his personal fears is to engage students with philosophical debates because he does not feel confident in that field. Therefore, he is not willing to do philosophical things.

In addition, he told the fact that he decided to not use the model curriculum was both his emotional and logical reaction to the original program because in abstract level he likes to be creative. He says "I do not think there is just one recipe to make a taco. I see myself a teacher, not a professor, so I am not going to do anything that requires lectures, take notes and all that stuff." This means he does not like to lead his class by lecturing, the method that is the main method advocated by the UTeach model curriculum. I will describe his instructional method in the next section.

In summary, here is how he views the UTeach model:

> There are different sources that I use, and because I am uncomfortable with content, I looked through different books (15-20) they can use. I pulled sections that they [students] read and all of them together make a contribution to the whole course. So, the main answer is that I find the original syllabus by UTeach quite boring, it presents the instructor as a lecturer, I am not comfortable with that. I find history and philosophy too limited. I am not interested in facts. I am interested in swiping of ideas going from ancient to postmodern. I want to have enough content to show changes over time in math and science. How they integrated, how they served each other and who they are part of the society and how society had an impact on them.

Instructional Method: An Overview

The first part of his class consists of NOS/NOM instructor activities which I will explain soon; the second part consists of student presentations which I have explained in the assignment section to come.

His methods are using activities that present ideas and then through discussion and debriefing, he works with student to extract the meaning of those lessons. He has an activity that models NOS and he called it PPT model (Process, Product, Technology model). These are hands-on lessons and activities that are designed using Electricity as science context and depict process, product, and technology and interaction between all that stuff. It is related to observations. “We show students how science has changed from Aristotle to the Renaissance and how doing experiments added to what scientists used to do (In ancient time scientists had their interpretation from their observation only without conducting an actual experiment or probing more deeply). The point is that he wants to teach with a high level of students’ involvement.

There are times he lectures using PowerPoints which the students can download to their laptops. Groups of students are then assigned particular slides and are asked to review them and talk about their viewpoints and understanding of assigned slides in a presentation for the rest of their classmates. Once the instructor feels there is a misconception or misunderstanding he clarifies the content. Some of the topics he uses are the same with UTeach model but all in all he has his own model.

Here I provide the list of activities he does in his class. I copied this part exactly from a file he sent me when I asked more clarification about the activities.

Several class activities are provided during a semester. In *NOS ESP Activity* the instructor claims to have Engineering Science Practice (ESP) and provides evidence that students debunk via inquiry; *Nature of Math* (*NOM) Cube Activity:* Students observe relationships the qualitative and quantitative relationships depicted on five faces of a cube and then predict the contents of the hidden sixth face; *NOS - PPT Model*: A learning cycle is used to conceptualize the three parts and interrelationships of the science enterprise: process, product, and technology. Processes are identified as are the five science products and four types of technology.

He added that he believes math in school is taught mechanically. The students just learn the operations and manipulate symbol without context or relevance. The kids often do not know why they are doing what they are doing, but do it because they are told to do. So, adding some history and context makes it more relevant.

He mentioned a radio program called "Engines of Our Ingenuity "(a five minute program about history and nature of science) and his students select one episode from the web-based archive of the program and make a PowerPoint for the class (I have provided more explanation about this in the assignment section).

In addition, He wants to teach by inquiry, engagement, and the use of hands-on activities -- beyond just memorization. For example, he has a coffee can, like a typical "black box" activity. Students cannot see inside but they can ask him yes and no questions. Based on the answers posted on the board and their observations, they develop a model for what is inside the box. They talk about potential energy, kinetic energy and what is inside the box (apparently, what is inside the box works with some kind of energy change from kinetic to potential or vice versa). Then, he tells them "now you have an imaginary model and if you are an engineer make the prototype".

He gives them materials and ask them to make the prototype and then asked them to process this prototype and learn what engineering is.

He recognizes that classes in which these preservice teachers will teach are diverse. So, he uses examples of students' local culture to draw on beliefs and particularly the myths they have, but there are many different cultures so he cannot focus in some.

> I ask Asian students whether they cut their noodles or not, or if they believe in fortune tellers. I ask about their belief system when they are walking to the classroom. They are using different belief systems and it is okay as long as they know what they are doing. They need to reflect on validity and reliability of this kind of things and data.

Class Assignments

Assignments are unique in this class. Students read three books[27] and write a summary paper for each. In addition, each student selects one Engines of Our Ingenuity (the radio program) episode from the web-based archive and prepares/presents a PowerPoint that communicates the main events of the episode and communicates the NOS/NOM significance.

NOS Connections

In his syllabus, he offers many connections to NOS. such as, difference between inference and observation, the role of culture and society in science, tentative nature of science, the role of empirical evidence and experiments in science. He helps student develop a view of the nature of mathematics and science through reading, discussions, and writing reflections in which philosophical bases, assumptions, strengths, and limitations of mathematics and science are included. He introduces many resources for the course including several

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[27] Rooney, A. (2009). *The Story of Mathematics*. Arcturus Publishing.; Pallen, M. (2009). *The rough guide to evolution*. Dorling Kindersley Ltd. and The Gould, S. J. (1996). *The mismeasure of man*. WW Norton & Company.

reference books about the nature of mathematics and science. In the survey, he indicates that all the elements of NOS are in the class; in the interview, he mentioned several times that the nature of science and math are the focus of his class. He does not introduce much history or philosophy per se, but uses the history of science as a vehicle to teach aspects of the nature of science.

Suggestions for improving the course

His suggestion is clearly emphasizing the nature of science and math in the objectives of the course. He thinks the history of science should be used as a context to communicate NOS ideas to students. In addition, he thinks more interactive methods should be used in a model curriculum instead of lecturing.

Appendix I

Case Study 7: Gama State University

This site, Gama state University, is a very large public research university with a student population of almost 28 thousand. The Gama State site offered Perspectives since 2010. The course has been offered during ten semesters. The instructor of this site, who I interviewed by phone, has taught the course eight times and has a background in education. At Gamma, they only teach *Perspectives* to science students; there is a different class for the mathematics students to take as a version of *Perspectives*. This class meets one time per week for a total of three hours per week. This instructor shared all his class materials including assignments, readings, and each week's PowerPoint.

When Gamma U started the UTeach program, there was no one in the university o teach that class (just as a reminder, UTeach prefers historian of science teach this course), so, they made a deal that the science students would use an existing "Philosophy of Science" class and math students would use a "History of Mathematics" course. A couple years ago they decided that it was time to reconsider the *Perspectives* class when the instructor which whom I talked was hired, but mathematics faculty still wanted their students to take the history of math course, so now they just offer *Perspectives* to science students. The mathematics course is more of a history course but his class has a strong NOS focus.

The Importance of the Course

The instructor thinks *Perspectives* is a vital course.

> When teachers come into teaching they usually have a degree in science and so they feel good about the topics they are teaching, but the nature of science and this idea of how science works, is something very few people walk in with, so I I've taught this course in many different forms in different universities for about ten

> years, and I have never had students . . .really having an idea about how science works. So, to me, it's an important course that helps them think about how science works and then think about what that means in terms of teaching science.

Resources for the Course

There is only one book[28] students all read and it is an autobiography basically. This book according to google scholar "describes how scientists bring their own interests and passions to their work, illustrates the dynamics between researchers and the research community, and emphasizes a contextual understanding of science." The book, from his perspective, does a really nice job. He explains how the book separates science into two parts:

> Part of your job as a scientist is discovery. And that's messy and there are lots of ways of doing it and it doesn't work well most of the time until it finally does and then the other part, the part that we forget about the most, especially in school, is the idea of credibility that you have to go get credibility for your ideas and so that's where you go to the community and it's a community of scientists that provide credibility for new ideas whether by citing it or using it.

So, he spends a lot of time talking about what happens once a scientist writes a paper, because that's the part people don't talk about in schools. In school, students do experiments they write their lab report, and think the work is finished.

So, thinking about this is the argumentation piece of his class. I looked at the PowerPoint for this topic. The instructor asked students to read a chapter from a book[29] and Choose a minimum of 10 quotes from this reading that best represent the author's intent.in addition, he wants students be prepared to discuss this quote: "How do we pack the world into words?". There is one more

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[28] Grinnell, F. (2011). *Everyday practice of science: Where intuition and passion meet objectivity and logic*. Oxford University Press.
[29] Latour, B. (1999). *Pandora's hope: essays on the reality of science studies*. Harvard university press.

reading[30]. Then, he talks about the intersection of science and society (politics, religion, culture, gender, economics, history, etc.). In later slides they discuss about “What is the role of the community?”

In addition to the textbook, students read a lot of shorter articles which are categorized based on each week’s theme. For example, one week’s theme is “What have we learned from the philosophy of science, and how does this strengthen or limit our current thinking?” There are 10 short book chapters[31] (other than his text book) related to this topic in students’ learning materials for this specific week.

Class Assignments

For all assignments, the instructor provides students with one page long explanation about the assignment regarding both the content and the format.

Assignment one, “Defining Nature of Science in Context”, is a paper assignment students write in which they generalize from their studies in the *Perspectives* class what would be especially relevant in their own science teaching. In the instructions for this assignment he explains:

> You must look across readings to lift out the ideas that appear as themes throughout. Please remember that the scientific context (i.e., biology, chemistry, etc.) is important. Some ideas are broad and are relevant in all contexts. Others, however, are more relevant in some scientific disciplines than others.

[30] Koerth-Baker, M. (2011). The scientist who studies scientists—An interview with Harry Collins. Boing Boing.
[31]For example, chapter 4 & 2 from Ben-Ari, M. (2005). *Just a theory: Exploring the nature of science*. Prometheus Books.

For second assignment, “Science-in-Action Report”, students read a book-length account of the scientific enterprise[32]. Students compare the account to course ideas, making connections, finding examples, and discovering discrepancies. In other words, they are looking for how the story exemplifies the nature of science. Several questions are mentioned in the assignment’s guideline that students should answer them in the form of narrative in their paper. For example, “What element of this episode seems to you most characteristic or most revealing about the nature of science? Why?” Students are supposed to illustrate their findings in two ways: a written report and a class presentation.

In a third assignment, “Science Case Study”, students work in a group. They are given a research publication from a scientific journal that describes a scientific finding or discovery. Unfortunately, there is not any example of name of these resources in the guideline. Additionally, they receive a reading from an additional source that gives a “behind the scenes” look at the processes involved in coming to that discovery. The students’ job in the group is to compare and contrast these two readings and present findings to the class.

Instructional Method: An Overview

The instructor’s class is a seminar course with two distinct halves. The first half is very academic. They do not talk much about teaching but dive into the literature of the history and philosophy of science and science studies. Before each class, students are expected to read a selection from the list of weekly topics. For example, one week’s topic is “How do scientists construct scientific knowledge?” The instructor give a PowerPoint based lecture on the topic and then asks students to develop an idea for their context papers.

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[32] Partridge, H. L., & Hallam, G. C. (2004). The double helix: a personal account of the discovery of the structure of the information professional's DNA.

Each week's PowerPoint includes a same map of the topics in the course with one topic highlighted to show it is focus of that week. Headlines that he is going to lecture or open a discussion about them are clear. Interesting pictures and diagrams are included. One example that I enjoyed is a flowchart that includes several paths to do science. Students should read an article named "Asteroids and dinosaurs" and highlight the words or phrases that indicate Alvarez was 'doing science. Then, using these, students should trace the 'path' of this investigation on the flowchart. The whole idea is showing students that there are several ways to do science.

In the second half of the course students' focus on teaching the ideas they have gained. Together they think about pedagogy and how they adopt their teaching ideas to the Next Generation Science Standards. In addition, students do other projects and are in charge of twenty minutes of a class to run a workshop on an idea but most of the class is reading and discussion.

There are important elements he spends a lot of time talking about, for example, the fact that there is not a single scientific method. Students read a lot of accounts about what scientists actually do. For instance, he has students read the original paper from the discovery of messenger RNA and then they read a chapter of the autobiography of the scientist involved, so, they can see the difference between the story told in the scientific journal paper and what really happened.

Instructor's View about The Model Curriculum

He thinks his class is a very different class from than specified by the UTeach model of the *Perspectives* course. Regarding using the model curriculum he said:

> I teach it as a graduate level, so, I knew I had already put together a course that was fit to this class, so when I went to see how UTeach did it, I like mine better. We were going to have to change it quite a bit anyway because there was no math. And I thought

> the way it was done in the perspective course is covering a lot of topics but without details. So, I chose to have less topic but get more detail into them.

Regarding the necessity of the model curriculum, he thinks he has a unique background as a science educator so it was better for him to design his own curriculum. However, for someone who doesn't have a background in philosophy and history of science having something as a model is really important. In the same time, if historians and philosophers come to teach the class, since they would have no way of talking about pedagogy, a model curriculum could help.

He explained to me that his method was accepted by UTeach and other instructors.

> A couple of years ago, they asked me to do pre-conference workshop in this class. And there were three or four of us who presented about how we do the class, and everyone else did the class like the model, but mine was very different. I was a little nervous about going to Uteach but doing something completely different, but after I finished, most of the people in the audience wrote me and asked for my materials. So, that gave me some nice feedback that OK other people are seeing this as a relevant thing to do.

NOS Connections

From his point of view, NOS and "Perspectives" are very similar classes, but he noticed after attending UTeach conferences in Austin, what has presented there is very much a history of science class. He thinks it makes sense because a lot of places get a historian of science or a philosopher of science to teach and not a science educator.

Appendix J

Case Study 8: Phi State University

This site, Phi State University, is a public moderate research activity university in a state in South with a population of almost 30 thousand students. The Phi State site has offered Perspective once a year since 2014, so it had been taught four times at the time of the interview. All the sessions have been taught by the instructor who I interviewed face to face at the UTeach workshop. His class meets one time per week for three hours. His background is in philosophy, with a minor in the history of science.

The Importance of the Course

He thinks this course provides students with a humanities approach and critical thinking skills. He thinks science teachers teach in an special paradigm (accepted paradigm of today) but they need to realize the difference between the characteristics of “real science” and how they portray science as educators:

> I find that in science education people tend to do what is called “normal science”, which doesn't tend to be particularly critical of the paradigm itself, so, I think a course like this can show the long run picture of how science unfolds.

He thinks that because this course makes students have conversations about differences between the humanities and science disciplines this is one of the things makes the course valuable.

Instructors’ View about the Model Curriculum

He thinks *Perspectives*’ model curriculum is great because it’s flexible enough and yet there is a required core component. He thinks the model has to be flexible because people from different backgrounds are teaching it.

The research, essay and the presentation (discussed in the assignment section) are his favorite parts of the overall curriculum. He did criticize the requirement that students write a lesson plan because he thinks students learned that skill in other classes.

The first time he taught the course, he was not aware of the materials on the website. After learning about these resources, he used them the second time he taught that class, and now selects a few that he thinks are useful. He believes the mathematics lesson plans and the book "The Cult of Pythagoras" are useful, especially because the book is an extension of lesson plans.

Challenges of the Course

First, he believes that having science and math preservice teachers in the same class is a challenge but still an opportunity to help them to see how the nature of two disciplines are different:

> That's an opportunity because you don't get the same kind of paradigm shifts in math [as we find in science]. You get a different kind of paradigm shifts, but you don't get the same kind that we thought in the past was false. It's an opportunity to point out the differences between math and science.

Moreover, he thinks the fact that the science students say they hate math, and math students don't see why they need to learn science is exactly why we shouldn't separate them and this course may help them to see the relevance in both disciplines.

Second, guiding students to design 5E lesson plans for teaching science and math in the context of history are kind of challenges for him, but he thinks doing this is possible. He thinks that everybody who teaches the course should move to a directions beyond his/ her expertise because it is an interdisciplinary course.

Third, the mathematics lesson plans are challenging for him to teach because they require more preparation time since he needs to learn the content first.

Resources for the Course

In this instructors' syllabus, the course objectives and students learning outcomes are mentioned; these objectives are similar to UTeach's model syllabus. There are a few sentences that explaining each assignment; the criteria for grading is not provided. There is a list of the textbooks he uses, students should buy the main textbook[33], but he mentioned in syllabus the readings from rest of the book are provided on the course website. A tentative list of topics and readings for each week is included.

As I mentioned, there are several textbooks for this class[34] and from a review of the weekly schedule in the syllabus, it is clear that students should read chapters from them each week. In addition, primary resources are introduced weekly for extra readings[35].

Class Assignments

Students are asked to create two 5E lesson plans on topics in the history of science and mathematics. For example, they can choose atomic model as their topic and teach it in the

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[33] Lindberg, D. C. (2010). *The beginnings of Western science: The European scientific tradition in philosophical, religious, and institutional context, prehistory to AD 1450*. University of Chicago Press.
[34]Westfall, R. S. (1971). *The construction of modern science: Mechanisms and mechanics*. Cambridge University Press.
Hankins, T. L. (1985). *Science and the Enlightenment*. Cambridge University Press.
Coleman, W. (1971). *Biology in the nineteenth century: problems of form, function and transformation* (Vol. 1). Cambridge University Press.
Martinez, A. A. (2012). *The Cult of Pythagoras*. University of Pittsburgh Press.
Kuhn, T. S., & Hawkins, D. (1963). The structure of scientific revolutions. *American Journal of Physics*, *31*(7), 554-555.
[35] For example, Nicolaus Copernicus: On the Revolutions of Heavenly Spheres, and selection Johannes Kepler Cosmographic Mystery.

context of history. From these two lesson plans, one should be written individually and another with a partner. Students also should write an expository essay about an episode in the history of science, both tasks require an annotated bibliography.

In addition to assignments, there are reading comprehension quizzes, a midterm, and a final exam.

Instructional Method: An Overview

The instructor's instructional method is lecture and discussions. For example, on day's topic is "Copernicus, Kepler, and Galileo on helio-centrism". Students in his class should read resources before class to prepare for discussions. He did not mention if he uses a PowerPoint or not for guiding the discussion.

He emphasized in the interview that the focus of the class is comparing primary and secondary documents to give a "more historically accurate picture".

As he explained in his syllabus,

> In this class, we read original scientific and mathematical texts written by the great scientists and mathematicians themselves. These primary texts present the theories and results from the perspective of their original formulation rather than in the isolated and sterilized form in which they often appear in textbooks. These primary texts are supplemented by secondary sources that provide the philosophical and historical background within which these scientific theories and mathematical results developed. Between the primary and secondary texts we try to understand the questions and goals of the individual scientists and mathematicians. We examine what problems they were trying to solve or what phenomena they were trying to explain.

He thinks students like the course, especially when they see there are disagreements in history. Students use to think that everyone agrees with everything in math, and they get excited to learn about disagreements. Furthermore, when students make a mistake, they do not feel silly after they realize Newton (as an example) made similar errors. He believes that students find the course challenging and difficult but useful.

He thinks his background in philosophy is extremely helpful for students because the questions philosophers take seriously are not the same as questions in other disciplines. As an example, he said scientists sometimes focus on an idea and ignore others but philosophers are more open to examining different sides. For example, even if the questions scientists asked in past does not seem useful today it worth to look at them.

NOS Connections

Demarcation problems, philosophical questions, talking about Kuhn, normal science, scientific questions, paradigm shifts, something about difference between induction and (abduction) on one hand and deduction on the other side, scientific method, are parts he mentioned he covers in his class when I asked about what is he does related to NOS. He added that the course is 80 percent history and 20 percent philosophy but it is not about nature of science. NOS needs a pure philosophy course from his point of view, so he strongly believes this is not a NOS class. He then mentioned “as long as we look at nature of science from broader perspective it can be an outcome of this class.”

Suggestions for Improving the Course

He thinks updating the information that is on the website is necessary to reflect the way the course is really taught at the different UTeach sites. He adds since people from different backgrounds are teaching the course, the model should not be written from just one point of view. He thinks we first should reach agreement in objectives if we want a new model curriculum but believes that the current model curriculum meet its own objectives well.

Appendix K

Case Study 9: Kappa State University

This site, Kappa State University, is largest public research university in a state in the NE part of the U.S. with a student population of 22,285. Kappa State has offered *Perspectives* five times since 2013 at the time of the study reported here. The instructor of this site with whom I conducted a phone interview has taught the course these five times but had just retired at the time of the interview (Fall 2015). He majored in mathematics and history making him an interesting subject particularly from a mathematics focus. This class meets three times per week for a total of three hours.

Importance of the Course

The instructor believes that teachers should talk about history to bring some fun to their future science classes, shows their students that science is a human endeavor and convince kids about their ability to do science by showing them that scientists are regular people. He thinks many people come into this course having a sense that science or mathematics always has all the answers. He wants them to recognize that the real task of science is to be continually asking, answering and again checking out questions and even each new finding is just opening a new door for new findings.

Instructors' View about the Model Curriculum

He thinks the model curriculum is generally good, but teacher candidates need more background information in the content of science before taking this course and even during this course. He thinks the model helps instructors in putting structure into a course when they teach it for the first time, but he is glad they didn't say that he had to follow the model curriculum exactly as they presented it.

> There was an opportunity to modify it to fit my own situation better and I think that was good. When I first read it, I was nervous. I liked the concept of the course but I didn't like all the details that they were having for the instructional approach. So, when you say do I like the model I say: yes, I do as long as they allow that kind of flexibility.

Ultimately, he used a few lesson plans from the model curriculum.

Resources for the Course

In this instructors' syllabus, the course objectives and students learning outcomes are mentioned. There are a few sentences that explaining each assignment, but there is no mention to criteria for grading. The name of only textbook he uses is provided without any description. A tentative list of topics and readings for each week is included.

The textbook[36], Ascent of Man was first published in 1973 to accompany a BBC television series. The instructor discovered it not long after it was published and believes the book has a very thoughtful approach to history. He notes that the book includes mathematics too and that's why he was first interested in the book. The author of the book had made a television series for public television about history and science and much of the text is taken directly from his scripts for that presentation, but he just uses the book. The weekly schedule shows all the readings are from this book.

Class Assignments

Students are asked to write a biography of a noted scientist or mathematician who lived after 1500. Students should provide 8-10 pages information about the scientist; there is not any special focus for this biography. A handout that offers suggestions for a mathematician or scientist is given to students, (e.g. Gauss, Cantor, Newton), but students are not obligated to

[36] Bronowski, J. (2011). *The ascent of man*. BBC Books, Random House.

choose from the list. Students should prepare a bibliography of the source materials they accessed in writing their biography.

Each student will teach one class, based on a written lesson plan that they have prepared using the typical UTeach 5E lesson plan pattern. Students should research the topic to prepare the lesson plan. Students should submit the lesson plan for review to several of their colleagues before the presentation. There are midterm and final exams that covers readings from the book and class discussions.

Instructional Method: An Overview

The instructor asks students to read the assigned text prior to the coverage of a given topic in the class and bring questions or comments to class for this discussion. As he explained in the syllabus, many classes include open discussions and activities to demonstrate the ideas of the topic and probe more deeply. In the interview, he explained his method for teaching the class is a quite a bit of lecture but with activities mixed in almost every class (sometimes the students were doing an activity related to content of science). For example, he found a set of activities to make a model of a DNA molecule. So, they talked about the discovery of the structure of DNA from a historical viewpoint but they also made a model of DNA.

He thinks students know some content in their area but they do not know much beyond, so this course is a good opportunity for them to learn a little about other science branches and mathematics.

> Even if you are a chemistry teacher you need to know some math and you need to know some biology. The main value of this course is learning some of the content background as well as the history.

So, besides the history of science, he does a little of the content of science especially modern science.

> Students had learned some of Newton's laws of physics, but they didn't know much about quantum mechanics, for example. You can't teach quantum mechanics in one class but you can at least let people know what it's all about and that was what I was trying to do. So, in the course, we covered so many different topics.

He thinks most of the history is, in fact, the development of new content that people had never thought about before and students need to have the content background to have a better sense of the history and to be teaching across in an interdisciplinary way. He sense that the model curriculum, did not contact much of the actual content of science as he thinks is necessary and finds that problematic.

In his class, each student was responsible for leading a 30 minute class in which they taught he suggested at the beginning of the semester (i.e. evolution, force and motion, etc.). Students researched the history of the topic and wrote a 5E lesson plan based on it. What they basically did was a class presentation of their 5E lesson plan. He tried to use some of the 5E model in his teaching but thinks it works better at middle or high school or even elementary school level than it does at the university level and this is why he was more lecture approach to be able to cover more content.

He tried to show with readings and discussions, there is an interaction among mathematics, science and culture. He mentioned. As an example, to the growth of Renaissance art in the fourteen hundred in which they were using valuable mathematics and geometry to figure out how to make beautiful representations with symmetry. So, some of the leading artists were, in fact, good mathematicians too. As another example, he mentioned valuable medicines that were discovered by talking to people in the Demo, in Brazil, and learning about techniques they were using for healing; the medicine came from the bark of trees or some plants. So, he wants to make sure that students see that these other cultures can contribute to science. Besides, students should realize some of these cultures are dying and we may be losing some of their valuable experience if we don't try to learn from them.

He pointed out that in two thousand years ago, and more than that for the Greeks and Babylonians and the Islamic mathematicians there wasn't much good science going on. So, he takes advantages of this fact in the history part of the course. During the first part of the semester he concentrated on math and in the second part he concentrated on science because after around the time of Newton there was much growth in science too. Since he formally taught the history of math he brought his favorite topics from there and left the rest of the space for the science.

Challenges of the Course

He thinks it is good to have preservice students from both science and math together in class because many brought their own experience into the class. He did offer one complaint and discussed it several times with the Uteach leaders and this related to writing lesson plans for middle school and high school students. He thinks there is not enough time for that. Besides, students in his opinion had enough experience writing lesson plans in other UTeach courses. He would rather students present to each other rather than thinking about what it would be like if they were presenting to middle school students. He believes trying to fit the lesson into middle school means his students must talk a lower level of content to fit it to middle school level. He thinks students need to be learning the history and content and issues of science and mathematics rather than trying to talk about how that would be presented to middle school kids. It seems he is not satisfying that this is a method class.

NOS Connections

He thinks people who don't know very much about how science works are the people who sometimes dispute science, don't believe in evolution, and don't accept global warming. “They say, oh it is just a science; you have not proven anything. They do not know it is nature of science”. He added that students should know the work of science is asking questions and after scientists have tested things and learn how they work, they are open to further questions and possible changes. He emphasizes that science is never going to “prove” something. He thinks that the problem in political discussions recently is due to lack of knowledge of NOS. Because of this, he suggests that part of history class should teach students a little bit better about how we understand science and how we accept it. Even with these ideas in place, the point is that he does not mention NOS explicitly in his class and believes students will learn these points from readings and discussions.

Suggestions for Improving the Course

As a suggestion for improving the course, he would like to seem more emphasis on the content of the history and content of the science and reduce the amount of coverage about methodology and teaching approaches. He believes UTeach can use the time of lesson plan presentation to teach science and math content to students.

Appendix L

Case Study 10: Sigma State University

This site, Sigma State University, is largest public research university with a population of almost 50 thousand students. Sigma state has offered the *Perspectives* class once a year since 2010, which means it had been taught 5 times when data were collectyed for this study. In addition to the survey and a review of the syllabus, I interviewed an instructor from the history department who has taught the course one time as the current instructor of the class. This class meets twice per week for a total of three hours per week. Unfortunately, the interview was very short due to his time limitation so I extracted most of the information from his syllabus and survey. He believes his class consists of 75 percent history of science and the rest history of math.

The Importance of the Course

The Sigma instructor says “I think it's a very helpful and it will help the student to take advantages of the course over the long term, although that may not have recognized immediately.” He wants students to walk away from his class understanding that science and mathematics are very human activities and know that science is a matter of culture just as much as art or music.

Resources for the Course

This instructors’ syllabus is one of the most complete syllabuses compared with others. The instructor provided a general description of weekly meeting times (e.g. Thursdays will be mostly lecture and discussion). The course objectives and students learning outcomes are mentioned. There are a few sentences that explaining each assignment and criteria for grading. There are short paragraphs about each textbook he uses. A tentative list of topics and readings for each week is included. The instructor uses several text books[37]. The short explanations of the texts included in the syllabus are useful. For example, for the Hatton and Plouffe book he wrote:

> This is an excellent anthology of scientists and other authors writing about science and math. It has some history, some philosophy, some ethics, and some wild conjectures. Read it carefully and pay attention to the discussion questions. One or two might show up on an exam.

There are also supplemental readings that instructor posts on the site website and explain them as "These are the most important readings each week. They are largely primary sources and can be difficult at times due to historic syntax and outdated spelling conventions. These are the most important readings each week." The title of this readings can be found in weekly schedule.

Instructional Method: An Overview

As I mentioned due to short time for the interview I had to draw the following information directly from the syllabus: This class meets on Tuesday for 50 minutes and on Thursdays for two hours. Most Tuesdays is for discussing ideas and concepts pertinent to that week's readings and lectures. As the semester progresses, Tuesdays are used for lesson plan demonstrations. Thursdays are mostly lecture and discussion of important historic periods, ideas and people. This is an upper-division history course. The assigned readings vary in length, and come from primary and secondary texts. For example, in week five, the readings include a chapter

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[37] Benjamin, J. R. (2015). *A student's guide to history*. Macmillan Higher Education. Thirteen Edition.
Gregory, F. (2008). *Natural science in western history*. Houghton Mifflin.
Hatton, J., & Plouffe, P. B. (Eds.). (1999). Science and Its Ways of Knowing. Addison-Wesley; First Edition
Darwin, C. (1967). On the origin of species: a facsimile of the first edition with an introduction by Ernst Mayr. New York: Atheneum.

from one of the textbooks and two primary resources[38]. Primary resources are both written by Galilei. The first half of the semester has much more reading than the second half.

He strongly wants students to learn methods of historical research with particular focus on the analysis of the origin and reliability of print and internet sources. He explained that learning to do research in history is a process that students should learn via reading lots of valid documents.

Challenges of the Course

He thinks that having science and math students together was a little problematic more than helpful. His class was much larger than a normal class with thirty-five students. So, he thinks separating them might have been helpful because half of them are math students. However, on the other hand, he thinks it's useful for them to hear from each other.

Instructor's View about the Model Curriculum

The instructor believes that the model curriculum is very helpful and he used some of the lesson plans, activities and reading with some changes. In answer to a question about his rationale for using some lesson plans but not others, his answer was:

> I hate to say it but I picked things which spoke to my strength, even maybe didn't try the things it did not fit my strengths. So maybe I was playing it safe, because it was a new course. I think if I try it again I try one of the other one or lesson plans I don't like.

He thinks the course is a very well organized at the Texas level, and makes a good connection to the science curriculum and other aspects of ordinary life and professional life and it can be a very valuable course. He believes a lot of people just repeat their old history of science courses as they teach this course, and he does not think that is right. He thinks instructors should try to make it fit the goals of UTeach as a teacher preparation experience.

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[38] Galilei, G. Letter to the Grand Duchess Christina of Tuscany. *Published online at Modern History Sourcebook*. Galilei, G. (1967). *Dialogue concerning the two chief world systems* (p. 185). Berkeley: University of California Press.

Class Assignments

Most weeks students are supposed to write a two pages paper that answers a simple question or address a theme pertaining to that week's readings and class discussion and lecture. The question or theme is disseminated a session ahead, but there is not any example of them in the syllabus. In addition, students should complete a historical and analytical paper on some aspect of the history of science and mathematics. Not surprisingly, students are also asked to write a 5E lesson plan and present it as well.

NOS Connections

He starts the semester talking about the scientific method formally defined and then talks about the different ways that people actually do science, he also discusses the role of society in the science. Interestingly, when I told him about NOS with giving him the definition and introducing some elements of it, he answered he does not have any idea about it and he does not do anything related to it because this is a history of science and math class. Yet, it is clear that some ideas many would recognize as NOS are part of instruction.

Suggestions for Improving the Course

The instructor's suggestion is more support for the history and philosophy of mathematics. He thinks most of the people who teach the course have more resources and experiences with history of science compared with math, so it would be helpful if UTeach would introduce and provide resources for teaching history of mathematics. He even suggested maybe in one of the workshops they should invite a math historian to share more ides of teaching history of math with the instructor of *Perspectives*.

Appendix M

Case Study 11: Pi State University

This site, Pi State University, is a very large public research university with a student population of almost 40 thousand. The Pi State site offered Perspectives for first time in the Spring 2016. I interviewed the sole instructor at the site in the summer just after his first teaching experience. The instructor has a degree in the history. He believes his class is 60% history of science, 30% philosophy of science but only 5% history and 5% philosophy of math. This class meets two times per week for a total of three hours per week.

The Importance of the Course

The instructor believes that although *Perspectives* does not seem very interesting for STEM people (that STEM people generally wouldn't like a humanities class such as this), it is important for them to know how science is developed historically. Knowing this history can provide a satisfaction like knowing science itself and can give science a human face (In other words, HOS can show science is a human endeavor, an important NOS element too). He also thinks history of science can help students overcome some misconceptions about the content of science.

Instructional Method: An Overview

The sole instructional method this instructor uses is a technique called "Reacting to the Past" (http://reacting.barnard.edu) which consists of elaborate games, set in the past, in which students are assigned roles informed by classic texts in the history of ideas (such as, Frederick Douglass, Slavery, Abolitionism, and the Constitution). The game is actually a role playing. In the syllabus, it is explained

> Class sessions are run entirely by students who are playing their roles; instructors advise and guide students and grade their oral and written work. The game seeks to draw students into the past, promote engagement with big ideas, and improve intellectual and academic skills.

In his *Perspectives* class, they use two science-focused games: The Trial of Galileo, and Charles Darwin.

The web site for the game provides the following information:

> In most classes students learn by receiving ideas and information from instructors and texts, or they discuss such materials in seminars. "Reacting to the Past" courses employ a different pedagogy. Students learn by taking on roles, informed by classic texts, in elaborate games set in the past; they learn skills—speaking, writing, critical thinking, problem solving, leadership, and teamwork—in order to prevail in difficult and complicated situations. That is because Reacting roles, unlike those in a play, do not have a fixed script and outcome. While students will be obliged to adhere to the philosophical and intellectual beliefs of the historical figures they have been assigned to play, they must devise their own means of expressing those ideas persuasively, in papers, speeches or other public presentations; and students must also pursue a course of action they think will help them win the game.

He explained that using this method, students consider the scientific careers of Galileo and Darwin as case studies, but they are "gamified" as a way of increasing student engagement. Instead of the typical seminar format, they play game to draw students into the past, promote engagement with big ideas, and improve intellectual and academic skills. It's also a lot of fun. But it is a lot of work too. "We will be playing 'games,' but with a serious purpose. Ultimately students will be assessed on how well they demonstrate a deep understanding of the roles you are playing and the texts they are reading."

As an example I provided explanation for one of the games he uses from webpage:

> ***Charles Darwin, the Copley Medal and the Rise of Naturalism, 1861-64*** **(**W.W. Norton, 2010) thrusts students into the intellectual ferment of Victorian England just after publication of The Origin of Species. Since its appearance in 1859, Darwin's long awaited treatise in "genetic biology" had received reviews both favorable and damning. Thomas Huxley and Samuel Wilberforce presented arguments for and against the theory in a dramatic and widely publicized face-off

> at the 1860 meeting of the British Association for the Advancement of Science in Oxford. Their encounter sparked a vigorous, complex debate that touched on a host of issues and set the stage for the Royal Society's consideration of whether or not they ought to award Darwin the Copley Medal, their most prestigious prize. While the action takes place in meetings of the Royal Society, Great Britain's most important scientific body, a parallel and influential public argument smoldered over the nature of science and its relationship to modern life in an industrial society

He believes with this method students are very engaged, and to play the game they must present some of the scientific theories. For example, in the Galileo game students come to understand how observing the phases of Venus helped disprove the Copernican model.

He thinks students need a background in the history of science to play the game successfully and the game's website provides supporting materials and resources for students. Many history professors are using the game and they are able to get support from the website. He says he is not a trained historian of science although the subject is his interest, so if he can use the game, others can too. He says it is not easy for students to present ideas. For example, theory of natural selection of the origin of species in Darwin's game is hard for students to present effectively but again he believes if students can do it, it means that they have developed a good understanding of materials.

The game also provides students with some key issues in the philosophy of science. For example, if students are on the Copernican side, they realize the empirical evidence is not supporting that position. By competing in the game, students learn about the conditions that led to the paradigm shift in science.

Resources for the Course

His syllabus is available online with links to videos and readings. Unfortunately, most of the links connects to the course webpage that requires a student ID to log in, so I am not able to access. Most of the syllabus explains the game. There is not any objectives or students learning outcomes in the syllabus. There is a weekly schedule that says students about each weeks' reading assignments. There are very short explanations of assignments, and the name of text books are provided.

The main source for this course is the game's website. The website has following course materials for every game:

- A student game book, which outlines the historical context, game premise, central debates, and rules;
- An instructor's manual with role descriptions; and
- Companion texts / primary source readings (may also be included as appendices to the student game book).

In his class, students read the game books related to two games he uses. Each book is a guideline to play game. Students' roles are in the book and rules for preparing materials to defend their position during the debate. In addition, on the website of game there is a link for using primary and secondary resources that instructor said he uses to provide students with documents they need to defend their arguments in the game. These resources are accessible only to instructors. In addition to the game books, there are two textbooks[39]in his syllabus that students are asked to have available.

Challenges of the Course

Although the instructor is concerned he lacks a background in history of mathematics, he points out that in any university it is challenging to find someone to teach the class who has experience in both history of science and mathematics.

[39] Linder, D. O. Trial of Galileo Galilei.
Dunn, E. E., & Siems, D. (2009). *Charles Darwin, the Copley Medal, and the Rise of Naturalism 1862-1864*. Pearson College Division.

He said he has problem with historical experiments which recently UTeach is advertising. He explained:

> For example, we try to do the same with inclined plane experiments. Galileo did this experiment to show how bodies accelerated, but it is very hard to do . . .we tried to kind of have students recreate this, but it is quite challenging

I should point out, historical experiments are not in the model curriculum, but the last Perspective workshop's instructor suggested the instructors to add them to their syllabus. In the last Perspectives workshop, where he saw the folks at UT Austin do historical experiments, he did not quite know how and he ended up being a bit confused. He hopes they improve their explanations and demonstrations for future workshops.

Class Assignments

In his class, students write a paper related to the game and present it as an argument. Trying to prove their argument is difficult for students, he thinks it is useful for them to try. He explained this assignment in his syllabus as:

> Games involve group cooperation as students are divided into factions that collaborate in pursuit of their victory objectives. Thus, faction members will need to communicate with each other outside of class. Faction maintenance will be assessed using graded discussion board threads.
> Reacting games are won and lost according to the quality of written and oral argumentation. The papers you will write for the games will form the basis of your in-class presentations.

Writing and presenting a 5E lesson plan is another required assignment. He explains this assignment in syllabus:

> *5e lesson plans are required as part of the UABTeach curriculum. Because a great deal of the in-class speeches and presentations in Reacting are dedicated to peer-to-peer teaching of scientific concepts, the 5e lesson plans will follow naturally from this.*

Instructor's View about the Model Curriculum

He does not use the model curriculum because he had a successful experience teaching with these games and wanted to try out teaching using that strategy. He thinks thinks that lesson plan writing is very challenging and he gets help from master teachers. In addition, in his visit to one site, he found students do not like *Perspectives* but at the same time his students liked the game, so he decided to replace it with the model curriculum and he got a good feedback from students. He is very happy UTeach people were fine with his model.

NOS Connections

He involves NOS in instruction implicitly and believes it comes out around the games, but he does not have a part of the course that explicitely includes NOS topics. The elements he mentioned that are connected to NOS are: paradigm shift, importance of evidence, induction, social context of science, and controversy issues. He mentioned them in interview and told students see when they want to support Galileo how much the empirical evidence helped them to support their argument or what was the role of society. Interestingly, his reason for ignoring NOS was they do not need to connect science teaching to NGSS although NGSS makes it very clear that this is not the case.

Suggestions for Improving the Course

He would like to go to Austin and offer his version of the class as a workshop for other insturctiors and work with them to focus on other episodes of the game and integrate them with goals they have for teaching *Perspectives*. He thinks classes should be more interactive and UTeach should use different methods rather than just lecturing if wants students to be prepare to be a teacher who are using creative methods.

UNIVERSITY OF ARKANSAS

Office of Research Compliance
Institutional Review Board

November 11, 2015

MEMORANDUM

TO:	Noushin Nouri William McComas
FROM:	Ro Windwalker IRB Coordinator
RE:	New Protocol Approval
IRB Protocol #:	15-10-272
Protocol Title:	*An Analysis of the Model and Enacted Curricula for History and Nature of Science in a Nationwide Teacher Education Program*
Review Type:	☒ EXEMPT ☐ EXPEDITED ☐ FULL IRB
Approved Project Period:	Start Date: 11/11/2015 Expiration Date: 11/10/2016

Your protocol has been approved by the IRB. Protocols are approved for a maximum period of one year. If you wish to continue the project past the approved project period (see above), you must submit a request, using the form *Continuing Review for IRB Approved Projects*, prior to the expiration date. This form is available from the IRB Coordinator or on the Research Compliance website (https://vpred.uark.edu/units/rscp/index.php). As a courtesy, you will be sent a reminder two months in advance of that date. However, failure to receive a reminder does not negate your obligation to make the request in sufficient time for review and approval. Federal regulations prohibit retroactive approval of continuation. Failure to receive approval to continue the project prior to the expiration date will result in Termination of the protocol approval. The IRB Coordinator can give you guidance on submission times.

This protocol has been approved for 45 participants. If you wish to make *any* modifications in the approved protocol, including enrolling more than this number, you must seek approval *prior to* implementing those changes. All modifications should be requested in writing (email is acceptable) and must provide sufficient detail to assess the impact of the change.

If you have questions or need any assistance from the IRB, please contact me at 109 MLKG Building, 5-2208, or irb@uark.edu