George Mason University
College of Education and Human Development

EDUC 547: Scientific Inquiry and the Nature of Science

Instructor:	Dr. Erin E. Peters Burton, NBCT
Date and Time:	MW 4:30-7:10 (June 4 -July 26)
Class Location:	West 1001
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Course Description

Incorporates advanced understanding about scientific knowledge in K-12 classrooms. Builds fundamental knowledge of scientific inquiry and the nature of scientific knowledge and skills to weave this knowledge explicitly in curriculum. Focuses on developing inquiry-based lessons for students to investigate science and assessing student understanding of science and the nature of science.

Course Format

The delivery of this course is designed to reach two major goals:

1. To learn a deeper meaning of Scientific Inquiry (SI) and the Nature of Science (NOS)
2. To develop, implement, and assess Scientific Inquiry and the Nature of Science in secondary classrooms

We will begin by participating in an activity that reveals ideas about scientific inquiry and the nature of science, then we will use these ideas to delve deeper into the concepts of SI/NOS. Following instruction on the aspect of scientific inquiry and the nature of science, teachers will incorporate their understanding of SI/NOS into their teaching and will report the planning, implementation and assessment back to the group. Reporting the results of implementation and

assessment of SI/NOS will not be treated as an endpoint, but rather as a reflection with the group so the activities can be enhanced and shared with other teachers.

Relationship to Program Goals and Professional Organization

EDUC 547 is designed to enable science education leaders to use strategies to implement and evaluate school change in science teaching and learning. Students need knowledge of effective instruction in science as well as vehicles for change so that they can be a catalyst for school improvement in mathematics. The course was developed according to the position statement of the National Science Teachers Association (NSTA) and the joint position statement of the National Council for Accreditation of Teacher Education (NCATE) and the National Science Teachers Association (NSTA) on Standards for Science Teacher Preparation.

These position statements indicate that the core knowledge expectations in science education include:

- Understand the historical and cultural development of science and the evolution of knowledge in their discipline.
- Understand the philosophical tenets, assumptions, goals, and values that distinguish science from technology and from other ways of knowing the world.
- Engage students successfully in studies of the nature of science including, when possible, the critical analysis of false or doubtful assertions made in the name of science.
- Understand the processes, tenets, and assumptions of multiple methods of inquiry leading to scientific knowledge.
- Engage students successfully in developmentally appropriate inquiries that require them to develop concepts and relationships from their observations, data, and inferences in a scientific manner.

Additionally, this course was designed with a vision for accomplished teaching, as indicated by NBPTS Science Standards for Early Adolescence (http://www.nbpts.org/userfiles/File/ea_science_standards.pdf) and Adolescence and Young Adulthood (http://www.nbpts.org/userfiles/File/aya_science_standards.pdf) the Five Core Propositions of the National Board for Professional Science Teaching:

- Proposition 1: Teachers are Committed to Students and Their Learning
- Proposition 2: Teachers Know the Subjects They Teach and How to Teach Those Subjects to Students
- Proposition 3: Teachers are Responsible for Managing and Monitoring Student Learning.
- Proposition 4: Teachers Think Systematically about Their Practice and Learn from Experience.
- Proposition 5: Teachers are Members of Learning Communities.

Readings

- Will be provided electronically by the instructor on the Blackboard site.
- Because this course is flexible to the needs of the teacher candidates, other articles/handouts than the ones indicated on this syllabus may be distributed in class or posted on-line at the course website.
- It is expected that the readings assigned for the class will be completed before the class meeting.

Learning Outcomes

The pre-service and provisionally licensed teacher will:

- Build knowledge in the historic, philosophical and social factors that have influenced the development of scientific knowledge
- Be able to categorize lessons along the continuum of scientific inquiry
- Build a repertoire of science teaching and assessment strategies in scientific inquiry and the nature of science by reading, writing, observing, participating in, and reflecting on the teaching and learning of science;
- Develop strategies to help students become scientifically literate, think critically and creatively, understand the nature of science, and see the importance of science as a way of knowing;
- Utilize a professional learning community to improve lesson planning, implementation and assessment.
- Construct more cohesive science units that focus on science as a way of knowing.

College Expectations and University honor Code

The Graduate School of Education (GSE) expects that all students abide by the following:

Students are expected to exhibit professional behavior and dispositions. See gse.gmu.edu for a listing of these dispositions.

Students must follow the guidelines of the University Honor Code. See http://www.gmu.edu/catalog/apolicies/#TOC_H12 for the full honor code.

Students must agree to abide by the university policy for Responsible Use of Computing. See http://mail.gmu.edu and click on Responsible Use of Computing at the bottom of the screen.

Students with disabilities who seek accommodations in a course must be registered with the GMU Disability Resource Center (DRC) and inform the instructor, in writing, at the beginning of the semester. See www.gmu.edu/student/drc or call 703-993-2474 to access the DRC.

Grading

Since this is a graduate level course, high quality work is expected on all assignments and in class. Attendance at all classes for the entire class is a course expectation. All assignments are due at the beginning of class on the day they are due. Graded assignments that are late will automatically receive a ten percent grade reduction (one full letter grade lower).

Assignments	*Points*
Concept mapping (check #1)	20
Concept mapping (final)	20
Clinical interview questions	10
Clinical interview report	50
Presentation Part 1	100
Presentation Part 2	100
Online discussions	150
Class participation (consultations)	50

Total Points: 500

Policy on Incompletes

If circumstances warrant, a written request for an incomplete must be provided to the instructor for approval prior to the course final examination date. Requests are accepted at the instructor's discretion, provided your reasons are justified and that 80% of your work has already been completed. Your written request should be regarded as a contract between you and the instructor and must specify the date for completion of work. This date must be at least two weeks prior to the university deadline for changing incompletes to letter grades.

Grading Scale

A = 93-100%
A- = 90-92%
B+ = 88-89%
B = 80-87%
C = 70-79%
F = Below 70%

Assignments

Science education research shows that frequent assessment of small amounts of material is most effective for learning science. Therefore, in this class formal and informal assessment will be continuously provided on assignments and class activities. Assessment is used as a tool for information that informs both learning and teaching, so this two-way communication loop is necessary for optimal learning.

1. Concept maps

The materials learned in this course tend to take a metacognitive approach. That is, the nature of science is a way of knowing the world, rather than a set of facts. Capturing this knowledge can be elusive, so to keep track of progress in the course, we will be using concept maps as a tool for displaying knowledge. Teachers will design their own concept maps and add to their maps after each class as a way of reflecting on what they have learned. The format of the concept map is up to the teacher, but it should be an effective means of communication about nature of science knowledge. There will be a formative assessment check on the concept map (see calendar for the date). The formative map should represent all of the information learned in the course at the time of the check. A final concept map will be turned in on the last class. This map should represent all of the knowledge learned during the course.

2. Clinical Interview

In this assignment, you will find an adolescent to interview about scientific inquiry and the nature of science. The purpose of this assignment is for you to gain experience in a one-on-one setting to understand individual student ways of knowing. You will be given more detailed instructions in class, but overall the task is to be completed in the following sequence:

1) For concepts about the **nature of scientific knowledge,** write two easy questions, two moderately difficult questions, and two more difficult questions that are all related and lead up to a "big idea". Note the easy questions should get at the student's understanding of the concept from past experience that may or may not be the product of schooling. The questions can be about the nature of science without context or can be contextualized within a content area. However, the questions MUST be eliciting ideas about the nature of science from the adolescent.
2) Audio tape an adolescent answering the questions and you probing for more understanding of the cognition of the student.
3) Writing a 3-4 page paper of the description of what occurred, an analysis of the learning of the student, and a reflection on what you learned.

3. Class Presentations

A major goal of this course is to enable teachers to incorporate more nature of science knowledge and scientific inquiry processes into their classes in an explicit and reflective way. To reach this goal, teachers will pair up to plan a lesson with explicit, reflective nature of science instruction and will present the objectives and assessment of the lesson and the ways they incorporate nature of science and scientific inquiry in their classes to their peers. Peers will conduct a "consultation" with the pairs of teachers, revealing and discussing strengths and weaknesses of their classroom activities. To prepare for the first presentation, teachers will bring any student materials needed for peers to understand the lesson's intent and assessment. During the second presentation, teachers will bring lesson plans and Template 1 along with any revised

student materials. The teachers will then teach the course in a 40 minute block. Templates found at the end of this syllabus should be used to provide framework for the other teachers about the lesson.

4. Online Discussions

A portion of this class will be conducted online in order to facilitate the incorporation of the new information about the nature of science into classroom lessons. In order for this component of the class to be successful, all teachers need to participate in the online sessions. The sessions may be a discussion about a reading that was posted, comments on an online system of lessons, or suggestions for a posted lesson.

5. Class Participation

Learning depends on the active engagement of the participant and frequent checking by the instructor as to the progress of the learner. Smaller assignments will be given as necessary in class in order to inform your learning and my teaching. Part of the class participation is providing feedback to peers when they present their lesson plans incorporating the nature of science (otherwise known as the consultations).

Students who are not in the teaching profession will be given the opportunity to do an alternative assignment that is approved by the instructor.

Instructions for Class Presentations

Criteria for Selecting Work to Share

Not all lessons and student work are conducive to a presenting for this assignment. Lessons that generate the most productive discussions are usually inquiry lessons or assignments where students express their ideas on their own. A multiple choice assessment is not as appropriate for this type of discussion because it is difficult to ascertain students' understanding of phenomena with a forced answer format. Some questions to guide teacher choice of lessons follow:

- Do you have a question that your colleagues could help you resolve?
- Is the work easily viewable for your colleagues?
- Does the work represent one aspect of the nature of science?
- Will the assignment and student work generate an interesting conversation among your colleagues?

Consider that sometimes your "best" work may not generate conversations to find creative approaches to teaching and learning, so bringing in a lesson that needs some improvement may also be an option.

Materials for Presentation Part 1
The presenting teachers should bring enough copies of the following items:

- The assignment materials that are to be given to the students
- The rubric or assessment scheme

Also please prepare to talk about the objectives (both content and NOS) of the lesson

The Presentation-Part 1

The presentation should begin by having the presenting teacher pair or group explain an overview of the expectations of the lesson that was designed to teach content and emphasize ONE aspect of the nature of science. Teachers will hand out the student assignment and assessment materials for discussion by peers. The purpose of this discussion is to improve the explicit, reflective nature of science instruction. To aid in this discussion, we will identify the objectives for the content and the nature of science and the assessment plans for the content and the nature of science. Other issues such as possible reasons for misconceptions come out of the discussions. The presentation should always end on a positive note, focusing on the achievements of the teacher pair. This presentation is expected to take 20 minutes including discussion.

Materials for Presentation Part 2
The presenting teacher should bring enough copies of the following items:

- An outline of what has been planned for the class (Template 1)
- A lesson plan of the presented lesson with expectations
- Revised class activity for all members of the groups to be "students"
- Any additional supporting materials needed for the lesson

The Presentation-Part 2

The presenting teachers should pass out Template 1 and the full lesson plan. As the presenting teachers explain the outline and lesson plan, the group can ask clarifying questions. Part 2 of the presentation of the lesson is to actually teach the lesson to the group. In doing so, the partners will implement the 40 minute lesson that was refined during the consultation with the group. At the end of the 40 minutes, we will conduct a discussion about how the NOS aspect was taught explicitly and reflectively and the connection of the aspect to the content. The lesson will be videotaped in order to refer to portions of the lesson. Following this, the teacher pair will **individually** fill out a reflective template (#2) and turn in to the professor.

Template #1
Teacher Information Worksheet

1. What aspect of the nature of science did you choose for this assignment? Why did you make this choice?

2. To complete the assignment, what should students know about the nature of science?

3. What would you accept as evidence that students understood that aspect of the nature of science?

TEMPLATE #2
REFLECTION

- What does this work tell you about how well a student understands the nature of science? Are they free to express complete thoughts?

Which piece of work would you rate below? And why?

- Exceeds expectations –
- Meets expectations –
- Does not yet meet expectations –

Does the assessment of the student work fairly reflect the nature of science objectives of the assignment?

What adjustments would you make to the assignment based on the consultation?
What adjustments would you make to the assessment based on the consultation?

SCHEDULE
(PLANS MAY CHANGE ACCORDING TO STUDENT NEEDS)

Date	Class topics and Assignments Due
June 4	**Prior Knowledge and Overview** • Why teach science? • What is scientific inquiry and how is it related to the nature of science? • What do we know from research about how SI/NOS should be taught? • How do we go about assessing SI/NOS?
	Before class please read: Syllabus
	Class Activities: Requirements of the Course Forethought form Views of Science and Education (VOSE) Pre-Test VNOS-B Pre-Test Overview of Scientific Inquiry and the Nature of science ➢ Understanding Science: How Science Really Works http://undsci.berkeley.edu/ Self-reflection form
	Assignments Due: *None*

Date	Class topics and Assignments Due
June 6	**Building Knowledge of SI/NOS** • How is classroom inquiry different from scientific inquiry? • What concepts about the scientific enterprise are appropriate for secondary students?
	Before class please read: Readings about SI and NOS ➢ Inquiry and the National Science Education Standards *http://www.nap.edu/openbook.php?record_id=9596&page=1* *Read Chapters 1, 3 and 4*

	➢ Next Generation Science Standards (if available) http://www.nextgenscience.org/next-generation-science-standards ➢ Peters, E. E. (2006). Connecting inquiry and the nature of science. *The Science Education Review, 5 (*2), 37-44. *(available on Blackboard site)* ➢ McComas, W. F. (1998). *The principle elements of the nature of science: Dispelling the myths.* http://coehp.uark.edu/pase/TheMythsOfScience.pdf. ➢ Peters, E. E. (2006). *Why is teaching the nature of science so important?* http://www.vast.org/content/File/v1n1/linkedwhole.pdf. ➢ Project 2061 – The Nature of Science http://www.project2061.org/publications/sfaa/online/chap1.htm
	Class Activities: Models of the nature of knowledge Examples of de-contextualized nature of science activities Nature of knowledge and ways of knowing
	Assignments Due: *Respond to questions about readings on the Blackboard site*

June 11	**Explicit and Reflective NOS Instruction** • What do we know from educational research about the most effective ways to teach NOS? • Why is NOS difficult to translate into classroom practice?
	Before class please read: ➢ Peters-Burton, E. E. (in press) Self-regulated learning as a method to develop scientific thinking. *Next Generation Learning Science.* New York: Sense Publishers. ➢ Peters, E. E. (2012). Developing content knowledge in students through explicit teaching of the nature of science: Influences of goal setting and self-monitoring. *Science & Education, 21(6)* 881-898.

	Class Activities: Self-regulated learning processes Parallels to explicit and reflective approaches to teaching NOS MPI-S Magnets unit
	***Assignments Due**:* ➢ *Be prepared to discuss readings in class*

June 13	**What constitutes empirical evidence?** • What makes empirical evidence different from other forms of evidence?
	Before class please read: About Implications of Heroic Science Stories ➢ Milne, C. (1998). Philosophically correct science stories? Examining the implications of heroic science stories for school science. *Journal of Research in Science Teaching, 35*(2), 175-187. Read about scientific approaches in making claims in a class activity ➢ Lawson, Anton E. (1999). A Scientific Approach to Teaching About Evolution & Special Creation". *The American Biology Teacher*,.61 (4), 266-274. **Please try out the following web-based activities for this class:** Evidence to make claims in student activities ➢ National Institutes of Health, (2005). Doing Science: The Process of Scientific Inquiry. http://science.education.nih.gov/Supplements/NIH6/inquiry/default.htm. Evidence to support ideas in science ➢ Differences between models and empirical evidence http://www.skepticalscience.com/empirical-evidence-for-global-warming.htm Perform a student activity that requires empirical evidence to make claims ➢ The World IS really flat! http://www.indiana.edu/~ensiweb/lessons/flaterth.html
	Class Activities: Reactions to Readings and Online Discussion Generating empirical evidence in the classroom Contextualized NOS lesson

	Assignments Due: ➢ *Clinical interview questions – draft* ✓ *Responses to questions on Blackboard site*
June 18	**Scientific knowledge is durable, but also tentative** ✓ How tentative is scientific knowledge?
	Before class please read: Lesson demonstrating tentativeness ➢ AAAS Science NetLinks – Abrupt Climate Change http://www.sciencenetlinks.com/lessons.php?Grade=9-12&BenchmarkID=1&DocID=323 How do scientists handle flux in major concepts? ➢ http://arstechnica.com/science/news/2006/10/5609.ars Different meanings of tentativeness ➢ http://physics.weber.edu/johnston/research/!TheMultipleMeaningsOfTentativeScience_IHPSTfi.PDF Dealing with tentativeness when teaching science ➢ http://www.actionbioscience.org/education/allchin2.html
	Class Activities: Plate Tectonic Theory Case Study – FAST3 Textbook series Dino-Data Forethought form Self-Reflection form
	Assignments Due: ✓ *Concept Map Check #1* ✓ *Reponses to questions on Blackboard site* ✓ *Check in on Clinical Interview Report*
June 20	**Laws and Theories** • What is the difference between theories and laws?
	Before class please read: McComas, W. F. (2003). A Textbook Case of the Nature of Science: Laws and Theories in the Science of Biology. *International Journal of Science and Mathematics Education 1*(2), 141-155. (Reprint found on blackboard).
	Class Activities: 2 Groups will do Presentation #1 (if needed)

	Perform an online lesson that explicitly illustrates Theory ➢ AAAS Science NetLinks – Comparing Theories: Lamark and Darwin http://www.sciencenetlinks.com/lessons.php?Grade=9-12&BenchmarkID=10&DocID=0
	Assignments Due: ✓ *2 groups will present Presentation Part 1(if needed)*
June 25	**Scientific Habits of Mind** • What habits of mind do scientists adopt?
	Before class please read: Barber, B. (1961). Resistance by scientists to scientific discovery. *Science*, *134*, 596-602. Answer questions on the Blackboard site about this lab: ➢ http://www.teach-nology.com/worksheets/science/phy/lab1/ (Is this lab teaching laws, theories, neither or both?)
	Class Activities: 2 Groups will do Presentation #1 Perform a lesson illustrating scientific habits of mind ➢ AAAS Science NetLinks – The Mozart Effect http://www.sciencenetlinks.com/lessons.php?Grade=9-12&BenchmarkID=12&DocID=36 Perform online lesson illustrating how scientists strive for accuracy ➢ Opinion surveys http://www.sciencenetlinks.com/lessons.php?Grade=9-12&BenchmarkID=12&DocID=451 2 groups will present Presentation Part 1
	Assignments Due: ✓ *2 groups will present Presentation Part 1* ✓ *Responses to questions on Blackboard*
June 27	**How do social and historical factors influence scientific knowledge?**
	Before class please read Mendelsohn, E. (1977). The Social Construction of Scientific Knowledge. E. Mendelsohn, P. Weingart and R. Whitley (Eds.) *The Social Production of Scientific Knowledge*. *Sociology of the Sciences*, Vol I, 3-26. Boston: D. Reidel Publishing Company Read how to incorporate more issue based lessons in science ➢ http://www.actionbioscience.org/education/lewis.html

	Class Activities: 2 Groups will do Presentation #1 Perform activity to show historical change in scientific values ➢ Women in Medicine: Past and Future http://www.sciencenetlinks.com/lessons.php?BenchmarkID=1&DocID=115 Discussion of the use of history of science in class Joy Hakim's *The Story of Science*
	Assignments Due: ✓ *Respond to challenges to create issue based and historically based lessons in science on Blackboard* ✓ *2 groups will present Presentation Part 1*
July 2	**In what ways are scientists creative?**
	Before class please read Holton, G. (1995). Chapter 4 Imagination in Science from *Einstein, history and other passions.* New York: Addison-Wesley. Listen to a portion of PRI's Creativity in Science series ➢ http://www.publicbroadcasting.net/dfrw/.jukebox?action=viewPodcast&podcastId=15003 Listen to podcasts ➢ The Death Ray ➢ Plastics ➢ Biomimicry
	Class Activities: 2 Groups will complete Presentation #1 Discussion on creativity in science Discussion on creativity in the classroom
	Assignments Due: ✓ *Final Clinical Interview Report* ✓ *Respond to Creativity discussion board on Blackboard* ✓ *2 groups will present Presentation Part 1*
July 4 Holiday– no class	

July 9 and July 11 – work days with groups to complete teaching presentations	
July 16	**How do you teach NOS explicitly and reflectively while still teaching science content?**
	Before class ➢ Prepare for Presentation #2
	Class Activities: 2 groups will present Presentation Part 2 Groups presenting will fill out the Forethought form before presenting
	Assignments Due: ✓ *Template #2 for people who presented* ✓ *Performance form due for people who presented*
July 18	**How do you teach NOS explicitly and reflectively while still teaching science content?**
	Before class ➢ Prepare for Presentation #2
	Class Activities: 2 groups will present Presentation Part 2 Groups presenting will fill out the Forethought form before presenting
	Assignments Due: ✓ *Template #2 for people who presented* ✓ *Performance form due for people who presented*
July 23	**How do you teach NOS explicitly and reflectively while still teaching science content?**
	Before Class: ➢ Prepare for Presentation Part 2
	Class Activities: 2 groups will present Presentation Part 2 Groups presenting will fill out the Forethought form before presenting

	Assignments Due: ✓ *Template #2 for people who presented* ✓ *Performance form due for people who presented*
July 25	**How do you teach NOS explicitly and reflectively while still teaching science content?** **Measurement of growth in NOS knowledge**
	Before class ➢ Prepare for Presentation #2
	Class Activities: 2 groups will present Presentation Part 2 (if needed) Groups presenting will fill out the Forethought form before presenting VOSE post-test VNOS-B post-test Self-Reflection form Class Evaluation
	Assignments Due: ✓ *Template #2 for people who presented* ✓ *Performance form due for people who presented* ✓ *Final concept map*