EDUC46:
STEM and Education

Winter Term, 2020	Professor: David J.M. Kraemer, PhD
12: Monday, Wednesday, Friday @ 12:50 – 1:55	Email: *david.kraemer@dartmouth.edu*
x-hour: Tuesday @ 1:20 – 2:10	Office Location: Raven House 212
Blunt 007	Office Hours: Friday @ 11 – 12:30, 2 – 3:30

COURSE DESCRIPTION

How do we learn, understand, and teach science, technology, engineering, and math (the STEM disciplines)? In this class, we will explore the nature and development of the scientific mind; how we formulate theories, design experiments, and understand scientific, technological, and mathematical concepts; and how we learn and teach related skills in the classroom, addressing the debate about the effectiveness of direct instruction and hands-on approaches.

The main goals of this course are to:

- Become proficient at reading empirical research articles in experimental psychology, neuroscience, and education focusing on STEM learning
- Become familiar with the major concepts and theoretical models from psychology and neuroscience that relate to STEM learning
- Become adept at evaluating the merit of claims from proposed educational interventions regarding science and math

COURSE REQUIREMENTS

- All readings will be available on Canvas and you are required to read the assigned papers before class.
- In-class discussion of assigned readings is a critical component of this course and will be facilitated by bringing the articles to class for your reference.
- Developing the skills of critically reading empirical research articles and writing for a scientific audience are central to achieving the course goals.

GRADING OVERVIEW

30%	Midterm Exam 1
32%	Midterm Exam 2
15%	Class Debates and Position Paper
10%	Social Impact Practicum Research Paper
10%	Quizzes (average of all 6)
3%	Class Participation and Attendance

ASSIGNMENTS and ASSESSMENTS

Midterm examinations – ***Friday, FEBRUARY 1ST and MONDAY, FEBRUARY 25TH***

- Mix of fill-in-the-blank questions (~1-3 word responses) and short answer questions (~1-3 paragraph responses)
- Covers material from lecture slides, class discussions, and assigned readings (the aspects of the readings highlighted in class are the most relevant)

Class Participation & Attendance

- Arrive on time for each class
- Prepare for class discussions (read the assigned materials, stay awake during class, stay off internet, etc.)
- Demonstrate that you are familiar with the assigned readings. Complete understanding of the readings prior to class discussion is not expected – questions about the readings are always encouraged. Hopefully discussion will help elucidate any confusing aspects of the articles. In this way, your comments and questions will help everyone understand the material in greater depth.

Quizzes – *Six quizzes throughout the term*

- Any material covered to date is fair game, including that day's assigned readings
- These are intended to be low-stakes opportunities to gauge your understanding of the material.
- Your quiz grade will be the average of your 6 quiz scores

Social Impact Practicum

- We have partnered with two local educational venues, Vital Communities—creators of ValleyQuest—and the Montshire Museum—a local science museum oriented towards children and families—to design lesson plans for some informative activities into classrooms and outdoor learning environments
- You will work with your group on a specific project (assigned after the midterm) related to, for example, Ecology, Geology, or pre-engineering skills and write up a brief report on the lesson you design as a group.
- On the last two days of class the groups will share their lessons with the class.

GENERAL POLICIES

1. **Read all materials and prepare for class.** You are expected to read the materials posted on Blackboard *before* each class. Be prepared to discuss that material *in class*. Everyone is expected to come to every class and to arrive on time. You are also expected to contribute to class discussion. You will learn the material better and others will learn from you. The success of this course depends on everyone coming to class prepared and ready to discuss the material. Both attendance (on-time) and preparation for class will determine a portion of your grade (see "Assignments and Assessments" below).
2. **Before you turn in your papers…** make sure that you use 12-point Times New Roman font, that you double-space the whole document, that your print margins are 1-inch on all sides (not the default in *Word)*, that all your pages are numbered, and that your document is stapled together (if printed). For citations in all papers, you must use APA Style formatting (refer to the APA Style Manual or online guides, such as: **http://owl.english.purdue.edu/owl/resource/560/01/**)
3. **Tell me sooner rather than later.** If you know ahead of time that you will be missing a class, e.g., for sports, please let me know in advance in order to avoid losing participation credit. Some students may wish to take part in religious observances that occur during this academic term. If you have a religious observance that conflicts with your participation in the course, please meet with me before the end of the second week of the term to discuss appropriate accommodations.
4. ***ASSUME THAT I WILL NOT ACCEPT LATE ASSIGNMENTS.*** It's always better to check with me ahead of time (or as soon as possible) if you think you'll be turning in something late due to travel, or unexpected illness, etc.
5. **Cell phones are not to be used in class.** If an emergency arises that requires the use of a phone, please quietly excuse yourself from the room to respond.
6. **Accommodations.** Students with learning, physical, or psychiatric disabilities enrolled in this course who may need disability-related classroom accommodations are encouraged to make an office appointment to see me early in the semester (i.e., within the first two weeks). If you have not done so already, students requiring disability-related accommodations should register with the Student Accessibility Services office (301 Collis Student Center).
   Dartmouth's policies and resources: **http://www.dartmouth.edu/~accessibility**
   Contact info: 646-9900, **Student.Accessibility.Services@Dartmouth.edu**
7. **Plagiarism is unacceptable.** All work submitted as your own must be written by you and not previously submitted for any other class. It is important to attribute material that is the work of others to the original source. If you are unsure how to properly cite a source, please consult with me prior to handing in an assignment (and see: **http://www.dartmouth.edu/~writing/sources/**). You should be familiar with Dartmouth's Honor Principle, which applies to all courses at Dartmouth (available here: **www.dartmouth.edu/~uja/honor/**). I do not expect any violations of this code, but if any concerns do arise I will forward all related materials to Dartmouth's Committee on Standards.

SCHEDULE
(ASSIGNED READINGS ARE POSTED ON CANVAS)

Friday, January 4

INTRODUCTION and COURSE OVERVIEW

INFORMAL MATH: ESTIMATION AND NUMBER REPRESENTATIONS

Monday, January 7 + Wednesday, January 9

MAGNITUDE AND THE APPROXIMATE NUMBER SYSTEM (ANS)

Readings:

1) Cantlon, J. F., & Brannon, E. M. (2006). Shared system for ordering small and large numbers in monkeys and humans. Psychological Science, 17(5), 401–406.
2) Berger, A., Tzur, G., & Posner, M. I. (2006). Infant brains detect arithmetic errors. Proceedings of the National Academy of Sciences, 103(33), 12649–12653.
3) Halberda, J., Mazzocco, M. & Feigenson, L. (2008). Individual differences in nonverbal number acuity predict maths achievement. Nature, 455, 665-668.

Friday, January 11

NUMBER REPRESENTATIONS AND THE TRIPLE CODE MODEL

Readings:

1) Park, J., & Brannon, E. M. (2013). Training the approximate number system improves math proficiency. *Psychological Science*, 1-7.
2) Ansari, D. (2008). Effects of development and enculturation on number representation in the brain. *Nature Reviews Neuroscience*, *9*(4), 278–291. doi:10.1038/nrn2334
3) Lemer, C., Dehaene, S., Spelke, E., & Cohen, L. (2003). Approximate quantities and exact number words: Dissociable systems. *Neuropsychologia*, *41*(14), 1942–1958.

Monday, January 14

NUMBER LINES: LOG VS. LINEAR REPRESENTATIONS

Readings:

1) Dehaene, S., Izard, V., Spelke, E., & Pica, P. (2008). Log or Linear? Distinct Intuitions of the Number Scale in Western and Amazonian Indigene Cultures. *Science*, *320*(5880), 1217–1220. doi:10.1126/science.1156540
2) Siegler, R. S., & Opfer, J. E. (2003). The development of numerical estimation evidence for multiple representations of numerical quantity. *Psychological Science*, *14*(3), 237–250.
3) Siegler, R. S., & Ramani, G. B. (2008). Playing linear numerical board games promotes low-income children's numerical development. *Developmental Science*, *11*(5), 655–661. doi:10.1111/j.1467-7687.2008.00714.x

FORMAL MATH: INSTRUCTION AND CALCULATIONS

Wednesday, January 16 + Friday, January 18

MATH INSTRUCTION STRATEGIES; ELEMENTARY MATH

Readings:

1) Slavin, R. E., & Lake, C. (2008). Effective programs in elementary mathematics: A best-evidence synthesis. Review of Educational Research, 78(3), 427–515.
2) Ritter, S., Anderson, J. R., Koedinger, K. R., & Corbett, A. (2007). Cognitive Tutor: Applied research in mathematics education. Psychonomic bulletin & review, 14(2), 249–255.
3) Carpenter, T. P., Fennema, E., & Franke, M. L. (1996). Cognitively guided instruction: A knowledge base for reform in primary mathematics instruction. The Elementary School Journal, 3–20.

Monday, January 21—*no class today*

MARTIN LUTHER KING, JR. DAY

Wednesday, January 23

FRACTIONS AND ADVANCED MATH

Readings:

1) Siegler, R. S., Thompson, C. A., & Schneider, M. (2011). An integrated theory of whole number and fractions development. *Cognitive Psychology*, *62*(4), 273–296. doi:10.1016/j.cogpsych.2011.03.001
2) Grabner, R. H., Ansari, D., Koschutnig, K., Reishofer, G., Ebner, F., & Neuper, C. (2009). To retrieve or to calculate? Left angular gyrus mediates the retrieval of arithmetic facts during problem solving. *Neuropsychologia*, *47*(2), 604–608. doi:10.1016/j.neuropsychologia.2008.10.013
3) Krueger, F., Spampinato, M. V., Pardini, M., Pajevic, S., Wood, J. N., Weiss, G. H., … Grafman, J. (2008). Integral calculus problem solving: an fMRI investigation. Neuroreport, 19(11), 1095.

Friday, January 25

DEBATE #1

MOTION: *"Elementary math classrooms (K-5) should be using physical manipulatives as a regular part of instruction."*

Readings:

1) TBD by Debate Group 1
2) TBD by Debate Group 2

Monday, January 28 + Wednesday, January 30

MATH ANXIETY AND STEREOTYPE THREAT

Readings:

1) Ashcraft, M. H., & Krause, J. A. (2007). Working memory, math performance, and math anxiety. Psychonomic Bulletin & Review, 14(2), 243–248.
2) Krendl, A. C., et al. (2008). The Negative Consequences of Threat. A Functional Magnetic Resonance Imaging Investigation of the Neural Mechanisms Underlying Women's Underperformance in Math. Psychological Science, 19(2), 168–175.
3) Ramirez, G., & Beilock, S. L. (2011). Writing About Testing Worries Boosts Exam Performance in the Classroom. *Science*, *331*(6014), 211–213. doi:10.1126/science.1199427

Friday, February 1

MIDTERM EXAM 1

Monday, February 4

SIP ASSIGNMENTS and DESIGNING A LESSON PLAN

Readings:

1) See example science lesson plans for Inquiry-based activities: https://www.dartmouth.edu/~academicoutreach/gk12/inquiry.html

Wednesday, February 6

SOCIAL IMPACT PRACTICUM PROJECT WORK—Guest Speaker: Lauren Griswold, Director of Valley Quest Program for Vital Communities

Friday, February 8

NAÏVE SCIENCE CONCEPTS

Readings:

1) Reiner, M., Slotta, J. D., Chi, M. T. H., & Resnick, L. B. (2000). Naive physics reasoning: A commitment to substance-based conceptions. Cognition and Instruction, 18(1), 1–34.
2) Goldberg, R. F., & Thompson-Schill, S. L. (2009). Developmental "roots" in mature biological knowledge. Psychological science, 20(4), 480–487.

Monday, February 11

LEARNING TO THINK AS A SCIENTIST: OBSERVING, QUANTIFYING, TESTING

Readings:

1) Kuhn, D., & Pearsall, S. (2000). Developmental origins of scientific thinking. Journal of cognition and Development, 1(1), 113–129.
2) Chen, Z., & Klahr, D. (1999). All other things being equal: Acquisition and transfer of the control of variables strategy. Child development, 70(5), 1098–1120.

Wednesday, February 13

CONCEPTUAL MENTAL MODELS; ANALOGY IN SCIENTIFIC DISCOURSE

Readings:

1) Kastens, K., & Rivet, A. (2010). Using analogical mapping to assess the affordances of scale models used in Earth and environmental science education. Spatial Cognition VII, 112–124.
2) Chan, J., Paletz, S. B. F., & Schunn, C. D. (2012). Analogy as a strategy for supporting complex problem solving under uncertainty. Memory & Cognition, 1–14.

Friday, February 15

SOCIAL IMPACT PRACTICUM PROJECT WORK

Monday, February 18

ACTIVE AND CONSTRUCTIVE LEARNING

Readings:

1) Chase, C. C., Chin, D. B., Oppezzo, M. A., & Schwartz, D. L. (2009). Teachable agents and the protégé effect: Increasing the effort towards learning. Journal of Science Education and Technology, 18(4), 334–352.
2) Klahr, D., & Nigam, M. (2004). The equivalence of learning paths in early science instruction Effects of direct instruction and discovery learning. *Psychological Science*, *15*(10), 661–667.
3) Prince, M. (2004). Does active learning work? A review of the research. JOURNAL OF ENGINEERING EDUCATION-WASHINGTON-, 93, 223–232.

Wednesday, February 20

"HANDS-ON" LEARNING

Readings:

1) Klahr, D., Triona, L. M., & Williams, C. (2007). Hands on what? The relative effectiveness of physical versus virtual materials in an engineering design project by middle school children. *Journal of Research in Science Teaching*, *44*(1), 183–203.
2) Zacharia, Z. C., & Olympiou, G. (2011). Physical versus virtual manipulative experimentation in physics learning. *Learning and Instruction*, *21*(3), 317–331.
3) Kontra, C., Lyons, D. J., Fischer, S. M., & Beilock, S. L. (2015). Physical Experience Enhances Science Learning. *Psychological Science*, *26*(6), 737–749.

Friday, February 22

SPATIAL SKILLS FOR STEM LEARNING

Readings:

1) Wai, J., Lubinski, D., Benbow, C. P., & Steiger, J. H. (2010). Accomplishment in science, technology, engineering, and mathematics (STEM) and its relation to STEM educational dose: A 25-year longitudinal study. *Journal of Educational Psychology*, *102*(4), 860–871.

2) Miller, D. I., & Halpern, D. F. (2013). Can spatial training improve long-term outcomes for gifted STEM undergraduates? *Learning and Individual Differences*, *26*, 141–152.
3) Sorby, S., Veurink, N., & Streiner, S. (2018). Does spatial skills instruction improve STEM outcomes? The answer is 'yes.' *Learning and Individual Differences*, *67*, 209–222.

Monday, February 25

MIDTERM EXAM 2

Wednesday, February 27—*no class*

Debate prep

Friday, March 1
DEBATE #2
MOTION: *"Hands-on Labs are an Integral Component of High-School Science Education."*

Readings:
1) TBD by Debate Group 3
2) TBD by Debate Group 4

Monday, March 4 + Wednesday, March 6

CLASS DEMONSTRATIONS OF SIP LESSONS