EDUC46:
STEM and Education
Winter Term, 2022

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12 Block: Classes M, W, F @ 12:50-1:55	Professor: David J.M. Kraemer, PhD
Office hours: Live or Zoom by appointment	*Office: Moore 353*
& Wednesdays from 2:00-3:00	*david.kraemer@dartmouth.edu*

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 required readings will be available on Canvas.
- Developing the skills of critically reading empirical research articles and writing for a scientific audience are central to achieving the course goals.

GRADING OVERVIEW

33%	Exam 1
33%	Exam 2
10%	Class Debates and Policy Memo
10%	Final Project, including Project Writeup
10%	Quizzes (average of all 6)
4%	Completion of all assignments and participation

ASSIGNMENTS and ASSESSMENTS

Two exams – ***MONDAY, JANUARY 31ST and MONDAY, FEBRUARY 28TH***

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

Debates and Policy Memo

- An important skill to develop is the ability to distill a large body of opinions and research on a given topic down to a concise set of practical actions that can be argued for and implemented. Accordingly, in this course you will practice doing just that, in the form of crafting an argument with your debate team and then writing a short policy memo (~ 1,000 words) which presents a clear case for a specific course of action regarding your debate topic.
- For the members of each debate team, a short policy memo is due after each debate. The full description of the assignment for each paper will be found on Canvas. For each position paper I'm looking for a well-researched, well-reasoned essay relating to your take on each topic, of roughly 1,000 words in length (about 3 double-spaced pages). Additionally, each paper must reference at least 4 sources (peer-reviewed journal articles, news pieces, etc.) that were not assigned in class; and remember: always cite your sources when you assert a fact (see details on the next page). Each position paper is an individual assignment (not a group project), and will be graded as such – *you are expected to do your own research and convey your own assessment and understanding of the material.*
- For the audience members, each debate team will post the most convincing single article they can find the week before the debate; audience members should come to class prepared having read the article and generated questions to ask of both teams. If you are an audience member, email me at least one question for each team based on the readings *prior to class on the debate day*.

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

Final Project and Writeup – ***Presentations During WEEK 10, Writeup by MARCH 14TH***

- Design lesson plans for informative activities that teachers can use to guide students through various STEM learning experiences.
- Work with your group on a specific project (determined after the first exam) and then write up a brief report as a group on the lesson you design, with everyone contributing a specific individual component of the report.
- During week 10, the groups will share a demo of their activities with the class

COVID-19 INFORMATION

Source: https://covid.dartmouth.edu/faculty-teaching-undergraduate-courses-faqs

Attendance:

You are expected to attend class in person unless you have made alternative arrangements due to illness, medical reasons, or the need to isolate due to COVID-19. For the health and safety of our class community, please: **do not attend class when you are sick**, nor when you have been instructed by Student Health Services to stay home.

If you need to miss class:

- Recordings of class will be posted to Canvas and will be available for everyone.
- Let me know if you need help connecting to classmates who can share class notes.
- Also let me know if you need help with any material and would like to meet.

Safety:

In accordance with College policy, all members of the Dartmouth community are required to wear a suitable face covering when indoors, regardless of vaccination status. This includes our classroom and other course-related locations, such as labs, studios, and office hours. If you need to take a quick drink during class, please dip your face covering briefly for each sip. Eating is never permitted in the classroom. (The only exception to the face covering requirement is for students with an approved disability-related accommodation; see below.)

If you do not have an accommodation and refuse to comply with wearing a face covering or other safety protocols, I am obligated to assure that the COVID-19 health and safety standards are followed, and you will be asked to leave the classroom. You remain subject to course attendance policies, and dismissal from class will result in an unexcused absence. If you refuse to comply with masking or other safety protocols, and to ensure the health and safety of our community, I am obligated to report you to the dean's office for disciplinary action under Dartmouth's Standards of Conduct. Additional COVID-19 protocols may emerge. Pay attention to emails from the senior administrators at the College. I will communicate any changes and their resulting implications for our class community.

Quarantine and Isolation:

Given the evolving state of the COVID-19 pandemic, students may need to quarantine or isolate at some point during the term. Students are not required to disclose health information to faculty, including their quarantine or isolation status. However, in compliance with Dartmouth's Academic Honor Principle, students are expected to act with intellectual honesty and integrity in the performance of their academic assignments and responsibilities.

Students who need additional academic or access support due to a medical condition can reach out to the following deans:

Morgan.A.B.Ogreen@dartmouth.edu (covers '22s and '24s)

or Loren.L.Bowley.Dow@dartmouth.edu (covers '23s and '25s).

GENERAL POLICIES

1. **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/**)

2. **Accommodations:** Students requesting disability-related accommodations and services for this course are required to register with Student Accessibility Services (Getting Started with SAS webpage; student.accessibility.services@dartmouth.edu; 1-603-646-9900) and to request that an accommodation email be sent to me in advance of the need for an accommodation. Then, students should schedule a follow-up meeting with me to determine relevant details such as what role SAS or its Testing Center may play in accommodation implementation. This process works best for everyone when completed as early in the quarter as possible. If students have questions about whether they are eligible for accommodations or have concerns about the implementation of their accommodations, they should contact the SAS office. All inquiries and discussions will remain confidential.

3. **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.

Notifications regarding recording of instruction:

(1) Requirement of consent to recordings

By enrolling in this course, I hereby affirm that I will not under any circumstance make a recording in any medium of any lecture, one-on-one meeting with the instructor, or meeting with other students without obtaining the prior written consent of all those participating, and I understand that if I violate this prohibition, I will be subject to discipline by Dartmouth up to and including expulsion, as well as any other civil or criminal penalties under applicable law.

(2) Consent to recording of course and group office hours

a) By enrolling in this course, I affirm my understanding that this course and any associated group meetings involving students and the instructor, including but not limited to scheduled and ad hoc office hours and other consultations, may be recorded by the instructor within any digital platform used to offer remote instruction for this course;

b) I further affirm that the instructor owns the copyright to their instructional materials, of which these recordings constitute a part, and distribution of any of these recordings in whole or in part without prior written consent of the instructor may be subject to discipline by Dartmouth up to and including expulsion;

c) I authorize Dartmouth and anyone acting on behalf of Dartmouth to record my participation and appearance in any medium, and to use my name, likeness, and voice in connection with such recording; and

d) I authorize Dartmouth and anyone acting on behalf of Dartmouth to use, reproduce, or distribute such recording without restrictions or limitation for any educational purpose deemed appropriate by Dartmouth and anyone acting on behalf of Dartmouth.

Topics and Readings
(ASSIGNED READINGS ARE POSTED ON CANVAS)

January 5

INTRODUCTION and COURSE OVERVIEW

January 7 + 10

1. 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.

January 12

2. 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.

January 14

3. 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

January 17

Martin Luther King, Jr. Day – class will not meet today

January 19

4. 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.

January 21

5. 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.

January 24

DEBATE 1

MOTION: ***"It is important for elementary math classrooms (specifically, grades 2-5) to use physical manipulatives or demonstrations as a regular part of instruction."***

Readings:

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

January 26 + 28

6. MATH ANXIETY, TEST 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

January 31

EXAM 1

February 2

7. DESIGNING A LESSON PLAN
Readings:

1) See example science lesson plans for Inquiry-based activities on Canvas
2) Elstgeest, J. (1985) The right question at the right time.

February 4

8. NAÏVE SCIENCE CONCEPTS AND LEARNING TO THINK SCIENTIFICALLY
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.
3) Kuhn, D., & Pearsall, S. (2000). Developmental origins of scientific thinking. Journal of cognition and Development, 1(1), 113–129.

February 7

9. CONCEPTUAL MENTAL MODELS; ANALOGY IN SCIENTIFIC DISCOURSE
Readings:

1) 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.
2) 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.
3) 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.

February 9

10. 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.

February 11

Winter Carnival – class will not meet today

February 14

11. "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.

February 16 + 18

12. SPATIAL SKILLS FOR STEM LEARNING AND EXPERTISE

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.

February 21

DEBATE 2

MOTION: ***"Hands-on labs are an integral component of high-school science education."***

Readings:

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

February 23 + 25

In-class time to work on group projects and solidify project ideas with guidance

February 28

EXAM 2

March 2 + 4

Groups meet independently and check in with Prof. K for feedback

March 7 + 8

CLASS DEMONSTRATIONS OF GROUP PROJECTS

Note: March 8 is a Tuesday, we will meet during the x-hour @ 1:20-2:10