EDUC56:
STEM and Education

Winter Term, 2015	Prof. David Kraemer, PhD
Tuesday, Thursday 2:00 – 3:50	*david.kraemer@dartmouth.edu*
X-hr: Wednesday 4:15 – 5:05	Office: Raven 212
Kemeny 6	*Office hrs: Mon & Wed @ 2:00 – 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

20%	Midterm Exam
25%	Final Exam
15%	Quizzes: 6 total *(drop lowest)*
14%	Debate Presentation
14%	Research Paper
10%	Class Participation and Attendance
2%	Research Participation *(or alternative assignment)*

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.***
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.

ASSIGNMENTS and ASSESSMENTS

Midterm examination (20%) – ***THURSDAY, FEBRUARY 10TH***

- 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)

Final examination (25%) – ***SATURDAY, MARCH 14TH @ 3pm***

- Same question formats as the midterm
- Cumulative, but greater focus on the material since the midterm

Class Participation & Attendance (10%)

- 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.

Debate Presentation (14%)

- On two separate occasions, two groups will debate a given motion – one group will argue for the motion and one against.
- Each group will research the assigned topic and, as a group, decide on the best evidentiary and logical support for their designated position (for or against).
- Each group will divide the relevant aspects of their argument amongst their members such that *all team members except one* will make an opening statement reflecting a different aspect of their team's overall argument.
- Following the opening statements, class members who are not debating (i.e., the audience), will each ask a question directed at one or both teams.
- Finally, the team member on each team who *did not* make an opening statement will make a closing statement summarizing his or her team's position and incorporating points that were raised during the debate.
- At the start of the debate, I will poll the audience to determine what percentage agrees with the motion prior to the debate. I will poll again afterwards to see if anyone was persuaded by the debate to change his or her mind. The team who persuades the most audience members to choose their side wins the debate. In other words, the goal is to use facts and reasoned argument to change minds.
- Prior to the debate, each team will post 1 reading to Blackboard that they deem the most pertinent for the audience to read in advance. These readings are to be posted on Blackboard no later than 1 week preceding the debate.
- Audience members should form their initial opinions based on these readings and bring to class on debate day a 2-page opinion paper based on these readings.

Position Paper (14%)

- Each team will meet with me on the day prior to the debate to outline their arguments and get my feedback. **At this time, a written outline of your position paper is due from each team member that summarizes your team's position, emphasizing your unique contribution to the team's literature research.** The draft can be in bullet-point list format, but must contain at least 4 relevant scientific references. At least one of these must not be used by any other team member.
- The final version of the position paper will be roughly 8 pages in length (before References), will follow APA Style guidelines for a research paper (see Policies), and is **due one week** following your team's debate. It should incorporate key points from the debate and reference no fewer than 8 peer-reviewed articles.

Quizzes (15%) – *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 highest 5 quiz scores

Research Participation (2%)

- The goal of this assignment is to provide you with an insightful perspective on research studies. Please complete one of the following options by ***Thu, Mar. 18th***:

Option #1:
Volunteer to participate in lab research in the Education Department (2 hours total)

Volunteer to participate in one or more research studies conducted by any research lab in the Education Department, totaling **two hours** of participation (e.g., one two-hour study or two one-hour studies). Specific instructions on how to sign up for a research study are posted on Canvas. To get credit, you must hand in a signed *EDUC16 Participant Confirmation Form* (one signed copy for each study in which you participate) to me in class anytime before ***Thursday, March 18th.*** A copy of the form is posted on Canvas.

Option #2:
Write two methods critiques of published research articles (approx. 1 page each)

If you are unable to participate or uninterested in participating in a research study, you may write an in-depth critique of the methods employed in a published research article. First, locate two empirical articles that were not assigned for this course. Then, for each study, you will write approximately half a page (double-spaced, 12pt font) that explains one aspect of the study procedure that you think the researchers could improve upon without sacrificing the scientific integrity of the study. Be sure to explain why this change is relevant to the authors' conclusions and to how the authors expect the results will generalize to other individuals or other situations that were not

directly tested. Lastly, on the remainder of the page, briefly describe a research question that builds on the current study but that is not fully addressed by the methods in this article. In other words, given the results of the current study, *what is the next question you would like the researchers to address?* Describe how this research question follows from the results of the current study and briefly outline the new methods that the researchers could use to address this question. Hand in your overview to me in class anytime before ***Thursday, March 18th.*** Attach a copy of the first page of the empirical article, including the abstract.

You may also combine these two options. If you choose to do so, each 1-page critique is equivalent to 1 hour of research participation.

SCHEDULE
(ASSIGNED READINGS ARE POSTED ON CANVAS)

1. Tuesday, January 6

INTRODUCTION and COURSE OVERVIEW

ESTIMATION AND NUMBER REPRESENTATIONS

2. Thursday, January 8

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.

3. Tuesday, January 13

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) Carey S. (2004). Bootstrapping and the origin of concepts. *Daedalus*, Winter, 59-68.
3) Lemer, C., Dehaene, S., Spelke, E., & Cohen, L. (2003). Approximate quantities and exact number words: Dissociable systems. *Neuropsychologia*, *41*(14), 1942–1958.

4. Thursday, January 15

LOG VS. LINEAR AND LEARNING NUMBER LINES

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

MATH OPERATIONS AND INSTRUCTION

5. Tuesday, January 20

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.

6. Thursday, January 22

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.

7. Tuesday, January 27

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., Richeson, J. A., Kelley, W. M., & Heatherton, T. F. (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

7.5 Wednesday, January 28

X-Period *(required for Debate 1 teams)*: DEBATE PREP

OUTLINE OF POSITION PAPER DUE*

Meet with each team to outline their positions

8. Thursday, January 29

DEBATE #1

MOTION: *"'Singapore Math' is a worthwhile investment for US schools."*

Readings:

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

9. Tuesday, February 3

NUMBER SYSTEMS AND LEARNING REDUX

** **DEBATE 1 POSITION PAPERS DUE** **

Readings:

1) 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

10. Thursday, February 5

MIDTERM EXAM

Tuesday, February 10

NO CLASS

11. Thursday, February 12

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.

12. Tuesday, February 17

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.

13. Thursday, February 19

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.

14. Tuesday, February 24

LEARNING THE VOCABULARY OF SCIENCE; LEARNING VIA OBSERVATION

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.

15. Thursday, February 26

SMART BOARDS AND CLASSROOM TECH; ED SOFTWARE

Readings:

1) Preston, C., & Mowbray, L. (2008). Use of SMART Boards for teaching, learning and assessment in kindergarten science. Teaching Science, 54(2), 50–53.
2) Emurian, H. H., Holden, H. K., & Abarbanel, R. A. (2008). Managing programmed instruction and collaborative peer tutoring in the classroom: Applications in teaching Java™. Computers in Human Behavior, 24(2), 576–614.
3) Nehm, R. H., Ha, M., & Mayfield, E. (2012). Transforming biology assessment with machine learning: automated scoring of written evolutionary explanations. Journal of Science Education and Technology, 21(1), 183–196.

16. Tuesday, March 3

ONLINE INSTRUCTION; ONLINE MATH AND SCIENCE TUTORING

Readings:

1) Yeh, Y. C. (2009). Integrating e-learning into the Direct-instruction Model to enhance the effectiveness of critical-thinking instruction. Instructional Science, 37(2), 185–203.
2) Sitzmann, T., Kraiger, K., Stewart, D., & Wisher, R. (2006). The comparative effectiveness of web-based and classroom instruction: A meta-analysis. Personnel Psychology, 59(3), 623–664.

16.5 Wednesday, March 4

X-Period *(required for Debate 2 teams)*: DEBATE PREP

OUTLINE OF POSITION PAPER DUE*

Meet with each team to outline their positions

17. Thursday, March 5

DEBATE #2

MOTION: *"Science labs are worthwhile for US high schools."*

Readings:

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

18. Tuesday, March 10

VIDEO GAMES AS CLASSROOM INSTURCTION

** **DEBATE 2 POSITION PAPERS DUE** **

Readings:

1) Thompson, M. E., Ford, R., & Webster, A. (2011). Effectiveness of Interactive, Online Games in Learning Neuroscience and Students' Perception of the Games as Learning Tools A Pre-experimental Study. Journal of allied health, 40(3), 150–155.
2) Kazimoglu, C., Kiernan, M., Bacon, L., & Mackinnon, L. (2012). A Serious Game for Developing Computational Thinking and Learning Introductory Computer Programming. Procedia-Social and Behavioral Sciences, 47, 1991–1999.

FINAL EXAM

Saturday, March 14 @ 3pm