Multiple Representations in Physical Science
15:256:557 (1)
3 Credits

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Office Hours: by appointment	Prerequisites or other limitations: “Development of Ideas in Physical Science”
Mode of Instruction: ___ Lecture __X_ Seminar ___ Hybrid ___ Online ___ Other	Permission required: _x_ No __Yes Directions about where to get permission numbers: from the instructor

Learning goals

1. To connect learning of physics with the structure and function of the brain.
2. To apply the knowledge of brain science and cognitive science to problem solving in a physics class.
3. To master different ways to engage diverse students in meaningful problem solving in every unit of a high school physics/physical science course focusing specifically on formative assessment and self-assessment.
4. To deepen your own understanding of physics concepts, relations and multiple representations.

Course catalogue description

The goal of the course is to acquaint prospective and in-service science teachers with the multiple representation method used in constructing concepts and problem solving in physical science. Multiple representations are a powerful tool that aids the brain during concept acquisition and problem solving. Multiple representations enhance metacognition and epistemic cognition. Being familiar with the multiple representations used in a discipline is crucial for mastering and teaching it. In this course we will focus on such representations as pictorial representations, motion and force diagrams, graphs, energy bar charts, ray and wave front diagrams, and applications of these representations to problem solving. We will also learn how to help students construct and use analogies.

Class materials:

A set of papers from the Reading List additional papers will be posted on the class website.
E. Etkina, M. Gentile, & A. Van Heuvelen, Physics the process approach (in press).
A. Van Heuvelen & E. Etkina. Active Learning Guide. (Student and Teacher version), San Francisco: Addison Wesley, 2006. ISBN 0-8053-90782
J. Zull, *The art of changing the brain*. Sterling, VA: Stylus Publishing. 2002.
J. Zull, *From brain to mind.* Sterling, VA: Stylus Publishing. 2011.
G. P. Wiggins & J. McTighe, Understanding by Design, NJ: Pearson, 2005.

Physics Union Mathematics (PUM) Curriculum modules, to download the modules and final assessment go to http://pum.rutgers.edu then click on Teacher Resources, then Resources for Teachers. To access the site use login name **pum** and password **pum2009.** *Please make sure you have all HS modules downloaded before the semester starts.*

ActivPhysics by A. Van Heuvelen [available on-line] at http://wps.aw.com/aw_young_physics_11
PHET resource by University of Colorado, Boulder: http://phet.colorado.edu
Web sites with class activities: http://paer.rutgers.edu/pt3 and http://paer.rutgers.edu/scientificabilities

PLEASE IF YOU OWN A LAPTOP, BRING IT TO ALL CLASS MEETINGS, MAKE SURE YOU CAN ACCESS ALL OF THESE WEBSITES AND HAVE THE SOFTWARE TO USE THE RESOURCES

Optional, but is a good resource
A. Arons, Teaching Introductory Physics, Wiley&Sons, 1997. ISBN 978-0471137078

Reading List

1. Gentner, D., & Gentner, D. R. (1983). Flowing waters or teeming crowds: Mental models of electricity. In D. Gentner & A. L. Stevens (Eds.), *Mental models* (pp. 99-129). Hillsdale, NJ: Lawrence Erlbaum Associates. (Reprinted in M. J. Brosnan (Ed.), *Cognitive functions: Classic readings in representation and reasoning*. Eltham, London: Greenwich University Press).
2. Glynn, S. M., Duit, R., & Thiele, R. (1995). Teaching science with analogies: A strategy for constructing knowledge. In Glynn, S. M., & Duit, R., Eds. *Learning science in schools: Research reforming practice*. Mahwah, NJ: Lawrence Erlbaum Associates, Publishers 247 - 271.
3. Van Heuvelen, A. (1991). Learning to think like a physicist: A review of research-based instructional strategies. *American Journal of Physics*, 59 (10), 891 - 897.
4. Van Heuvelen, A. And Xou, X. (2001). Multiple Representations of Work-Energy Processes, *American Journal of Physics,* 69 (2), 184 - 194.
5. Van Heuvelen, A. and Maloney, D. P. (1999). Playing Physics Jeopardy, *American Journal of Physics,* 67*,* 252 - 257.
6. Etkina, E., Warren, A., & Gentile, M. (2005). The role of models in physics instruction. The Physics Teacher, 44 (1), 34-39.
A series of papers that can be downloaded from the Physical Review Special Topics Physics Education Research website: http://prst-per.aps.org/

Suggested Extra Reading

7. N. D. Finkelstein, W. K. Adams, C. J. Keller, P. B. Kohl, K. K. Perkins, N. S. Podolefsky, S. Reid, and R. LeMaster, Phys. Rev. ST Phys. Educ. Res , **1**, 010103 (2006).
8. W. K. Adams, K. K. Perkins, N. S. Podolefsky, M. Dubson, N. D. Finkelstein, and C. E. Wieman, Phys. Rev. ST Phys. Educ. Res , **1**, 010101 (2006).
9. L. Ding, R. Chabay, Bruce Sherwood, and R. Beichner, Phys. Rev. ST Phys. Educ. Res. **2**, 010105 (2006).
10. G. Kortemeyer Phys. Rev. ST Phys. Educ. Res. **3**, 010101 (2007).
11. N. S. Podolefsky and N. D. Finkelstein Phys. Rev. ST Phys. Educ. Res. **3**, 010109 (2007).
12. S. J. Pollock, N. D. Finkelstein, and L. E. Kost Phys. Rev. ST Phys. Educ. Res. **3**, 010107 (2007).
13. D. T. Brookes and E. Etkina Phys. Rev. ST Phys. Educ. Res. **3**, 010105 (2007).
14. J. Tuminaro and E. F. Redish Phys. Rev. ST Phys. Educ. Res. **3**, 020101 (2007).

__Grading and Activities__ Your course final grade will be based on how you meet the standards listed below. Each standard will be assessed __multiple times__ according to the rubric. If at any point you fail to meet the standard, you will have an opportunity to be assessed again. **Each assignment can be improved.** I encourage you to try as many times as you need to make the assignment perfect.

Rubric: 1 – does not meet expectations, 2 – moving towards meeting expectations; 3 – meets expectations; 4 – exceeds expectations (I want to brag about you). I believe that every student in this course will work to exceed my expectations.

General standards:

GS1: Is familiar with NJ Science Core Curriculum Standards and can use them when planning instruction.

GS2: Is able to connect recommendations of brain research to physics instruction, specifically to interpret literature recommendations and apply to specific instructional moves.

GS3: Is able to interpret student responses (oral or written) and revise planned instruction based on the responses during microteaching.

GS4: Is able to collect (or to describe) evidence that will indicate that students achieved a proposed goal.

GS5: Is able to write a problem-solving multiple representations oriented lesson plan that has all required elements and implement the lesson in practice.

GS6: Is able to devise a beginning of a problem-solving lesson that builds on student ideas and engages them in meaningful application of physics ideas (problem solving) during microteaching.

GS7: Is able to write a unit plan that has all required elements.

GS8: Is able to solve (or explain why the solution is not possible) for any physics problem at the level of algebra-based physics in the areas that are addressed in the course.

Lesson Specific Standards (broken down into Content Standards – CK and Pedagogical Content Knowledge Standards – PCK)

Area of physics	CK	PCK
Geometrical optics	**CK-1 Can use real optical systems and ray diagrams to locate an image produced by a reasonable optical system, including glasses.**	**PCK- 1 Can show how to help students learn and use ray diagram and combine them with mathematical representations.**
Electric field	**CK-2 – Can use different graphical and mathematical representations of electric field to reason about electrostatic processes in a vacuum, dielectrics, and conductors.** **CK-3 Can use capacitors to enhance understanding of electric fields.**	**PCK-2 Can show how help students write and use a rubric to self-assess their use of graphical representations of electric field (electric field vectors, electric field lines and equipotential surfaces).** **PCK-3 Can plan a sequence of instructional moves that will help students master productive representations of electric field and solve quantitative problems.**
DC current	**CK-4 Can use analogies, microscopic models and physical quantities to reason about electric circuits**	**PCK-4 Can solve the same problem using analogies, microscopic models and physical quantities and explain what students will benefit from which**

	CK-5 Can solve complex electric circuit problems involving multiple loops, multiple batteries and batteries having internal resistance.	**approach.** **PCK-5 Can show a sequence of instructional moves to help students master the concepts of DC circuits using simulations.** **PCK-6 Can plan a problem solving lesson in DC circuits that involves quantitative reasoning.**
Magnetic field	**CK-6 Can use all graphical and mathematical representations of magnetic field to reason about magnetic processes in a vacuum, diamagnetics, paramagnetics and ferromagnetics.** **CK-7 Can use capacitors to enhance understanding of electric fields.**	**PCK-7 Can show how help students write and use a rubric to self-assess their use of graphical representations of magnetic field (magnetic field vectors and magnetic field lines).** **PCK-8 Can plan a sequence of instructional moves that will help students solve progressively more difficult problems in magnetic fields.**
Photon model of light	**CK-8 Can explain photoelectric effect using the photon model of light and energy bar charts.** **CK-9 Can provide experimental evidence for the photon model**	**PCK-9 Can show how to use simulations to help students learn about photoelectric effect.**
Mechanics	**CK-10 Can use motions diagrams, kinematics graphs, force diagrams and momentum and energy bar charts to analyze typical mechanics situations**	**PCK-10 Can describe in detail how to help students master the representations used in mechanics (see the column on the left) and how to use them to make a bridge from concrete phenomena to mathematics. Specifically can describe student ideas related to these representations and ways to help students learn.**

Description of activities

Attendance, participation in class discussions: Attendance and participation in each class meeting are crucial for your learning. Discussions in class will focus on problem solving and research on student learning in a particular area.

Quizzes Every class will start with a quiz. A quiz will consist of a physics problem that you will need to solve and a set of questions regarding cognitive processes and student learning. If you wish to have more time for the quiz, please come to class early, I will be in the room at 4.30 pm. Every quiz can be improved.

Homework: Homework assignments will vary each week. All of them will address a specific standard. The homework is due Wednesday night by e-mail to Eugenia. The file should be labeled with your first name and week number: Laura1.doc

2. Each week you will be given a reading assignment. It is your responsibility to read the papers and the chapters from 2 books. The material from assigned readings will be on the exam.

Micro Teaching: You will choose a topic for problem-solving lesson in class from the class schedule table (160 min). It will be a problem-solving lesson, not a concept construction lesson. You can choose any lesson format you want, creative ideas are welcome. It is very important that your lesson is based on student ideas, uses productive representations, engages the students in quantitative problem solving and shows connections to their lives (though technology, usefulness and applicability of ideas, etc). Please, plan your lesson in advance and submit the first draft 2 weeks prior to your teaching. You will need to submit a lesson plan after you teach the lesson (this is the plan that goes into your portfolio if you are in the teacher certification program). Make sure that the lesson addresses general standards GS1-6 and specific CK and PCK standards.

Unit plan and lesson plan: After you teach the lesson, you will write a unit plan for a unit where this representation is most heavily used. The unit plan together with the lesson plan will be shared with your classmates. The unit plans goes into your portfolio. Make sure that the unit addresses general standard GS7 listed for the course and specific for this unit CK and PCK standards.

Final exam: At the end of the course there is an oral examination (May 13th). You will receive a list of exam questions in advance. They will be posted on the class website. The exam will consist of a discussion with Eugenia on two of the questions (selected randomly) and problem solving.

Academic integrity: Make sure that you provide proper citations for all materials that you use in your lesson and unit plans.

Tentative list of topics for discussions (by week)

Week	**Topic**	**Assignment (Ch)**	**PTS**	**NSCS**	**NJCCCS**
1	Using MR to understand complex phenomena. Types of MR. MR in problem solving.	Preface	PTS Standard VIII: iii(3, 4).	A	5.1 (A) 5.2 (E)
2-4	Brain, memory, analogies and MR. MR in electric circuits; lesson 4 to **pick for teaching** – complex circuits with batteries having internal resistance	PTPA Ch. 17; ALG Ch. 17; PUM DC circuits module; Zull I Introduction Chapters 1-3	PTS Standard VIII: iii (3, 4).	B	5.1 (A-D); 5.2 (C-E)
5-6	MR in geometrical optics; lesson 6 to **pick up for teaching** – glasses	PTPA Ch. 21-21; ALG Ch. 21-22. Zull I Chapters 4-6 UBD chapters 6-10	PTS Standard VIII: iii (3, 4).	B	5.1 (A-D); 5.2 (C)

8-9	MR in electric field; lesson 9 – capacitors **pick up for teaching**	PTPA Ch. 15; AG Ch. 15; PUM Electric field module ALG. Ch. 9 Zull I chapters 10-14	PTS Standard VIII: iii (3, 4).	B	5.1 (A-D); 5.2 (A-E)
10-11	MR in magnetism. Lesson 11 – projects in diamagnetism, paramagnetism and ferromagnetism, all participate	PTPA Ch 17, 18; ALG Ch. 17-18 Zull II chapters 1-3	PTS Standard VIII: iii (3, 4).	B	5.1 (A-D); 5.2 (C-E)
12	Traditional physics assessments (FCI, MBT, CSEM, BEMA)	Zull II Ch.4-6			
13-14	Multiple representations in modern physics (photoelectric effect and atomic structure)	PTPA Ch 26, 27 Zull II chapter 7-10	PTS Standard VIII: iii (3, 4); PTS Standard I: iii(2)	B, G	5.1 (D), 5.1 (B-E)
15.	Final exam.				