Chemistry 758 – Chemistry Education Research

Fall 2022

Instructor: Professor Ryan Stowe
Email: rstowe@chem.wisc.edu
Office: CHEM B221
Instructor Availability: by appointment
Course Website: https://canvas.wisc.edu/courses/323166
Credits: 2

Meeting Time and Location: TR 9:55-10:45am; Room CHEM 8431

Instructional Mode: Face-to-face

How Credit Hours are Met: The credit standard for this course is met by an expectation of a total of 90 hours of student engagement with course learning activities (at least 45 hours per credit). This includes 27 50-minute class periods throughout the fall semester and carries the expectation that students will work on course activities (reading, writing, studying, etc.) for about 2-3 hours out of the classroom for every class period. The syllabus includes additional information about meeting times and expectations for student work.

OFFICIAL COURSE INFORMATION

Course Description: An introduction to chemistry education research and the theories that underpin it. Models of learning will be developed and refined throughout the semester on the basis of primary literature discussed in-class. How theories of cognition could and should inform learning objectives and assessments in college chemistry learning environments will be explored. Substantial emphasis will be placed on critically reading and analyzing studies in the chemistry education research literature with an eye toward the implicit and explicit theories of cognition informing the work. No prior experience with coursework in the learning sciences is assumed. Appropriate for students engaged in discipline-based education research as part of a graduate degree, those interested in pursuing academic careers, and those broadly interested in scholarship related to teaching and learning.

Course Requisites: Graduate/professional standing

Course Options: 50% Graduate Coursework Requirement

Course Learning Outcomes:

- Develop and refine a model of learning based on discussion and analysis of the primary chemistry education and science education literature
- Articulate outcome(s) for a chemistry course and justify why they are worthwhile
- Assess the validity of conclusions in the literature
- Design a plan for investigating whether a chemistry learning environment is supporting students' progress toward your desired outcome(s)

REPRESENTATIVE LIST OF TOPICS

Week 1 - What is the point of science learning?
Week 2 - Early theories of learning
Week 3 - Conceptual change
Week 4 - What should students know and be able to do after a course in chemistry?
Week 5 - Modern reform efforts (3DL, Systems Thinking etc.)
Week 6 - Assessing Learning
Week 7 - Curricular Transformations
Week 8 - Epistemology
Week 9 - Practices and Pseudopractices
Week 10 - Uncertainty
Week 11 - Models for sensemaking
Week 12 - Epistemological Messaging
Week 13 - Class-chosen topic

Weeks 14-15 will be dedicated to student presentations. The topic for Week 13 will be chosen by the class. Possible topics include: scaling up innovations (Design-Based Implementation Research), characterization of student motivation, affect and identity, equitable and inclusive chemistry learning environments, course-based research experiences, faculty attitudes and beliefs toward teaching etc.

REPRESENTATIVE ASSIGNMENTS LIST (distributed over the semester)

Preparation for and participation in class discussions. Each week we will discuss readings that address various aspects of science education research. Students are expected to come to class prepared and ready to participate actively in class discussions, having carefully and critically read the assigned text(s).

Reflective reading journal. Students will be expected to write weekly written reflections on the assigned readings, which will be periodically reviewed (once every three weeks). Most weeks, you will use a general template for reflections (described below). Some reading assignments will also have more specific guiding questions to reflect on in your journal.

Lead discussant. Students will be asked to facilitate a discussion related to one of the course readings/topics during the latter half of the semester. Core readings will be provided by Ryan, but students are encouraged to identify supplementary materials and develop strategies for actively engaging the whole class.

Course portfolio. Students will develop 1) a learning outcome for a college chemistry course

together with justification for why this outcome is worthwhile, 2) a strategy for assessing progress toward this outcome, 3) a curricular unit with the potential to support students toward your learning outcome and a strategy for assessing the efficacy of your curricular unit. The weighting of each assignment as well as the dates they are due are listed below.

Final presentation. Students will present a 15-minute presentation detailing how they would study the impact of their curricular unit.

REPRESENTATIVE READING LIST (distributed over the semester)

(1) Feinstein, N. Salvaging Science Literacy. *Science Education* **2011**, *95* (1), 168–185. https://doi.org/10.1002/sce.20414.
(2) Feinstein, N. W.; Waddington, D. I. Individual Truth Judgments or Purposeful, Collective Sensemaking? Rethinking Science Education's Response to the Post-Truth Era. *null* **2020**, *55* (3), 155–166. https://doi.org/10.1080/00461520.2020.1780130.
(3) Phillips, D. C.; Soltis, J. F. Behaviorism. In *Perspectives on Learning*; Teachers College Press, Columbia University: New York, NY, USA, 2009; pp 21–32.
(4) Phillips, D. C.; Soltis, J. F. Piagetian Structures and Learning. In *Perspectives on Learning*; Teachers College Press, Columbia University: New York, NY, USA, 2009; pp 41–50.
(5) National Research Council. *How People Learn: Brain, Mind, Experience, and School: Expanded Edition*, 2 edition.; National Academies Press: Washington, D.C., 2000.
(6) von Glasersfeld, E. Cognition, Construction of Knowledge, and Teaching. *Synthese* **1989**, *80*, 121–140.
(7) Vosniadou, S. Reframing the Classical Approach to Conceptual Change: Preconceptions, Misconceptions and Synthetic Models. In *Second International Handbook of Science Education*; Fraser, B. J., Ed.; Springer International Handbooks of Education; Springer: Dordrecht, 2012; pp 119–130.
(8) Posner, G. J.; Strike, K. A.; Hewson, P. W.; Gertzog, W. A. Accommodation of a Scientific Conception: Toward a Theory of Conceptual Change. *Sci. Ed.* **1982**, *66* (2), 211–227. https://doi.org/10.1002/sce.3730660207.
(9) Hammer, D. Student Resources for Learning Introductory Physics. *American Journal of Physics* **2000**, *68* (S1), S52–S59. https://doi.org/10.1119/1.19520.
(10) Gillespie, R. J. The Great Ideas of Chemistry. *J. Chem. Educ.* **1997**, *74* (7), 862–864. https://doi.org/10.1021/ed074p862.
(11) Atkins, P. Chemistry: The Great Ideas. *Pure Appl. Chem., PAC* **1999**, *71* (6), 927–929. https://doi.org/10.1351/pac199971060927.
(12) Murphy, K.; Holme, T.; Zenisky, A.; Caruthers, H.; Knaus, K. Building the ACS Exams Anchoring Concept Content Map for Undergraduate Chemistry. *J. Chem. Educ.* **2012**, *89* (6), 715–720. https://doi.org/10.1021/ed300049w.
(13) The National Research Council. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*; National Academies Press: Washington, D.C., 2012.
(14) Cooper, M. M.; Posey, L. A.; Underwood, S. M. Core Ideas and Topics: Building Up or Drilling Down? *J. Chem. Educ.* **2017**, *94* (5), 541–548. https://doi.org/10.1021/acs.jchemed.6b00900.
(15) Freeman, S.; Eddy, S. L.; McDonough, M.; Smith, M. K.; Okoroafor, N.; Jordt, H.; Wenderoth, M. P. Active Learning Increases Student Performance in Science,

Engineering, and Mathematics. *PNAS* **2014**, *111* (23), 8410–8415. https://doi.org/10.1073/pnas.1319030111.
(16) Wieman, C. E. Large-Scale Comparison of Science Teaching Methods Sends Clear Message. *Proc Natl Acad Sci USA* **2014**, *111* (23), 8319. https://doi.org/10.1073/pnas.1407304111.
(17) Mahaffy, P. G.; Matlin, S. A.; Whalen, J. M.; Holme, T. A. Integrating the Molecular Basis of Sustainability into General Chemistry through Systems Thinking. *J. Chem. Educ.* **2019**, *96* (12), 2730–2741. https://doi.org/10.1021/acs.jchemed.9b00390.
(18) Ralph, V. R.; Scharlott, L. J.; Schwarz, C. E.; Becker, N. M.; Stowe, R. L. Beyond Instructional Practices: Characterizing Learning Environments That Support Students in Explaining Chemical Phenomena. *Journal of Research in Science Teaching* **2022**, *59* (5), 841–875. https://doi.org/10.1002/tea.21746.
(19) Mulford, D. R.; Robinson, W. R. An Inventory for Alternate Conceptions among First-Semester General Chemistry Students. *J. Chem. Educ.* **2002**, *79* (6), 739–744. https://doi.org/10.1021/ed079p739.
(20) Stowe, R. L.; Cooper, M. M. Assessment in Chemistry Education. *Israel Journal of Chemistry* **2019**, *59*, 598–607. https://doi.org/10.1002/ijch.201900024.
(21) Cooper, M. M.; Kouyoumdjian, H.; Underwood, S. M. Investigating Students' Reasoning about Acid–Base Reactions. *J. Chem. Educ.* **2016**, *93* (10), 1703–1712. https://doi.org/10.1021/acs.jchemed.6b00417.
(22) Coffey, J. E.; Hammer, D.; Levin, D. M.; Grant, T. The Missing Disciplinary Substance of Formative Assessment. *Journal of Research in Science Teaching* **2011**, *48* (10), 1109–1136. https://doi.org/10.1002/tea.20440.
(23) Sevian, H.; Talanquer, V. Rethinking Chemistry: A Learning Progression on Chemical Thinking. *Chem. Educ. Res. Pract.* **2014**, *15* (1), 10–23. https://doi.org/10.1039/C3RP00111C.
(24) Flynn, A. B.; Ogilvie, W. W. Mechanisms before Reactions: A Mechanistic Approach to the Organic Chemistry Curriculum Based on Patterns of Electron Flow. *J. Chem. Educ.* **2015**, *92* (5), 803–810. https://doi.org/10.1021/ed500284d.
(25) Cooper, M.; Klymkowsky, M. Chemistry, Life, the Universe, and Everything: A New Approach to General Chemistry, and a Model for Curriculum Reform. *J. Chem. Educ.* **2013**, *90* (9), 1116–1122. https://doi.org/10.1021/ed300456y.
(26) Cooper, M. M.; Stowe, R. L.; Crandell, O. M.; Klymkowsky, M. W. Organic Chemistry, Life, the Universe and Everything (OCLUE): A Transformed Organic Chemistry Curriculum. *J. Chem. Educ.* **2019**, *96* (9), 1858–1872. https://doi.org/10.1021/acs.jchemed.9b00401.
(27) Hofer, B. K.; Pintrich, P. R. The Development of Epistemological Theories: Beliefs about Knowledge and Knowing and Their Relation to Learning. *Review of Educational Research* **1997**, *67*, 88–140. https://doi.org/10.2307/1170620.
(28) Hammer, D.; Elby, A. On the Form of a Personal Epistemology. In *Personal Epistemology: The Psychology of Beliefs about Knowledge and Knowing*; Hofer, B. K., Pintrich, P. R., Eds.; Lawrence Erlbaum Associates: Mahwah, N.J., 2002; pp 169–190.
(29) Russ, R. S. Epistemology of Science vs. Epistemology for Science. *Sci. Ed.* **2014**, *98* (3), 388–396. https://doi.org/10.1002/sce.21106.
(30) Berland, L. K.; Schwarz, C. V.; Krist, C.; Kenyon, L.; Lo, A. S.; Reiser, B. J. Epistemologies in Practice: Making Scientific Practices Meaningful for Students. *J Res Sci Teach* **2016**, *53* (7), 1082–1112. https://doi.org/10.1002/tea.21257.
(31) Berland, L. K.; Hammer, D. Framing for Scientific Argumentation. *J. Res. Sci. Teach.* **2012**, *49* (1), 68–94. https://doi.org/10.1002/tea.20446.

(32) McNeill, K. L.; González-Howard, M.; Katsh-Singer, R.; Loper, S. Pedagogical Content Knowledge of Argumentation: Using Classroom Contexts to Assess High-Quality PCK Rather than Pseudoargumentation. *Journal of Research in Science Teaching* **2016**, *53* (2), 261–290. https://doi.org/10.1002/tea.21252.
(33) Manz, E. Resistance and the Development of Scientific Practice: Designing the Mangle Into Science Instruction. *null* **2015**, *33* (2), 89–124. https://doi.org/10.1080/07370008.2014.1000490.
(34) Manz, E.; Suárez, E. Supporting Teachers to Negotiate Uncertainty for Science, Students, and Teaching. *Science Education* **2018**, *102* (4), 771–795. https://doi.org/10.1002/sce.21343.
(35) Odden, T. O. B.; Russ, R. S. Defining Sensemaking: Bringing Clarity to a Fragmented Theoretical Construct. *Science Education* **2019**, *103*, 187–205. https://doi.org/10.1002/sce.21452.
(36) Gouvea, J.; Passmore, C. 'Models of' versus 'Models For.' *Science & Education* **2017**, *26* (1), 49–63. https://doi.org/10.1007/s11191-017-9884-4.
(37) Russ, R. S. Characterizing Teacher Attention to Student Thinking: A Role for Epistemological Messages. *Journal of Research in Science Teaching* **2018**, *55* (1), 94–120. https://doi.org/10.1002/tea.21414.
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GRADING

Your final grade for the course will be determined using the following scale, with the meaning of each grade paraphrased below:

A (92-100%): Excellent performance shown consistently in all aspects of the course
AB (88-91%): Good performance with high achievement in most of the course
B (82-87%): Adequate performance reflecting a basic understanding of the material
BC (78-81%): Adequate performance with some deficiencies
C (70-77%): Minimal performance with serious deficiencies
D (60-69%): Unsatisfactory performance
F (<60%): Very unsatisfactory performance

The success of this course will depend upon our shared responsibility to develop an active and respectful intellectual exchange. While attendance is required, it is only the first step toward meaningful participation. You are expected to come to class fully prepared to engage in lively, pointed, and collegial discussion and analysis of the week's assigned reading.

If you miss a class, you are required to submit a 500-word written review essay of the assigned reading(s) for that particular class. A hard copy of the essay is due no later than two weeks after

the missed class. To the extent possible, please notify me of your absence *in advance* via email. As a rule, you should also email me to check in following an absence.

Grades will be based on in-class participation (20%) and performance on assignments (80%). The percent contribution of each assignment to your overall grade is listed below:

20% - Serving as lead discussant
20% - Reflective reading journal
30% - Class portfolio
10% - Final presentation

Participation Grade Guidelines

A: This student never misses class, always completes assigned readings, and comes to class prepared to think carefully, making connections between readings and across topics. He or she is willing to take the lead in discussion periodically, posing interesting questions or taking risks by answering tough questions. He or she avoids dominating discussion, instead participating mindfully in discussion with other students, considering their ideas and responding thoughtfully and respectfully. He or she helps to create a sense of a shared conversation in the group as a whole. This student shows passion for the work of the class and is committed fully to our work while in the classroom.

AB: This student does most of what an A student does, but may be slightly deficient in one area – for instance, he or she may be a conscientious reader and thinker who tends not to listen to other students or otherwise dominates conversation instead of engaging in productive deliberation. Or, he or she may have been late to class a few times, or may have missed a reading or two.

B: This student participates often, but not consistently. He or she may attend every class and do all the readings but avoids taking the lead in discussion, instead only responding to questions or adding periodically to others' ideas. This student may participate well, **but may have missed a class and failed to submit the makeup assignment**.

BC: This student may be a frequent but superficial discussion participant. The student may let shyness keep him or her from participating as fully as he or she should. At times the student may seem not to have done the readings, though he or she usually comes prepared.

C: This student is intermittently prepared for class (**e.g., participates well but has missed two classes without submitting a makeup assignment**). He or she may have flashes of brilliance, but rarely participates beyond the occasional superficial comment.

D: This student very rarely participates, and only in superficial ways.

F: This student **has missed three classes without submitting a makeup assignment** and/or attends most classes but never participates.

Details regarding each assignment in CHEM 758 can be found below:

Reading Reflections

After completing each reading assignment, write brief responses (*i.e.,* 2-3 sentences) in response to 2 of the following 3 questions:

1. What are the main points of this collection of readings?
2. What information in this reading did you find surprising or new? Why?
3. What portions of the reading did you find confusing? Why?

Reading reflections should be added to the appropriate Discussion thread on Canvas (*i.e.,* Week 1 Reading Reflection should contain question responses linked to week 1 readings). **Reading reflections are due at 9am each Tuesday - Week 1 reading reflections are due at 9am on Thursday, Sept. 8th 2022 due to classes beginning mid-week.**

***Why reading reflections*?**

To help us reflect more deeply on readings in this course, we will use reading reflections. These reading reflections are designed to help the reader engage with the material in a deeper way, and to construct new meaning from it. The reflections also have the advantage of providing me as the instructor with detailed information about your learning in the course. This not only helps guide my preparation of course activities, but also helps connect us as a community of learners. Your response need not be long, but must clearly indicate careful reading and thoughtful reflection. Please respond to at least two of the three main questions listed above.

Rubric for Evaluation

10 points Responses to both questions are labeled and clearly indicate careful reading and deep reflection. Responses submitted on time.

5 points Responses are not specific, do not clearly indicate reflection in some instances, or are late.

0 points No response

Class Portfolio

You will be asked to submit three assignments over the course of the semester that, together, comprise your "class portfolio". This portfolio accounts for 30% of the points in the course. Descriptions of each portfolio component, as well as when they are due, are provided below:

Learning Objective (50 pts): Your learning objective should precisely describe some manner of valuable outcome that you can characterize. I encourage you to think broadly about "outcome" here - your objective does not have to relate to recall of canonical facts and skills. The objective you write may be related to an undergraduate-level chemistry course in any sub-discipline. Carefully consider the objective you write, as it will structure the remaining two assignments that will comprise your course portfolio.

A draft objective should be submitted to Ryan by **Tuesday, Sept. 27th at 9am CT**. Feedback on draft objectives will be delivered prior to Monday, October 4th, 2022.

Your final learning objective is due to Ryan by **Tuesday, Oct. 11th at 9am CT.** The final learning objective is worth 35 points.

Assessment Item (100pts): The assessment item you generate for this class should have the potential to elicit evidence of student progress toward your stated learning objective. Different sorts of objectives require different sorts of assessments. If, for example, you wanted to characterize students' understanding of what it means to know and learn chemistry, a suite of "predict the product" questions will be ill-suited to your goals.

Evidence Statements: Generation of the assessment item should involve first drafting statements of the evidence you would find convincing that students were progressing toward your objective. We take an expansive view of assessment in this class, so your evidence statements need not focus on how well students' answers align with canon. They do, however, have to represent concrete observations that could in principle be elicited by a task.

Item generation: After you have written appropriate evidence statements, you should work to design a task with the potential to elicit the evidence these statements describe.

A draft of your evidence statements and corresponding assessment item(s) are due to Ryan by **Tues., Oct. 25th at 9am CT.** Feedback on draft items will be sent out prior to Monday, Oct. 31st.

Your final assessment item is due to Ryan by **Tues., Nov. 8th at 9am CT.**

Curricular Unit Design and Assessment (150pts) The final part of your class portfolio will involve designing an instructional unit to support students in progressing toward your learning objective. You should write up 1) a description of the unit you propose together with why you believe it would support students in striving toward your learning goals and 2) a plan for assessing how well your instructional unit worked. Unit design should be informed by literature on how people learn from this course and clearly have the potential to support progress toward your stated learning objective. Assessment strategies may make use of the assessment item(s) you developed or other instruments published in the literature. Your plan should explain why your assessment strategy is well-suited to demonstrating the efficacy of your instructional unit.

The write-up for this portfolio component should be no-longer than 2000 words (excluding references) and consist of the following sections:

Description of Instructional Unit: This section should include details on how your instructional unit will support students in building toward your learning objective. It should specify learning environment pedagogies, conceptual or epistemological foci and activities that will be employed. Where appropriate, learning theory should be used to justify design choices.

Research Questions: Your write-up should explicitly describe the questions you are looking to answer by studying your learning environment.

Methods and Frameworks: Explicitly describe how you will assess the impact of your instructional unit on student learning (broadly defined). Define the measures you will use as well as how and when they will be administered. As appropriate, discuss the theoretical perspectives that will influence how you interpret evidence from the measures you administer.

Limitations: Every experimental design in ChemEd has a host of limitations. Describe how the inferences of your study design could support will be limited.

A draft of your curricular unit design and assessment summary is due to Ryan by 9am on Tues., Nov 22nd. You will receive feedback on this draft by Mon., Nov. 28th. This draft is worth 25pts, which will be awarded if the document is submitted online and the contents of the document represent a good-faith effort.

The final draft of your curricular unit design and assessment summary is due on Thurs., Dec. 15th at 9am.

ACADEMIC INTEGRITY

By enrolling in this course, each student assumes the responsibilities of an active participant in UW-Madison's community of scholars in which everyone's academic work and behavior are held to the highest academic integrity standards. Academic misconduct compromises the integrity of the university. Cheating, fabrication, plagiarism, unauthorized collaboration, and helping others commit these acts are examples of academic misconduct, which can result in disciplinary action. This includes but is not limited to failure on the assignment/course, disciplinary probation, or suspension. Substantial or repeated cases of misconduct will be forwarded to the Office of Student Conduct & Community Standards for additional review. For more information, refer to studentconduct.wiscweb.wisc.edu/academic-integrity/.

ACCOMMODATIONS FOR STUDENTS WITH DISABILITIES

McBurney Disability Resource Center syllabus statement: "The University of Wisconsin-Madison supports the right of all enrolled students to a full and equal educational opportunity. The Americans with Disabilities Act (ADA), Wisconsin State Statute (36.12), and UW-Madison policy (Faculty Document 1071) require that students with disabilities be reasonably accommodated in instruction and campus life. Reasonable accommodations for students with disabilities is a shared faculty and student responsibility. Students are expected to inform faculty [me] of their need for instructional accommodations by the end of the third week of the semester, or as soon as possible after a disability has been incurred or recognized. Faculty [I], will work either directly with the student [you] or in coordination with the McBurney Center to identify and provide reasonable instructional accommodations. Disability information, including instructional accommodations as part of a student's educational record, is confidential and protected under FERPA." (Windschitl, 2002)

DIVERSITY & INCLUSION

Institutional statement on diversity: "Diversity is a source of strength, creativity, and innovation for UW-Madison. We value the contributions of each person and respect the profound ways their identity, culture, background, experience, status, abilities, and opinion enrich the university community. We commit ourselves to the pursuit of excellence in teaching, research, outreach, and diversity as inextricably linked goals.
The University of Wisconsin-Madison fulfills its public mission by creating a welcoming and inclusive community for people from every background – people who as students, faculty, and staff serve Wisconsin and the world." https://diversity.wisc.edu/