

2-17-2011

Integrating Problem Solving and Critical Reflection Opportunities in First- and Second-Year Science Courses.

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Recommended Citation

Houde, Aimee Lee (2011) "Integrating Problem Solving and Critical Reflection Opportunities in First- and Second-Year Science Courses.," *Teaching Innovation Projects*: Vol. 1: Iss. 1, Article 7.

Available at: <http://ir.lib.uwo.ca/tips/vol1/iss1/7>

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Integrating Problem Solving and Critical Reflection Opportunities in First- and Second-Year Science Courses.

Summary

The development of problem solving and critical reflection skills is neglected in early-level science courses; however, such skills are necessary in upper-year science courses and scientific careers (Gupta 2005). Early-year science teaching seems to be about memorization and recall (McDonald and Dominguez 2009) because teachers feel that they have insufficient time to integrate problem solving and critical reflection components into their courses while covering the subject matter (Kronberg and Griffin 2000). Yet, integrating problem solving and critical reflection opportunities into science courses does not have to take too much time and can cover the same curriculum subject matter (Kronberg and Griffin 2000; McDonald and Dominguez 2009); students usually learn more and have a greater understanding of concepts resulting in better grades (e.g., Chaplin 2009); and teachers have more frequent assessments of what their students are learning and can make instructional changes as required (McDonald and Dominguez 2009). This seminar will demonstrate methods (that are not greatly time consuming or drastically change the current curriculum) to integrate problem solving and critical reflection opportunities into lectures, laboratories, and tutorials of early-level science courses. Participants also have the opportunity to actively demonstrate the methods. The benefits of developing problem solving and critical reflection skills earlier in university science education are better grades, better integration of complex topics, and a better understanding of what students are actually learning.

Keywords

first and second year, higher education, active learning

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Objectives

By the end of the seminar, participants will be informed of the various methods to integrate problem solving and critical reflection opportunities into lectures, laboratories, and tutorials. In addition, participants will have actively participated in a demonstration of the methods.

Summaries of Main References

Murphy, P., McCormick, R. 1997. Problem solving in science and technology. *Research in Science Education* 27(3): 461-481.

Students are given enough background information in a lesson to make up their own experimental design to a problem. These problems should be authentic and personally meaningful to the student in order to be interesting. Students are given the opportunity to make critical decisions in the design and multiple experimental designs are encouraged. Students should not be given minor decisions, such as aesthetic elements, while the teacher makes the critical decisions. Students conduct the experiment using their design and may run into design issues. The teacher gives suggestions for solutions to these issues in the form of guided questions. The teacher should not give the student the solution; a more meaningful approach makes the student think about possible solutions. Also, the teacher should pose guided questions if they foresee a future problem with the design to get students to reevaluate their design. These methods can be applied to first- and second- year laboratories and tutorials.

Wisehart, G., Mandell, M. 2008. Problem solving in biology: a methodology. *Journal of College Science Teaching* 37(4): 24-29.

Traditionally, teachers give the hypotheses and scientific methods to the students to run an experiment. The students do not learn how to design their own experiment to test hypotheses. The teacher gives students a five-part analysis of problems to design their own experiment. Part one is to state the problem: students are given a data set and generate one or more experimental questions. Part two is to analyze the given information: students isolate the background information and comment on its scientific reliability. Part three is to make a hypothesis statement: students describe the test of their arguments and give outcomes that would support or not support their arguments. Part four is to test the hypothesis: students either do active experimentation or a 'mental' experiment that reveals design issues such as adequate sample size, experimental groups, and unbiased experimental groups. Part five is to formulate conclusions: if not using active experimentation, students describe one possible outcome of the imaginary experiment. After the five-part analysis, students critically reflect on things that could be done to ameliorate the experiment and on other things that could be tested in a complementary experiment. This method can be applied to first- and second- year laboratories and tutorials.

Kronberg, J.E., Griffin, M.S. 2000. Analysis problems-- A means to develop students' critical reflection. *Journal of College Science Teaching* 29(5): 348-352.

The authors incorporated analysis problems into written exams. The benefit is that students began to logically integrate vast amounts of complex material. Analysis problems should be

introduced after the first exam in order for students to interrelate information from earlier lessons. Analysis problems are in the forms of multiple-choice and are typically problems that take fifteen minutes each to solve. The problems are constructed in a way that no one answer is obviously correct and they may be vague in assumptions so students must think. Students must choose one answer and must give a written explanation along with assumptions for why that choice is correct and the others are not. There may be more than one correct answer, but as long as the student provides the assumptions and justifies the answer, full points are awarded. This method can be applied to first- and second- year lectures during quizzes and examinations and tutorials.

von Aufschnaiter, C., Erduran, S., Osborne, J., Simon, S. 2008. Arguing to learn and learning to argue: case studies of how students' argumentation relates to their scientific knowledge. *Journal of Research in Science Teaching* 45(1): 101-131.

Argumentation allows students to consolidate scientific knowledge and develop a more secure understanding of scientific knowledge. The method requires that students have prior familiarity with the scientific subject; exposure to new scientific information leads to confusion and arguments are poorly formed. Problem scenarios are presented along with possible solutions, similar to multiple-choice. Groups of students must form arguments to support or not support solutions. This method can be applied to first- and second- year laboratories and tutorials.

McDonald, J., Dominguez, L. 2009. Developing patterns for learning in science through reflection. *Journal of College Science Teaching* 39(1): 39-42.

Student critical reflection exercises have many benefits: students discover what they should have learned, students connect scientific theory with practical application, and students improve their written and oral communication. In addition, teachers discover what students are learning and can make instructional changes as required. One critical reflection exercise is to use a journal or notebook where students do not collect data or interpret data, but instead record thoughts, observations, feelings, activities, and questions throughout the experiment or project period. The journal could be for individual students or if the component is student group-based, there could be a journal for the student group where individuals within the group contribute. Another critical reflection exercise is a guided reflection paper or group discussion where student writing or discussion is guided by teacher-provided questions regarding the learning experience. These methods can be applied to first- and second- year lectures and laboratories.

Other references cited

Brock, K.L., Cameron, B.J. 1999. Enlivening political science courses with Kolb's learning preference model. *PS: Political Science and Politics* 32(2): 251-256.

Chaplin, S. 2009. Assessment of the impact of case studies on student learning gains in an introductory biology course. *Journal of College Science Teaching* 39(1): 72-79.

Gupta, G. 2005. Improving student's critical-thinking, logic, and problem-solving skills. *Journal of College Science Teaching* 34(4): 48-51.

Wilson, C.D., Taylor, J.A., Kowalski, S.M., Carlson, J. 2010. The relative effects and equity of inquiry-based and commonplace science teaching on students' knowledge, reasoning, and argumentation. *Journal of Research in Science Teaching* 47(3): 276-301.

Content and Organization

Total Workshop Time: 90 minutes

Time into presentation	Time allocated	Description (presentation strategy)
0 min	10 min	Introduction (lecture)
10 min	10 min	Modifications to lectures (lecture)
20 min	10 min	Modifications to laboratories (lecture)
30 min	10 min	Modifications to tutorials (lecture)
40 min	30 min	Demonstration activity (group activity)
70 min	15 min	Sharing of demonstration activity results
85 min	5 min	Summary/closing (lecture)

Introduction

- Problem solving (PS) and critical reflection (CR) skills are necessary for upper year science courses and scientific careers. Definition of PS and CR. Examples of necessity in science.
- PS and CR are often neglected in early-year science courses because of insufficient time to incorporate these skills along with the learning material. Examples of current structure of courses, mostly all lecture and guided laboratory based.
- Benefits of PS and CR. Incorporating PS and CR does not have to take much time and can cover the same material. Examples of time requirements.
- Outline of the seminar

Modifications to lectures

- Ask questions while lecturing to engage more learning types (Brock and Cameron 1999). If answer is incorrect, do not give the answer, but hint to the right answer with another question (Murphy and McCormick 1997).
- Teacher substitutes talking time with the analysis of a case study (Gupta 2005; Chaplin 2009). Students prepare answers to questions of the case study for the next class or in a discussion.
- End lecture with a small group discussion to engage more learning types and reflect on what has been learned (Brock and Cameron 1999). Large classes could discuss with nearest neighbour.
- Quizzes and exams can incorporate analysis problems (Kronberg and Griffin 2000). Recommend starting with the second quiz or exam.
- Assign a critical reflection paper (McDonald and Dominguez 2009). A guided paper where the instructor provides questions regarding the learning experience.

Modifications to laboratories

- Replace lab books (recipe books) and get students to design their own experiment. Do a five-part analysis of a problem with a handout as a guide (Wisehart and Mandell 2008).

The teacher gives suggestions for solutions to the problem in the form of guided questions (Murphy and McCormick 1997).

- Students defend their design and answers to problems (Wilson et al. 2010). Maybe a group discussion to simplifying designs.
- Still do the lab either the same day or on another day to give the students enough time to prepare an experimental design (Wisehart and Mandell 2008).
- Assign a critical reflection journal (McDonald and Dominguez 2009). A journal not for collected data or interpreted data, but instead for recording thoughts, observations, feelings, activities, and questions throughout the experiment or project period.

Modifications to tutorials

- An overlap of methods from the lectures and laboratories. However, there is more of an emphasis on problem solving beyond the basic examples in lecture (e.g., genetics problems). There is also an emphasis on statistical analyses as opposed to an emphasis on experimental designs that occurs in the laboratories. In addition, this time could be used to teach students how to consolidate scientific knowledge.
- Harder problems than in lecture examples. For example, Mendelian genetics problems versus sex-linked genetics problems.
- Difficult case studies (Gupta 2005; Chaplin 2009). A problem that covers interdisciplinary concepts such as issues in environmental science or a problem that covers concepts from multiple sections in the same course.
- Put an emphasis on statistical analyses. Students seem to know statistics, but are not sure which statistical test may be the most appropriate.
- A debate consolidates scientific knowledge (von Aufschnaiter et al. 2008). Argumentation allows students to consolidate scientific knowledge and develop a more secure understanding of scientific knowledge. Groups of students must form arguments to support or not support multiple-choice answers to a scientific question.
- Analysis problems may also serve to consolidate scientific knowledge (Kronberg and Griffin 2000). Students must choose one answer and must give a written explanation along with assumptions for why that choice is correct and the others choices in the multiple-choice analysis problem are not.

Demonstration Activity

Divide participants into three groups:

1. Group 1: Participants of the same discipline (e.g. biology, medical science, chemistry, etc.) and come up with an analysis problem that encompasses various subjects in your discipline. Activity based off McDonald and Dominguez (2009).
2. Group 2: Participants are given a handout of information for a scientific problem to find an experimental design to test hypotheses (Option 1). Participants follow a five-part analysis of a problem with a handout as a guide (Option 2). Activities based off Wisehart and Mandell (2008).
3. Group 3: Participants devise some good debate questions for the subjects of the chemistry, biology, physics, and earth sciences. Participants provide support for their choice of question and multiple-choice answer. Activity based off Wisehart and Mandell (2008).

Sharing of demonstration activity results

- Participants of each group present the results of their activity
- Each group gets feedback from the other participants

Summary/closing

- Highlight key concepts
- Thank you!

Presentation Strategies

I will use a combination of presentation methods. Most of the time I will be lecturing and the rest of the time there will be group activities as demonstrations of the methods. I chose this strategy because the lecture provides the necessary background information and the group activities compliment the background information. The group activity also engages the active learners in the participants and reinforces the understanding of the background information presented in the lecture.