Implementation and Assessment of In-class Activities Designed to Improve Critical Thinking Skills in a First Semester General Chemistry Course for Majors

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Introduction/Project Overview

The goal of this research is to implement and assess in-class group activities designed to increase students' critical thinking skills in a first semester general chemistry course for chemistry and biochemistry majors. Critical thinking skills are important for success in university as well as in future career paths.[1] In a survey of employer priorities for college learning and student success conducted by the Association of American Colleges and Universities (AACU), 93% of employers agree that "a candidate's demonstrated capacity to think critically, communicate clearly, and solve complex problems is more important than their undergraduate major."[2] Whether their career path involves diagnosing a patient or reducing the amount of greenhouse gases in the atmosphere, students will need to have good critical thinking skills to be successful.

The traditional first semester chemistry course taught at CU covers a wide range of basic chemistry topics. While it provides a foundation of chemical knowledge it often fails to illustrate and teach the skills necessary to use that knowledge in the real world to analyze problems, synthesize solutions and evaluate theories. Thus one of the goals of this redesigned 1st semester chemistry course is to train students to analyze and evaluate data, to use models and representations to communicate ideas and solve problems, and to create and interpret graphs in order to improve students' critical thinking and analytical reasoning skills. The group activities will be designed to help achieve this goal. More explicitly, the course will foster critical thinking skills by being more explicit about this as a course goal, creating class activities that provide students with opportunities to develop these skills and obtain feedback on their level of "mastery" (e.g. depth of thinking/analysis), and ensuring that assessments (formative and summative) are aligned with this goal such that assessments clearly match expectations.

Background

Studies have shown that a significant amount of students in higher education fail to obtain a measurable gain in critical thinking skills.[3,4] Undergraduate science courses tend to focus on knowledge instead of the scientific process.[5] It has also been shown that higher education does not always correlate with skepticism of pseudoscience and the scientific literacy of college graduates has remained stagnant for many years.[5,6,7] Traditional introductory chemistry courses have been shown to fail to raise student critical thinking skills to necessary levels.[8] It has also been shown that student collaboration improves critical thinking skills.[9]

Theoretical Framework

Critical thinking can be defined in terms of argument skills, cognitive processes and intellectual development. Argument skills focus on detecting and avoiding fallacious reasoning as well as analyzing deductive and inductive arguments. Cognitive processes focus on creating and testing a model based on previous knowledge, reasoning and evidence. Intellectual development focuses on the transformation of students' beliefs in regards to the variability of knowledge and truth.[10] The course goal aligns well with the cognitive processes definition since students will be trained to create well-reasoned evidence-based models and representations to solve problems.

Studies have shown that it is difficult to obtain a valid assessment for critical thinking skills.[11,12] The separation of critical thinking skills from simple problem solving and knowledge acquisition is not a trivial process.[11] The Critical thinking Assessment Test (CAT) has been developed and extensively validated to test skill areas which cover the goals of this course.[13] These skills are highlighted in pink in Table 1. The CAT test consists of mostly short answer essay questions and has a 1 hour time limit. Short answer essay questions are considered a better form of assessment for critical thinking because the reasoning is often more important than the answer. Focusing purely on the answer can reduce the complexity of the question and the creativity of the student.[13] The CAT's validity has been assessed by faculty across disciplines from multiple institutions and correlations have been observed with other tests of academic success (ACT, SAT, GPA, California Critical Thinking Skills Test (CCTST)).[13] The CAT has also been validated for use as a measure of critical thinking gains on a course/semester basis which is how it will be used in this study.[14]

Skill Areas Assessed by CAT
Evaluating Information
Separate factual information from inferences.
Interpret numerical relationships in graphs.
Understand the limitations of correlational data.
Evaluate evidence and identify inappropriate conclusions.
Creative Thinking
Identify alternative interpretations for data or observations.
Identify new information that might support or contradict a hypothesis.
Explain how new information can change a problem.
Learning and Problem Solving
Separate relevant from irrelevant information.
Integrate information to solve problems.
Learn and apply new information.
Use mathematical skills to solve real-world problems.
Communication
Communicate ideas effectively.

Table 1: Skills assessed by CAT adapted from Harris *et al*. with skills correlating with course goals highlighted in pink.

Study Design and Methods

This study will take place in CHEM 1400 (Foundations of Chemistry) which is a replacement for a traditional introductory chemistry course for chemistry and biochemistry majors, CHEM 1251. CHEM 1400 will be developed by Professor Amy Palmer as a 4-unit course with a mandatory recitation and inquiry, research-based lab co-requisite. The course will have an enrollment of approximately 120 students split into two sections with one section taught by Professor Amy Palmer and the other by Professor Robert Parson. An active-learning classroom, MCDB A120, will provide the environment necessary for the partially flipped classroom format.

This partially flipped format will have pre-lecture online videos and an approximately 10-20 minute in class lecture combined with in-class group activities. Sixteen activities will be designed such that they teach students to analyze and evaluate data, to use models and representations to communicate ideas and solve problems, and to create and interpret graphs. The activities will require students to use foundational knowledge from the material presented at each lecture. These activities will involve in-class demos as well as hands-on activities guided by a worksheet. First, the activities will be designed to address deficiencies found by the CAT which was administered at the end of the original traditional course, CHEM 1251. A CAT test will also be administered at the beginning of CHEM 1400 to assess the status of incoming students' critical thinking skills. Based on these results the activities will be adapted to address any deficiencies which were not found in the assessment of students in the traditional course. For example, in an activity designed for the CAT category 'Identify new information that might support or contradict a hypothesis' students could be given different evidence for the structure of the atom, say Thompson or Rutherford's experiments, and be asked to develop their own explanations based on the evidence. Each group could be given a different experiment and develop their own hypothesis for the structure of the atom based on that experiment. Then students switch groups in a think-pair-share manner and share their data with members of other groups. Then the original groups reconvene and reevaluate their previous hypothesis based on the evidence from the other groups. The CAT test will be administered at the end of the semester to determine if CHEM 1400 has increased students' critical thinking skills. An IRB has already been approved to administer the CAT test (Protocol: 15-0744, PI: Palmer) and an addendum will be submitted to include the author in the protocol.

Basic chemical knowledge is necessary to understand and interpret the problem and evidence. Since critical thinking skills in chemistry require a foundation of knowledge, formative assessment data, in the form of answers of student groups to open ended questions via electronic personal response systems such as uRespond, will be analyzed using similar criteria to the CAT test in order to evaluate chemistry-specific critical thinking skills. These results can then be compared to CAT and final course grade data in a pair-wise manner. For example, if a student's course grade was low and their reasoning on the formative assessments was flawed but they scored well on the CAT it could be inferred that the student lacked the necessary chemistry knowledge to use their critical thinking skills in the chemistry context.

Timeline

Summer 2016:
Submit IRB Amendment
Analyze CAT results from students in traditional course (CHEM 1251)
Develop activities based on CAT scores from CHEM 1251
Fall 2016:
Administer CAT to CHEM 1400 at the beginning of the semester
Analyze initial CHEM 1400 CAT results
Modify activities if necessary based on initial CHEM 1400 CAT scores
Record Student Response on Formative Assessments
Administer CAT to students in CHEM 1400 at the end of the semester
Analyze CAT results
Look for correlations between end of semester CAT results, student response on formative assessments and final course grades

Outcomes/Impacts

Tangible Outcome

This study will produce 16 active-learning exercises focused on developing critical thinking skills for use in an introductory general chemistry class.

Projected/Predicted Impacts

After taking CHEM 1400, students will be able to effectively analyze and evaluate evidence to create models, solve problems and communicate ideas with their peers. Since students will be working with real evidence and making their own cases for current scientific discoveries, they will obtain enhanced foundational knowledge and deeper understanding of core chemistry concepts. The strong critical thinking component of the course will also give students the professional skills necessary to succeed in their chosen fields.[2] The CAT test will encourage faculty involvement which will motivate changes in pedagogy by making faculty aware of student deficiencies in critical thinking.[13] Awareness of the impact and importance of teaching critical thinking will be increased.

References

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