Chemistry in Context: Using Research Methods to Identify Effective Teaching Tools

SHANE RUEBUSH

At BYU-Idaho we enjoy great measures of freedom and assistance to innovate teaching. I have personally discovered this freedom because of three specific practices. These practices are first, by attending professional development workshops, either on campus or externally, where I have learned many effective teaching practices; second, establishing close working relationships with other members of the faculty so that responsibilities and ideas are shared and implemented more effectively, and third, listening to the Holy Ghost and having faith to prepare and implement the knowledge that comes from God, knowing that He is interested in what occurs in my classroom.

During the five years that I have taught at BYU-Idaho in the chemistry department I have taught first semester general chemistry (CHEM 105) and Biochemistry (CHEM 481), and have enjoyed the freedom to improve my teaching. Coming here with a research background, I had little previous teaching experience, but I did find the people and resources to aid my teaching development. The first concern I had was in the quality of teaching I was providing to the students and the department. I found this was shared by Hector Becerril and Aaron Johnson with whom I now collaborate closely in teaching a curriculum and developing pedagogy in the general chemistry course (CHEM 105).

As chemists we like numbers. The numbers that I initially had at my disposal were my teacher evaluations, semester grade data shared among all sections of common classes, and a common final exam (American Chemical Society standardized test) given in all general chemistry sections of our department. Having these data allows us to gauge how our students compare to all other sections, and this also enables an environment for innovation in teaching by providing a way to measure what my teaching outcomes look like through the students' performance in my classes. Having discussions with Hector about these outcomes allowed us to investigate how we influence the students' learning. The use of assessment data gave us confidence that we could try new methods of teaching and determine the benefits and detriments beyond our own intuition.

The power of collecting assessment data has been enhanced through working with others in the department with faculty who teach the same course and even reaching out to other colleges to utilize expertise of others. Originally this came about as Hector and I started to discuss our experiences in teaching the first semester of general chemistry. We had taught the curriculum in different ways and, as a result, we wanted to understand if the types of teaching activities we used made a difference in the students' learning. We identified what types of activities we had used and the distinction in our pedagogical approaches. We made an analysis of students' scores on each type of learning activity and the final outcome for each student as determined by their grade and score on the common ACS exam. We anticipated discovering which pedagogy had an impact and the types of activities that showed strong potential for learning.

To re-confirm our initial work, we repeated the analysis. Why exactly? We met and discussed our work with Yohan Delton from the Department of Psychology. He understood the statistical analysis of the data better than we did, and this led to developing a better methodology and tools for effectively analyzing the teaching data. Our relationship was facilitated through a workshop in which all three of us were participating. This experience with Yohan illustrates the importance of cross-disciplinary interactions in furthering our steady improvement.

In our course analysis, we looked at learning activities such as narrations, laboratory reports, homework, quizzes, mid-term exams, and the ACS final exam. We also examined differences in delivery modes used in class, including traditional and hybrid course structures. We knew of another member of the department who employed a different pedagogy—peer oriented guide inquiry learning (POGIL)—and asked him to participate by sharing his course data to compare with our classes.

Using the common assessment instrument of the ACS exam, we were able to make some conclusions from our analysis. First, it appeared that student learning was not heavily impacted by any of the three teaching methods (traditional, hybrid, or POGIL). This suggests that pedagogical differences do not lead to a significant difference in content and skill knowledge, so long as the same material is covered in each course. Second, many of the learning activities showed a poor correlation between the student scores and the final exam. These results have led us to consider the need for alternative assessment tools to gain a more representative and accurate measure of the types of learning we are seeking to improve.

During this time of self-assessment, Hector and I both felt that there were other things we would like to incorporate into our teaching, in particular how to make

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the material more relevant to the students. Because we had embarked on a scholarly tack in analyzing data for our courses, we looked to the education literature in an attempt to learn more about teaching. In searching the Nuts and Bolts of Chemical Education Research (Bunce and Cole, 2008), a text published by the American Chemical Society, we discovered an article entitled, "Let's Teach them How We Think and Not What We Know" (Talanquer and Pollard, 2010). The title certainly caught our attention, and we read about an approach that seeks to build chemical models and apply them to real world problems. This was appealing to us. We saw that many of our students used strategic learning to move past difficult content and failed to develop the model building skills to think through problems. This struck a chord for us. This is not surprising as it is a common desire among teachers to share with students their fascination and passion for their own discipline, and so it was for us with chemistry.

The article stated that in many general chemistry curricula are still focused on facts, abstract concepts and instruction in algorithmic skills. The material taught is often removed from practices, thought and applications that take place in current chemistry research. The challenge in modern chemical education is helping students realize that chemistry is a way of thinking rather than a body of knowledge to be memorized. The authors propose that chemical education should be more contextual and less abstract. The typical chemistry curriculum rarely provides opportunities for students to approach scientific problems from a chemical perspective using the useful and productive models that chemists regularly employ. The proposed curriculum purports to address this issue while maintaining the necessary knowledge and related skills.

So, we had found something that we thought would be worthwhile, but would we dare to make a significant change to our instruction? We felt something in it ring true. Innovation can only come when we allow ourselves to follow line upon line to the end of a sincere inquiry. Comfortable practices and habits will be set aside.

We contacted Talanquer and Pollard, established a collaboration to use the materials they had developed and in return we would share our experiences in teaching. With the support of members of our department, we planned for the introduction and testing of a "new approach" to teaching chemistry. Our previous data could be used to compare the performance of students taught in our sections before and after adopting the Chemical Thinking curriculum. In addition, we could still weigh the student performance of our sections to the standard of those in other sections taught each semester in general chemistry.

The method of teaching was not explicit with the Chemical Thinking curriculum so this left us opportunity to implement and adopt practices from the BYU-Idaho Learning Model. We have included in the course architecture preparation assignments of reading typically 10-15 pages, a module (lasting three class periods), with the expectation that the student is accountable to understand it sufficiently to discuss the ideas and models presented in the text. This is assessed using an individual and team readiness test at the start of class when each module begins. Implementing the practices of Team Based Learning (Team-Based Learning, Michaelsen, Bauman Knight, Fink; 2004) has improved the level of preparedness and classroom discussions. Students work together in groups that are formed for the duration of the semester. They collaborate on solving questions that are based in current issues that involve chemistry. The types of problems that are generally of interest to chemistry students are medicine, materials, the environment, and energy. We have the students work through the thinking process together using application activities and giving them formative assessment. These activities are based in one of the four general areas of interest and require the teams to apply the models that they have studied to propose solutions to each challenge. They have to justify their choice with an appropriate explanation, whether part of an in-class discussion or on paper. This type of peer instruction benefits students that choose to participate fully and motivates many of them to do so.

For the past year we have worked at teaching and assessing the progress of the students we have taught. Part of the assessment has been to add other tools to determine if concepts in chemistry are better understood along with the content. We are tracking students' performance in other chemistry courses to identify the strengths and weaknesses. We have also introduced a course survey that addresses the students' perceptions of relevance of chemistry in their lives and their interest in chemistry. We have made these additional assessment tools available to the other members of the department so we can have an external validation of our results. We are trying to learn what best helps students to learn the necessary thinking skills to make sense of the issues that involve chemistry, which are many, whether in a classroom or in their own lives.

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We have learned of the advantages to meeting together frequently and regularly as a teaching group to discuss successes and failures. This helps us to move forward in a way that I have not experienced when teaching on my own—it is exciting. We have developed materials for class and improved our teaching very rapidly from close collaboration. Students benefit from the ideas that are shared and used in classes from our various expertise. We are blessed knowing that in the event of an emergency any one of us can substitute for the other because the sections are synchronized. Power to continue the upward course comes from a unifying purpose.

In conclusion, I appreciate having such fine people to work with in my department and across campus. The practices for good teaching abound here and will continue as the commitment to teaching remains strong. In following the knowledge and inspiration that have come from peers, the literature and the Spirit I have found a greater enthusiasm and higher standard for my own teaching.

References:

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