Overview: Goals, Expected Outcomes, & Anticipated Challenges

The over-arching goal of the project is to foster understanding of the nature of science and of important science content by non-science majors as a means of increasing scientific literacy.

Our outcomes to this end are:

1. development of effective inquiry-based (constructivist) curriculum materials – Chemistry for the Informed Citizen (CIC);
2. improving the knowledge by participating faculty of best practices in teaching chemistry and the nature of science;
3. adaptation of the inquiry-based curriculum to multiple instructional contexts; and
4. dissemination our curriculum and findings.

Curriculum Development

We are engaged in development and evaluation of the Chemistry for the Informed Citizen (CIC) curriculum, a collection of inquiry-based learning activities that target common misconceptions about the particulate nature of matter and chemical change.

In each learning activity students:
- identify and share their initial ideas related to a target concept,
- collect and interpret evidence
- build on or change their initial ideas by constructing explanations of the evidence.
- reflect on how their thinking has changed and how their explanations compare to those of scientists.

These learning activities explicitly target common misunderstandings about the nature of scientific knowledge and inquiry, and are supplemented with appropriate readings and reflection prompts to help students connect ideas about the nature of science with the process undertaken to construct their knowledge of chemistry concepts.

Anticipated Challenges:

Implementation of college-level constructivist science can be challenging for a variety of reasons:

- enrollments for many college science courses are quite large, making it difficult to foster a culture where students can discuss their ideas in a meaningful way.
- students are often resistant to inquiry-based curriculum because of previous experiences and/or stereotypical images of science lecture courses.
- college students, especially those at the introductory level, have widely varying goals and values, depending upon their motivations for taking the course (e.g. their major and career interests). Therefore, what one must do to build a constructivist culture may be different in different courses, or even for different students.
**Preliminary Results & Key Findings: Content Knowledge**

Content Knowledge was measured using the Chemical Concepts Questionnaire (CCQ). Scores were compared for three sets of questions:

1) All questions;
2) Questions related to course content only (these vary slightly between CHEM Trad, CHEM CIC, and the SCED courses, due to different curriculum emphases) and
3) conservation of matter questions (8 total), which were chosen as a comparison because this content received similar emphasis in each course.

Results are summarized in Figures 1 and 2 below.

**Figure 1.** CCQ Pre- and post-instruction scores. *p < 0.05; **p < 0.01 in Wilcoxon signed-ranks test.

**Figure 2.** CCQ Gains. Normalized gain scores were calculated as a percentage of the possible gain: \( \frac{(\text{post-pre})}{100\times\text{pre}} \times 100. \)
Discussion: Findings on two research questions

The two questions we were attempting to answer in comparing the various classes were:

**Evaluation Question #1:** How does a constructivist curriculum impact students differently from traditional lecture-based instruction?

**Evaluation Question #2:** How do class size, structure, and student goals (e.g. pre-service vs. non pre-service) mediate student learning in a constructivist environment?

**Evaluation Question #1** was addressed by comparing the CHEM CIC course to the CHEM Trad course (Table 1).

- The constructivist curriculum was more successful at improving students’ content knowledge and beliefs about the nature of science compared to the traditional lecture curriculum.
- Students perceived that they learned less in the constructivist curriculum than in the traditional course, and that the constructivist course was less challenging than the traditional delivery. (Responses to the second item on the student evaluation were triangulated by open-ended comments on student evaluations to support this conclusion).

For **Evaluation Question #2** we compared CHEM CIC to SCED CIC B, as the student population of the latter course is more similar to that of the CHEM courses than SCED CIC A, which had a larger percentage of pre-service teachers.

- The smaller class size and/or more fluid structure represented by the SCED class (students flow between discussion and laboratory activities rather than having one set lab time per week as in the CHEM classes) seems to have had a positive impact on content knowledge and NOS beliefs.
- Despite its smaller size and more flexible structure, students in SCED B were less satisfied with the class than in the CHEM CIC class. The most frequent complaint in SCED B was that students never received any “answers” or were able to compare their ideas to expert ideas, which explains the lower scores on the first and third items in Figure 3. Indeed, the CHEM courses used a textbook as a reference for the chemistry content, while the SCED courses relied only on consensus ideas developed by the class.

Impact of student goals:

To assess the impact of student goals on the outcomes of the curriculum, we compared SCED A to SCED B, which were similar in every way except for the student populations. SCED B was attended by a larger percent of students taking the course to fulfill a general education requirement compared to SCED A, which was mostly attended by pre-service teachers.

- The younger, more general education-oriented audience seemed to have had a negligible influence on content knowledge but a large positive effect on NOS beliefs. We are not sure how to explain this except that perhaps the students taking the course for a general education requirement were more invested in the NOS content than were the pre-service teachers because it was closer to the content of humanities courses, to which they may have been more attuned.
- Pre-service teachers seemed much more receptive to the constructivist style of teaching on all student evaluation measures than the general education students did. This is probably due in large part to the fact that this population was more used to the constructivist-style curriculum from previous science education courses and were more interested in learning how to teach and learn effectively.
Methods: (continued)

Specific questions addressed in this comparison are:

*Evaluation Question #1:* How does a constructivist curriculum impact students differently from traditional lecture-based instruction?

*Evaluation Question #2:* How do class size, structure, and student goals (e.g. pre-service vs. non pre-service) mediate student learning in a constructivist environment?

Three instruments were used to compare outcomes of the four courses:

- The **Chemical Concept Questionnaire (CCQ)**, which contains selected questions from the chemical concept inventory (Mulford & Robinson, 2002) and the Particulate Nature of Matter (ParNoMa) questionnaire (Yezierski & Birk, 2006), to assess content knowledge.
- The **Student Understanding of Science and Scientific Inquiry (SUSSI) questionnaire** (Adams et al., 2007; Liang et al., 2006), a combined Likert and open-ended questionnaire to assess views about the nature of science (NOS).
- **Student evaluations**, to assess students’ perceptions of the courses.

The CCQ and SUSSI were given as pre- and post-assessments in each course; the student evaluations were administered at the end of each course.

**Table 1:** Demographic information and possible comparisons for courses in this study

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>% pre-service teachers</th>
<th>% female</th>
<th>% upper-classmen</th>
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<tr>
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<td>86/75</td>
<td>6/7</td>
<td>58/61</td>
<td>21/21</td>
<td>X</td>
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<td>CIC</td>
<td>91/44</td>
<td>15/16</td>
<td>54/61</td>
<td>16/23</td>
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<tr>
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<td>84/82</td>
<td>96/95</td>
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</tr>
<tr>
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<td>62/58</td>
<td>62/58</td>
<td>69/67</td>
<td>X</td>
</tr>
</tbody>
</table>

^a Number of students enrolled in the course / number of students who gave permission to participate in the study. ^b Percent of students in each category enrolled in the course / percent of students in each category who gave permission to participate in the study.
Preliminary Results & Key Findings: Nature of Science Beliefs

Nature of Science beliefs were measured by administering the SUSSI before and after instruction in each class. Students’ responses were classified as naïve (N), emergent (E) or informed (I) based on their responses to 24 Likert-scale items organized in six sections, each representing a different NOS tenet. Gains are summarized in Figure 3.

Figure 3. SUSSI Gains. Gains were calculated as the percent of naïve, emergent and informed codes occurring on the post-instruction questionnaire minus their percent occurrences on the pre-instruction questionnaire. Every student had six codes on each questionnaire, each pertaining to one of the six sections on the SUSSI.
Preliminary Results & Key Findings: Student perceptions

Students’ perceptions of the constructivist teaching style used in the curriculum were measured using the standard student evaluation forms at WWU. Because of the different sizes and structures of the two courses, different forms were used. Two forms were used for the CHEM courses, a large lecture form and a lab form. A seminar discussion form was used for the SCED courses. Though each form had a different set of questions, there were some common items that allowed us to make comparisons. The scores on these items are summarized in the table below.
**Discussion: (continued)**

**Unexpected Challenges**

One unexpected challenge that the course comparison elucidated is the observation that students who have completed the CIC curriculum felt that they learned less, but actually learned more, with the constructivist curriculum compared to students who completed a traditional chemistry curriculum. This outcome has been observed by the first author to be a challenge to students in other inquiry-based curricula he has participated in developing. There is an ongoing risk in constructivist deliveries that the student will not have confidence in the understanding(s) that they build. One solution is to give them ample time to compare their thinking on a content topic with that of scientists. This should be followed by reflection on how they learned or improved their understanding of a particular big idea.

**Impacts in terms of its effect on students, your fellow faculty, your department or institution or other entity:**

The positive impact on student’s science literacy is demonstrable as described above. The impact on faculty partners in the project has also been positive. Our intensive two-week collaborative work session during the summer of 2009 and subsequent meetings and virtual communication involve highly productive discussions about both science content and about the best constructivist approaches to improving student understanding. We have developed a supportive yet intellectually challenging professional partnership.

**Plans for Dissemination:**

Project partners have given presentations at the international science education conferences describing some of the assessment results from several implementations of the CIC curriculum:


Dr. Emily Borda (P.I.) is currently preparing a manuscript on the assessment results to be sent to a science education journal.

We continue to work towards publication of the curriculum.

**References and Acknowledgements**


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