What Do We Know About Undergraduate Science Course Reform?

Since 1983, with *Nation at Risk,* reports and studies have identified undergraduate entry level course characteristics that contribute to discouragement and negativity toward science coursework among both majors and non-majors including the specialized group represented by elementary pre-service teachers. Among non-majors, pre-service elementary teachers are an important group as they will have responsibility for laying the foundations of science education in their classrooms after they graduate. The following factors have emerged strongly: lack of relevance, passive student roles, emphasis on competition, and focus on algorithmic problem solving (Tobias 1992; Seymour 1995). Calls for reform in undergraduate science have resulted.

The movement to develop and implement national science standards has contributed to calls for reform. Science standards for K-12 were devised and published in *Benchmarks for Science Literacy, Project 2061* (1993) and in the *National Science Education Standards* (NSES) (1996). While the primary focus of science standards is K-12 education, these standards impact higher education as well. Students whose K-12 science education reflects the nature of science and whose experiences have been investigative, problem-centered, and cooperative bring to undergraduate science courses a foundation that enables them to work at deeper levels of understanding beyond rote memorization, algorithmic problem solving, and passive following of cookbook laboratory instructions. When encountering traditional teaching in undergraduate science, such students may view that coursework as having a lack of relevance to their lives and to the careers to which they aspire. Higher education science faculty are called to begin with national science standards and build out their curriculum from this base. The *College Pathways to the Science Education Standards* (2001) is a document that demonstrates such a connection in which undergraduate science builds upon K-12 science education. The *Pathways* and existing K-

12 science standards bring coordination, consistency, and coherence to the improvement of science teaching (National Research Council [NRC] 1996).

As evidence grows that reform is needed in undergraduate higher education science coursework, faculty members have begun to address the concerns with students' lack of interest in science coursework and with the negativity expressed towards such coursework. Science faculty also have indicated some interest in addressing recommendations to build upon K-12 science standards (Fedock, Zambo, & Cobern, 1996; Sunal & Bland, 2004).

A literature base exists that includes numerous opinion pieces on, and some investigations of, reform in undergraduate entry level science coursework. As faculty members weigh investing time and effort in reforming coursework, a consideration of the existing literature base and a synthesis of recommendations that might be derived from it, is necessary. Such consideration can point out potentially useful directions faculty can consider. It also can address barriers to reform and approaches that focus on possibilities. Research studies are of special import in such a consideration. Those studies that occured three or more years after publication of the NSES standards in 1996 should be of most value to science faculty as they represent reform efforts that had such standards available. Here, we will attempt to outline the potentially useful directions indicated by a synthesis of existing research studies.

Limited research is available from 1999-early 2007 in regard to reform in higher education. Most published work during this period can be categorized as position statements, program descriptions, opinion pieces, or anecdotal descriptions. None of the studies are experimental but 23 used quasi-experimental and/or case study techniques and represent moderate rigor. What do these studies suggest as possible directions for reform in undergraduate science?

Studies suggest a number of different strategies and structures are being planned, implemented, and tested by undergraduate science faculty, most often in collaboration with others.(Ballone-Duran, Czerniak, & Haney, 2005; Wainwright, Flick, Morrell, & Schepige, 2004; Sunal, MacKinnon, Raubenheimer, & Gardner, 2004, Blackwell, 2002; Krockover, Shepardson, Adams, Eichinger, & Nakhleh, 2002; Sunal, 2001; Bland-Hodges, 1999). We discuss the suggestions that can be derived from the literature as possibilities for reform efforts below.

Narrow the Focus of the Reform

Because reform encompasses changing the curriculum, instructional strategies, and assessment procedures; it is a complex effort. Faculty often find that changing one component results in their examination of other components. To do it all at once is generally more than a small collaborative team can manage. The suggestion that surfaces, then, is to narrow the focus of the reform to a specific change such as the introduction of cooperative grouping or more modeling by the instructor of an inquiry approach to a problem. As the focus is narrowed, it is possible to concentrate on careful planning for its incorporation into a course and for data collection to determine its impacts. Faculty members have the time needed to develop their expertise with the reform, which is likely to require several terms course offerings. Finally, students can be oriented to the reform and learn “how to learn” within the reformed course. (Ballone-Duran et. al, 2005: Sunal et. al., 2004; Staples, 2004)

Use a Collaborative Faculty Team

Collaborative faculty teams support reform whether the focus is on reforming existing coursework or on developing a new course. Collaboration allows for more diverse input and for opportunities to discuss and select an option to implement based on the evidence brought forward by team members. As course reform is a complex endeavor, the workload is spread out more and stress is reduced. When glitches occur, collaborative team members bring different perspectives to bear on the problem and possible solutions. (Blackwell, 2002; Bland-Hodges, 1999)

Involve an Administrator

Effective collaborative teams often include a member representing administration like as a Department Head or a Dean. Such a member brings additional support to a team's efforts if the member has freely chosen to participate and such choice derives from a strong interest in course reform. The administrator-member can work to provide released time for faculty involved in the effort, appropriate course scheduling, graduate assistant help, and specific materials or technology appropriate to the reform. The administrator-member also can communicate the goals of the reform effort and the needs of involved faculty to upper level administrators. As tenure and promotion and merit pay increases are important considerations for faculty members involved in often time-consuming reform efforts, the administrator-member can insure that policies recognize and reward these efforts. (Krockover et al., 2002; Sunal et. al., 2001/2004)

Use an Instructional Grant

Instructional grants involving the allocation of direct monies to a collaborative reform team by the institution or department occurs at some institutions. Such grants can be awarded directly by administration to support the reform or can result from proposals submitted to an institutional committee supporting instructional reforms. These grants occur when laboratory components of courses are integrated and expanded, resulting in a need to purchase additional equipment and materials. The purchase of new technologies such as sensors for handheld computer-based laboratories, are another focus of instructional grant monies. Some institutions also have sought and been awarded external funding to support the reform's equipment and materials needs and personnel needs such as graduate assistants or faculty release time. (Bland-Hodges, 1999; Sunal et. al., 2001).

Carry Out Action Research

As the components are brought together, collaborative teams, in particular, have carried out action research projects to assess a specific reform, a specific problem that has arisen, and/or a solution to a problem. When a collaborative team is working with the effort, different perspectives are brought together to clearly identify and state the problem and to determine a possible solution. Team members may help with data collection, for example, interviewing a focus group of students or sitting in on a class to make an observation of how on-task cooperative groups are during an activity. Interpretation of the data collected by team members can bring out differing conclusions as well as clarify the conclusion best represented by the data. Team members learn how to work together in continuous development of the reform. (Sunal, et al., 2001/2004).

Model Inquiry Strategies and Techniques

Faculty reform efforts often address standards-based teaching that focuses on active student inquiry in science (Ballone-Duran, Czerniak, & Huey, 2005; Tinoca, Upadhyay, & Luft, 2005; Weld & Funk, 2005; Wainwright, et al., 2004; Staples, 2004/ 2002; Sunal et al., 2004; Krockover, et al., 2002; Sunal et al., 2001 Hammrich, 2001). Undergraduate science faculty have modeled strategies and techniques used in inquiry for their students. They also have modeled inquiry teaching for their graduate teaching assistants. Faculty recognized that students, including graduate students, may have experienced little inquiry teaching. Modeling was necessary as students did not know how inquiry was done. Students were focused on cookbook problems followed by cookbook activities that resulted in a foregone conclusion. One study followed elementary pre-service teachers out into their classrooms and found those who had experienced faculty modeling inquiry more often modeled it with their students and perceived inquiry as the basis for science teaching (Staples, 2002).

Recognize and Teach for Different Types of Concepts

Faculty involved in undergraduate course reform recognize that science concepts are of different types. They may be descriptive, hypothetical, or theoretical (Lawson, Alkhoury, Benford, Clark, & Falconcer, 2000). The goal is to enable students to have a meaningful understanding of important science concepts. Such an understanding includes the ability to apply important concepts to a situation that is new to the students, without duplicating the context in which it was learned. It further includes the ability to apply the concepts appropriately and consistently, and to understand their application in the real world (Ausubel, 1977). Students need to understand science concepts as relevant and related to the natural world. Faculty reform efforts have included identifying and planning for the use of real world examples to teach major course concepts. Some reform efforts have used applications of a concept in other disciplines to further connect a concept to real world examples. (Krockover, et al., 2002; Wainwright et al. 2004; Staples, 2004; Hammrich, 2001.

Use Cooperative Learning Strategies

Cooperative learning is a strategy with a history of implementation in recent decades. A significant amount of research is reported in regard to its use, particularly at the K-12 levels. Undergraduate science faculty themselves often work cooperatively on large research projects and recognize the possibilities of cooperative group learning. Two studies, Krockover, et al. (2002) and Staples (2004) reported greater scientific literacy among students in reform courses utilizing cooperative learning than in comparison courses. They also reported greater use of inquiry teaching in elementary schools by teachers who were graduates of the reform courses.

Adapt Assessment to the Reform

As course reform is implemented, assessment of students' outcomes assumes an important role in the reform. Faculty members recognize that the inclusion of a strategy such as cooperative learning or of the use of inquiry modeling and activities necessitates appropriate assessment. A wide range of assessment strategies is reported, ranging from short answer tests through student journals to student designed experiments. Faculty, typically, do not abandon traditional assessments such as laboratory reports or multiple choice quizzes. Other types of assessment are added, and the weighting of the total package of assessments used in a course gradually is adjusted to put more emphasis on products resulting from reformed course instructional strategies. Assessments also gradually put increased emphasis on process than on product to focus on how students apply and use the major course concepts in a variety of situations. (Krockover, et al., 2002; Ballone-Duran et al., 2005; Staples, 2004)

Conclusions

The outcomes of course reform in terms of content knowledge have been examined. Those reform courses implementing a greater focus on inquiry-oriented teaching reported increases in comprehension of content knowledge (Francis, Adams, & Noonan, 1998; Hake,1998; Jewett,1998; Hubbard & Abell, 2005; Luera & Otto, 2005; Weld & Funk, 2005; Staples, 2004; Sunal et al., 2004). Some studies also report greater understanding of the nature of science in students who have participated in reform coursework science (Tinoca, Upadhyay, & Luft, 2004; McGinnis et al., 2002, Backhus & Thompson, 2000). Science content knowledge increased, as well, among the students of teachers who were graduates of reform undergraduate science courses (Luera & Otto, 2005; Staples, 2004; Weld & Funk, 2005; Staples, 2002; Lee & Krapfl, 2002; McGinnis et al., 2002). These results indicate that reform efforts might impact the important goal of a deeper and more meaningful understanding of science and greater science literacy among course participants. The synthesis of the research literature presented here points to strategies that may be useful to undergraduate science faculty interested in reforming entry level coursework. Because the underlying foundation of research is of moderate rigor and limited in terms of the range and depth, these strategies should be considered likely possibilities or directions, not clear solutions in the reform process. The directions identified, instead, should be considered and adapted to the needs identified by faculty at their own institution of higher education.

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