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Using Action Based Research Teams to Reform Undergraduate Science Courses

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Numerous studies point to the need for the reform of the undergraduate science curriculum by university and college faculty (Adams & Slater, 1998; American Association of Physics Teachers, 1996; Krockover, 2001; Stokstad, 2001; Sunal & Wright, Eds, 2004). This concern is underscored by books and reports such as *Shaping the Future* (National Science Foundation, 1996), *Science Teacher Preparation in an Era of Standards-Based Reform* (National Research Council, 1997), *Reinventing Undergraduate Education: A Blueprint for America’s Universities* (Boyer Commission on Educating Undergraduates in the Research University, 1998), *Research in Science Education: Reform in Undergraduate Science Teaching for the 21st Century* (Information Age Publishing, 2004) and *The Case for Being Bold: A New Agenda for Business in Improving STEM Education* (Institute for a Competitive Workforce, 2011). Each of these reports recommends that college faculty should be moving away from lecture based courses and
moving toward integrative learning that incorporates laboratory and group work and discussion opportunities for all students.

The publication, *College Pathways to the Science Education Standards* (Siebert & McIntosh, 2001) discussed the importance of the university and college professors of science in preparing a scientifically literate society. Further, the importance of providing a quality, relevant science education experience for students preparing to become Kindergarten-12 teachers is an especially important task, since these future teachers will impact children’s learning in an exponential manner. Creating a system that encourages excellence in science, technology, engineering, and mathematics (STEM) achievement in higher education will not be easy. The National Academies report that the United States ranks 27th among developed nations on the percentage of college graduates who earn a degree in science or engineering. And, calls for universal STEM improvement often have not paid enough attention to rigor, compromising our ability to educate high achieving STEM students (Institute for a Competitive Workforce, 2011, p. 3).

Zeidler (2002) cautioned that, while relationships are possible between teacher educators in colleges of education and subject matter specialists in colleges of arts and sciences, seamless relationships are rare. [Furthermore, the problem with a seamless relationship is one never knows where it will tear apart. There is a fundamental lack of synchronicity between colleges in terms of conceptualizing the role or importance of distinctions among scientific content (SMK), strategic timing (PK), and allowing students to construct personal meaning and conceptual understanding (PCK). Efforts to form truly joint, mutually based collaborations are prone to discord (and many times failure) because each school hears and dances to music with inherent discord.” (Zeidler, 2002, p. 33)]

Faculty members at Purdue University in the departments of Earth and Atmospheric Sciences, Biological Sciences, Physics, and Chemistry with joint and courtesy appointments decided to address the concerns expressed by Zeidler (2002) and in the previously mentioned reports by utilizing a collaborative partnership of scientists, science educators, master teachers, graduate students, and undergraduate students referred to as collaborative action-based research teams to focus on improving undergraduate introductory science courses. The goal of this collaboration was to reform the education of preservice teachers, along with the education of science, mathematics, engineering, and technology majors in their introductory courses (Krockover, Ridgway, & Trop, 2000; Francisco, Nakhleh, Nurrenbern, & Miller, 2001; Kyle, 1997; MacIsaac, 1995; Purdue University, 1996).

**Collaborative Action Based Research Teams**

Collaborative action-based research (CABR) is a method to manage change in an instructional setting, produce documentation as to the effectiveness of the changes, and provide information on further changes needed (Keating, Diaz-Greenberg, Baldwin, & Thousand, 1998). CABR is defined as “an ongoing, self reflective process that involves critical examination of teaching practices or theories to improve personal practice and the education of the students” (Hamilton, 1995, p.79). It is also a systematic study to examine one’s own teaching and students’ learning using a collaborative team (Loucks-Horsley, Hewson, Love, & Stiles, 1998). Further, CABR is a method that can be used to develop one’s understanding of teaching scientific inquiry to
students. This involves descriptive reporting, purposeful conversation, collegial sharing, and critical reflection for the purpose of improving classroom practice (Loucks-Horsely et. al., 1998).

The CABR process addresses how to help students learn along with the development of a community of teacher-learners that mirrors scientific communities and addresses five areas: (1.) How science subject matter and inquiry outcomes can be built into learning experiences. (2.) How a deeper understanding of scientific concepts can promote discussion and the formulation of productive questions. (3.) How essential features of inquiry can be woven into learning experiences. (4.) What it feels like to learn this way including frustrations and struggles. (5.) What roles and behaviors instructors can use that promote and support learning (National Research Council, 2000, pp. 91, 101).

The literature clearly indicates that undergraduate science programs should actively engage the learner and model the type of teaching intended for the classroom. Research has indicated that experiences involving teachers as learners does, in fact, result in the construction of meaningful knowledge and skills (Brooks & Brooks, 1993; Sparks & Hirsh, 1997). And, while innovative teaching is making headway on some college campuses, these approaches must be more widely used rather than simply isolated successes (Lempinen, 2011, p. 1030). Thus preservice programs should model the same types of learning activities that they wish to have students experience. As a result, the goal of CABR is not to compare traditional versus nontraditional teaching approaches or to compare treatments, but rather to investigate specific team concerns and to assess how well these concerns are being addressed.

The Purdue University Collaborative Action Based Research Model

The CABR project identified four goal areas for improving undergraduate instruction: (a) utilization of inquiry-based, constructivist learning activities, (b) emphasis on the interrelatedness of science and mathematics and other areas of knowledge, (c) adaptations for the diversity of student populations within courses, and (d) utilization of constructivist authentic assessment strategies throughout the course.

**CABR Goals for Improving Undergraduate Science Instruction**

| Utilize inquiry-based, constructivist learning activities. | • Engaging in hands-on, minds-on activities.  
| • Providing opportunities for students to work cooperatively and collaboratively with peers.  
| • Planning activities which involve taking action.  
| • Emphasizing an understanding of the key concepts and how they developed through history.  
| • Planning activities based on students’ needs and interests.  
| Emphasize the interrelatedness of science and mathematics and other areas of knowledge. | • Drawing connections between concepts.  
| • Drawing connections between the sciences and mathematics.  
| • Relating course content to career opportunities.  |
| Adapt for the diversity of student populations within the course. | • Recognizing the impact that such things as gender, ethnicity, and learning style may have on a students’ understanding of course material.  
• Selecting from a range of teaching approaches and teaching media which will help students meet subject and personal learning objectives.  
• Providing experiences which will encourage the recruitment and retention of underrepresented individuals into science and mathematics careers, particularly that of teaching. |
| Utilize constructivist authentic assessment strategies | • Utilizing journals and portfolios.  
• Providing opportunities for oral, graphic, and written presentations.  
• Encouraging and enabling students to evaluate their own and each other’s work critically.  
• Selecting from a range of assessment strategies and projects that demonstrate student understanding of subject and personal learning objectives. |

The CABR project consists of three components: (a) the improvement of undergraduate science teaching, as reflected in the four goal areas, (b) the use of action-based research teams in reforming undergraduate teaching, and (c) action-based research for determining the effectiveness of the changes in undergraduate science teaching. The team structure was used to provide multiple perspectives in interpreting collected data about the effectiveness of the implemented changes. While action-based research can be an individual activity, our experience indicates that a team approach is productive for making sense of the data collected and using this to support and modify changes, especially when defending these changes to other faculty members.

The steps in CABR and its emphasis on continual improvement include (1.) identify the problem, what is not working or what needs to be improved. (2.) develop questions that can be addressed via collaborative action based research such as, “What are effective teaching, learning, and professional development modeling activities about ecosystems for preservice teachers and teaching assistants?” (3.) develop a plan and assign roles for team members. The plan needs to include details such as the point in the course at which the change will be implemented, the team and student actions, resources needed, and data to be collected to document the impact of the change. The plan should also include a timeline. (4.) put the plan into action. Our CABR teams decided to implement plans as a subsection of the semester. The advantage of this plan was that it allowed the course instructors to concentrate their efforts on a single revision rather than on developing a whole course at one time. Another advantage was that a focused effort allowed quick data collection and analysis that could then be used to improve the course.
(5.) use a variety of data sources to evaluate the impact of the implemented changes. One key factor is not the number and variety of data sources, but rather the quality of these sources in informing the CABR teams on what worked, what did not work, and why. This is supported by a recent study that was reported by Ruiz-Primo, et. al. 2011, which stated that, “almost half of the 310 comparative studies collected for review from the fields of biology, chemistry, engineering, and physics (undergraduate science course innovations) had to be excluded because they lacked the descriptive information needed”, p. 1270. Thus quality information is vital in deciding what should be modified, kept, or dropped with respect to the science content course. After the analysis of the data sources, the cycle begins again with a return to step 1, problem identification.

Evaluation Methods Used

The CABR evaluation employed a case study strategy, whereby each undergraduate course of instruction served as a unique case (unit of analysis) within the project. These case studies provided maximum variation in terms of class size, length and diversity of instructional subcomponents, and use of conceptual, physical, and pedagogical models. Each case was constructed based on the following data sources:

- Descriptions of program settings.
- Course instructor interviews.
- Team member interviews.
- Participant surveys.
- Course instructional artifacts.
- Course documents (e.g., syllabi)
- CABR plan, artifacts, and results.

These data sources were organized into a comprehensive case record for each undergraduate course of instruction that was used to construct each case study. Individual case and cross-case analysis was utilized to search for patterns and themes within and among the cases. Each case was analyzed from two perspectives: (1.) Inductively, whereby the categories emerged from the analysis process. (2.) From the use of existing categories based on the goals of the CABR project for improving undergraduate instruction: (a) utilization of inquiry-based, constructivist learning, (b) interrelatedness of science, mathematics, and other areas of knowledge, (c) instructional adaptations for student diversity, and (d) utilization of constructivist authentic assessment strategies.

Evaluation questions included (1.) In what ways did the CABR project change or improve undergraduate teaching? (2.) How effective were CABR teams at reforming undergraduate teaching? (3.) How effective was the CABR process at contributing to the reform of undergraduate teaching? The findings of this evaluation are a result of the constructions of the evaluation process itself. Further, the evaluation is based on the constructions that are dependent upon the range and quality of the information or evidence available (Guba & Lincoln, 1989). This perspective requires that the evaluation process focus on understanding how participants interpret the project and enact the project goals. The experiences, interpretations, and
enactments of different participants are bracketed, analyzed, and compared to identify the essence of the project in order to evaluate the program (Patton, 1990).

**Results and Implications of Action-Based Research.** Student final examinations, student pre/post interviews (utilizing drawings and concept maps), and student journals were analyzed in order to answer the CABR team’s research question “Are students better able to understand a complex system or cycle if, (for example), they participate in field trips that examine individual components of the system and construct small scale models of the system?” Based on these data sources, the CABR team found that students in an earth science course, for example:

- Had never participated on a field trip.
- Were better able to illustrate how groundwater travels through the subsurface and that topography influences groundwater transport.
- Were knowledgeable about sources of groundwater contaminants prior to course instruction and their understandings expanded to incorporate agricultural sources.
- Believed that studying the hydrologic cycle prior to course instruction was important.
- Believed the field trip to be beneficial and that the hydrologic simulator was a good representation of a groundwater system.
- Understood the hydrology of water wells and landfills and the ability of different types of sediments to purify water.
- Lacked a good understanding of the physical qualities of good aquifers, the controls on regional groundwater pathways, and the relationship between sediment grain size and permeability rate.

**Evaluation Results**

Case studies were conducted for each of the science content courses. Common patterns of strengths and weaknesses were identified and provided to each CABR team in order to continue to refine the process being used for this reform effort.

Revisiting the evaluation questions results in a summary regarding what has been learned from this project. **Question One:** In what ways did the CABR project change or improve undergraduate teaching? The CABR team was able to: (a) implement more inquiry-based teaching that emphasized conceptual understanding, (b) provide opportunities for cooperative learning experiences, (c) use models as an ongoing theme, (d) link concepts and models to real-world situations, (e) provide a more diverse range of assessment strategies and, (f) have students present their understandings in a variety of different forms. **Question Two:** How effective were the collaborative action-based research teams at reforming undergraduate teaching? The CABR team was able to (a) involve graduate and undergraduate students, classroom teachers, scientists, and science educators together to work on the reform in a collaborative manner, (b) bring multiple perspectives for teaching and for science to support instruction and, (c) provide scientists and graduate science students (who will become university professors) with more effective teaching models. **Question Three:** How effective was the collaborative action based research process at contributing to the reform of undergraduate teaching? The CABR team was able to (a) have the ownership of the courses involving a team approach to development rather than single person development, (b) involve practicing K-12 teachers in assisting higher
education in the preparation of teachers who will teach science, (c) generate focus questions to look at ways of improving undergraduate teaching and evaluating ways to improve the process via data sources, and (d) share change among members of a team rather than directing change only to one individual resulting in shared responsibility.

With respect to CABR teams, strengths included involving a diverse group of undergraduates, graduates, scientists, science educators, and teachers in course instruction, course development, action research, and decision making; using multiple perspectives on teaching and strengthening conceptual understanding; and providing scientists and graduate teaching assistants with a model for undergraduate teaching. One weakness was that team members were not consistently and actively involved. For example, some teachers were not involved in course instruction, decision-making, and action research to the level that they should have been involved. Also involvement of undergraduates in course instruction and in action research was limited.

The overall project provided insight into student perspectives about undergraduate teaching, which was used for informing course improvement. The focus on inquiry-based, constructivist learning engaged undergraduates in hands-on and minds-on activities that structured their experiences and thinking, which emphasized conceptual understanding. The project also provided opportunities for undergraduates to work cooperatively and at their own pace, encouraging students to take responsibility for their own learning. One weakness was that the activities were structured in a way that limited the degree to which students could identify their own questions and investigations to conduct. There was also limited development of the historical aspects of the key concepts presented in the courses.

With respect to the diversity of student populations, the project adapted to the diversity of the students’ learning styles via field trips, laboratory experiences, readings, and lectures. Cooperative learning and self-paced learning situations were used to match the needs of individual students. Some teaching assistants and a female science education professor provided female role models for the students. One weakness identified was that there were limited opportunities for encouraging, recruiting, and retaining underrepresented populations of students.

Regarding interrelatedness of science and other areas of knowledge, connections were built between concepts through a variety of instructional approaches, using models as an organizing theme. Mathematics was integrated as a learning tool. Career opportunities in teaching were emphasized throughout classroom applications of ways of teaching science. Concepts taught were related to the students’ world. Collaboration with scientists in the discipline was fostered. Another weaknesses was that the concept of a model was not clearly articulated to the students. The historical development of concepts and models was not addressed. Further, there was no collaboration across science disciplines or departments in terms of course instruction and concepts taught.

Constructivist and authentic assessments utilized a diverse range of alternative assessment strategies. Assessment was used for the purpose of determining students’ conceptual understanding and informing instruction. Students were provided opportunities to present their understandings in a variety of written, graphic, and oral forms/presentations. A third weakness
was the limited use of authentic assessment strategies in determining course grades. Grades were mainly determined from traditional examinations and quizzes.

Interviews indicated that one of the overall strengths was the collaborative nature of the project, in that several disciplines were involved. For example, one of the science faculty members stated,

I’ve learned a lot from interacting with chemistry and biology and again the ability to discuss some of these issues….I think the way chemistry handles large groups. So, how to handle large group instruction. I think the whole notion of how you might use concept mapping.

One of the drawbacks of the project has been the lack of support in terms of released time to accomplish the goals of the project. This concern is reflected in an interview:

Yes, there’s support there in terms of getting materials and so on, but the release time to do this, it’s been very difficult to squeeze all this in on top of the regular teaching responsibilities of the courses. Time’s a real issue…So, the design and the implementation and the assessment of the different things we’re doing in the course do take time. Because this is more in-depth and it involves more people, it, therefore, becomes more difficult to carry it out as a team too.

Advantages and Disadvantages of Collaborative Action Based Research

One advantage of CABR is that it provides a mechanism for implementing a curriculum innovation and documenting its effectiveness. If an instructor wanted to use collaborative groups, for example, to develop understanding of physics concepts, the steps outlined here would help with the implementation of the innovation and provide the evidence to defend its use and improve the implementation.

A second advantage is that the outcomes of the project can be communicated to a wider community through a variety of forums. At Purdue University the faculty teams reported their results during faculty colloquia and at national meetings, such as the American Chemical Society and National Association for Research in Science Teaching. The goal of this dissemination is that peers will know what has been done, why it has been done, and the impact it has had on students.

A third advantage is that evidence collected through action research speaks to scientists. One of the teams in this project has reported that other faculty members have seen the changes that are occurring and are now in the process of bringing these innovations into their classroom-classrooms that have not changed methods in 20 plus years. Not only does this have the potential to improve substantially undergraduate education in the sciences, but it also carries recognition by peers of efforts to improve teaching prowess.

A fourth advantage is that CABR fosters communication and collaboration between faculty in the same discipline and among faculty in different disciplines. Furthermore, enhancing
communication between colleagues, students, teaching assistants, and practitioners is beneficial to improving the science curriculum.

A fifth advantage is that CABR provides accountability for science instruction. The data collected as part of a project not only helps to evaluate and improve instruction, but also documents the "value added" or achievement of course and program goals. The political climate, which translates into issues related to accreditation, make it clear that the products of CABR can provide the type of evidence that is being sought by entities external to the institution.

One disadvantage observed at Purdue University is that the time commitment among faculty was substantially increased without a corresponding reduction of teaching load or responsibilities to other activities. This can result in faculty becoming reluctant to join a CABR team.

A second disadvantage is the problem of obtaining input from secondary practitioners since their time schedule does not match that of the faculty. For example, a high school science teacher may only be able to meet after 4 p.m. or on weekends, times that faculty may not wish to meet.

A third disadvantage is that scientists do not have experience with data collection and analysis for science education assessment. At Purdue University teams could be structured with science educators who have joint appointments between the College of Education and the College of Science. Other colleges and universities will need to consider the feasibility of establishing connections between scientists and science educators.

Conclusion

Efforts to implement CABR models in higher education settings, though limited in number, support our belief that action research is an effective means for the reform of teaching introductory college and university science (Chism, Sanders, & Zitlow, 1987; Cross, 1990; Fedock, Zambo, & Cobern, 1996; Author, 1994; Schratz, 1990). Additionally, results from the CABR project at Purdue University indicate that involving CABR teams in the study of both content and pedagogy increases the amount of connected knowledge and student-centered pedagogical knowledge gained by students, undergraduates, graduate students, and university faculty.

It should be evident that the process of CABR led us back to where we started: a set of questions to address for improving instruction. The Purdue University CABR teams are now in the process of conducting new action-based research projects based on the outcomes of their first investigation. This process provides evidence to make instructional decisions based on what works within the context of the institution.

From this effort, we learned that lasting reform can take place if shared, team responsibility is involved. It is also important for all team members to respect and value each person’s contributions, perspectives, and experiences. One reason our teams worked well is that our faculty in science education hold either joint or courtesy appointments between a science department and science education in the Department of Curriculum and Instruction. We also learned that to be successful in reform, we needed to focus on single aspects of a course, i.e.,
start small and improve each part of the course over time. Administrative support by department heads and deans is also an important aspect that contributes to a successful reform. Further, each team had a research question related to a theme that was agreed upon by all the teams which fostered collaboration and interaction between teams. In addition, an overarching evaluation was used to assess all teams.

The changes made are continuing and are refined each time the courses are offered. The changes have also impacted other courses and have served as an impetus to develop two new courses, i.e., environmental science and chemistry for pre-service teachers, using an action-based research model. All teams are continuing to work together supporting each other in continuing reform efforts.

While this reform process could be conducted with no additional funding, having external funding can provide the impetus to give faculty time to work on their reforms such as via summer employment. Funding also allows for the hiring of additional staff, such as graduate and undergraduate students, to develop, implement, and evaluate the reform effort.

In conclusion, the literature on college science teaching is replete with examples of teaching innovations. Each of these innovations is, to a greater or lesser extent, unique to the setting in which they originate. Action-based research provides a flexible, powerful mechanism for faculty to implement change, systematically analyze the impact of the innovation, and adapt it to the needs of their institutions.

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Author’s Note

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Faculty members at Purdue University collaborated on a project, which utilized a partnership of scientists, science educators, master teachers, graduate students, and undergraduates in order to foster improvements in the teaching of science content. The goal of the collaboration was to enhance the education of preservice teachers and the education of science, mathematics, engineering and technology majors in their introductory courses. The method of changing the curriculum, including the use of printed materials, was through the use of action based research teams. Action based research provides a method to manage change in an instructional setting, produce documentation as to the effectiveness of changes, and provide information on further changes. The goal is to provide a student-centered classroom where students take an active role in their learning process and the professor becomes a guide or mentor. It is also a goal to provide
students with the opportunity to create their own set of resources that they can take with them at the completion of the course."

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