ABSTRACT

Science departments in higher education have been adjusting their curricula to include more inquiry-based instruction, and research on inquiry-based teaching at the collegiate level has been increasing. However, more data are needed regarding the effectiveness of inquiry-based pedagogy in improving students' conceptual understanding and attitudes toward science. The investigation described here was focused on nontraditional students taking non-science-major science courses. The goal was to compare students' attitudes toward science before and after taking an inquiry-based or a traditional science course. The hypothesis that the inquiry-based course would significantly generate a more positive attitude toward science was supported. Nontraditional students' perceptions of an effective science curriculum were also explored. Students' perceptions were very positive regarding inquiry-based learning; however, those who had not been previously taught through inquiry-based methods had reserved perceptions of this teaching approach. Regardless of the course they were enrolled in, students agreed overall that an effective science curriculum includes three common themes: connection, interaction, and application.

Key Words: Attitudes toward science; nontraditional student; inquiry-based teaching; traditional teaching; student perceptions.

Introduction

Decline in the economic realm often bolsters an increase in nontraditional student enrollments in colleges and universities (Windolf, 1992). In 2013, the number of nontraditional students enrolled in postsecondary education was some 12 million; that number is projected to rise by 14% by 2024 (National Center for Education Statistics [NCES], 2016a). Almost 15% of the students at our institution are nontraditional – 25 years or older. Slightly more than 60% of these nontraditional students do not desire to major in some scientific area; however, they find themselves having to navigate through required science courses. Several studies have described methods for helping nontraditional students majoring in the sciences (Eves et al., 1990; Deutch et al., 2008; Sian Davies-Vollum & Greengrove, 2010). A search of the literature, however, reveals a gap in addressing the needs of nontraditional students taking non-science-major science courses.

Generally viewed as balancing multiple responsibilities at school, work, and home, the nontraditional student has often been defined by age – 25 years or older (Kim et al., 2010). The NCES defines the traditional student as one who enrolls in college full-time immediately after obtaining a high school diploma and works only part-time or does not work at all, relying on parents for financial support (U.S. Department of Education, 2003). For the purposes of our study, any student who did not meet the NCES's definition of a traditional student was considered a nontraditional student. Traditional students were not investigated in this study.

Inquiry-Based Teaching in the College Classroom: The Nontraditional Student

For over 50 years, the overall goal of many science educators has been to include more inquiry-based teaching in their classrooms (DeBoer, 1991). Over the last decade, science departments in higher education have been adjusting their curricula to include more inquiry-based teaching in their classrooms (Bernot et al., 2017). Whether the shift has occurred in the lecture part of the course or in the laboratory part, a clear trend has been apparent (Knight & Wood, 2005; Gormally et al., 2009).

Using inquiry-based pedagogy to organize a curriculum depends on a thorough understanding of inquiry. Inquiry has different meanings to different people (Anderson, 2007). The National Science Education Standards (National Research Council, 1996) refer to inquiry as "scientific inquiry," which points to an expression of the nature of science or doing the work of scientists. A variety of models of inquiry-based teaching can be used, depending on each unique teaching situation (Keys & Bryan, 2001). In the biology course described here, a "guided inquiry" approach (Gormally et al., 2009) was used to reduce students' frustration levels, especially involving those who...
had never learned under inquiry-based instruction. In this approach, the problem is presented by the instructor, who then guides the students in “selecting variables, planning procedures, controlling variables, planning measures, and finding flaws through questioning that will help students arrive at a solution” (Gormally et al., 2009, p. 2).

The main goal of this shift to inquiry-based science teaching in higher education has been to better prepare scientifically literate citizens. However, the collegiate literature is mixed as to whether inquiry-based instruction increases scientific knowledge or engenders more positive attitudes toward science (Hake, 1998; Udovic et al., 2002; Berg et al., 2003; Luckie et al., 2004; Neuby, 2010). In addition, few studies have addressed changes in science achievement and attitudes toward science classes when entire courses are converted from traditional curricula to inquiry-based curricula (Gormally et al., 2009). The research in these areas gets even sparser when focusing on nontraditional college students.

○ Study Objectives

Here, we describe a curriculum comparison project contrasting two different teaching styles in a small, suburban, two-year undergraduate university. We chose a teacher-oriented (action) research approach, which is a form of “backyard” research in which one “inquires into one’s own institution, agency, or community” (Glesne, 2011, p. 279) – or, in this case, one’s own classes. The goals of this project were to address the following questions: (1) Does guided inquiry-based teaching followed by student and teacher discussion (i.e., explore before explain) result in more positive student attitudes toward science than lecture teaching followed by cookbook lab confirmation (i.e., explain before explore)? (2) What perceptions do nontraditional students have regarding an effective science curriculum after taking a nonmajors biology course? Data gleaned from both quantitative and qualitative methods helped answer these questions. We anticipated that positive attitudes toward science after an inquiry-based course would exceed those found after a traditional course.

○ The Students

Each year, D.A.K. teaches two evening sections of Biology 110, a non-science-majors course. Students enroll in this eight-week course primarily to fulfill one aspect of their general education requirements. During this study, D.A.K. taught Biology 110 two nights per week, 4.5 hours per night. Each section consisted of 15–25 students, at least half of whom were classified as nontraditional. Data were collected from a total of 42 nontraditional students from four class sections during four semesters, two in fall and two in spring (Table 1). Brief surveys indicated that these nontraditional students were very demographically diverse; over half had not taken a science course since high school, and their ages ranged from 25 to 50 years. Institutional Review Board approval (Pro00017861) was obtained well before any data were collected.

○ Procedures

The two fall sections were taught in a traditional, lecture-based style followed by “cookbook” lab confirmation, whereas the two spring sections were taught in a guided inquiry-based lab style followed by student and teacher discussion. Students were not aware of the differences in teaching style when they enrolled in the course. Data from the two fall semesters (traditional) were pooled, as were data from the two spring semesters (inquiry-based). In all the courses in this investigation, D.A.K. tried to connect what the students were learning to a theme that could bring all the concepts together. That theme was homeostasis. Although both course styles had plenty of hands-on activities, the inquiry-based course was uniquely problem-based (Table 2). Concept maps were

| Table 1. Breakdown of students enrolled in the Biology 110 night sections under investigation. |
|---------------------------------|-----------------|-----------------|
| Semester                  | Nontraditional  | Traditional     |
|                           | Students       | Students        |
| Fall 2: Year 1/Year 2   | 12/7           | 12/6            |
| Spring 2: Year 1/Year 2 | 13/10          | 12/8            |

| Table 2. A typical class – comparison of traditional and inquiry-based styles. |
|--------------------------------|-----------------|-----------------|
| Traditional (Fall Sections)               | Inquiry-Based (Spring Sections)       |
| Engage Relevant news clip                | Evaluate Concept map                  |
| Explain Frontal lecture on the topic at hand | Engage Relevant news clip             |
| Students share a few facts on assigned topics (Break) |                       |
| Experiment Cookbook lab (Confirmation) | Experiment Guided inquiry-based lab (Exploration) |
| Main question presented by instructor Students Create hypothesis | Main question presented by instructor Students Create hypothesis |
| Follow prescribed directions Share conclusions with others Answer post-lab questions | Build own directions Critique one another’s directions Share and critique one another’s conclusions Answer post-lab questions (Break) |
| Evaluate Quiz next class | Evaluate Quiz next class |
| Extend (real-world visual) “Body Story” clip | Explain Post-lab round table discussion/lecture Students share a few facts on assigned topics |
| Evaluate Quiz next class | Extend (real-world visual) “Body Story” clip |
used at the beginning of each class to expose misconceptions; experiments that generated various questions occurred before explanations were given; students built and critiqued one another’s experimental procedures (instead of following step-by-step directions) before whole-class consensus; and group and whole-class critiques of students’ conclusions occurred, with a focus on the evidence acquired. Since the same quizzes and tests were used in all the courses, each course was nearly identical in terms of the chapter content covered and the amount of time spent on that content. Having the same instructor for all classes under investigation allowed for consistency among the courses. Students worked in pairs and sometimes in larger groups during experiments.

**EQUIP Evaluation**

All classes during the first year of research were video recorded to verify the intended teaching technique. The Electronic Quality of Inquiry Protocol (EQUIP) tool (Marshall et al., 2009) was used to assess and confirm the degree of inquiry-based teaching between the comparative courses. EQUIP describes four levels of inquiry. The range runs from pre-inquiry (Level 1) to developing inquiry (Level 2) to proficient inquiry (Level 3) and ends with exemplary inquiry (Level 4). EQUIP has been used recently to assess the inquiry-based practices of middle school and high school teachers. The tool’s reliability and validity were established during its development over a period of three years (Marshall et al., 2010).

All classes during the first year of research were watched and EQUIP assessed. To establish inter-rater reliability, 20% of the videos of the class sessions from each style of course were assessed by EQUIP-trained individuals other than the instructor who assessed the remaining 80% of the videos. EQUIP ratings were consistent among all assessors. Paired t-tests verified that the inquiry-based course had a significantly higher average EQUIP score ($M = 2.7$) than the traditional course ($M = 1.6$) ($P = 0.003$).

**Evaluation of Students’ Attitudes & Perceptions**

In assessing attitudes toward science as a subject in school, we employed pre- and post-course surveys with all 42 nontraditional students (19 in a traditional course, 23 in an inquiry-based course). We used a popular attitude survey created by Germann (1988), who also established its reliability and validity. Cronbach’s alpha was redone for this study, and the results confirmed a $> 0.7$ reliability statistic at 0.93, similar to Germann’s (1988) results. We implemented this attitude survey as a pre-course survey at the beginning of the semesters before any teaching occurred, and the same survey was conducted at the end of the semesters for comparison with the pre-survey. The Likert scale was treated as an interval so that an independent, two-sampled $t$-test could be used in data analysis (Knapp, 1990; Agresti & Finlay, 2009).

To address nontraditional students’ perceptions of an effective science curriculum, D.A.K. conducted focus group interviews at the end of the semester after final grades were submitted. Students were recruited to participate in the focus group interviews on a voluntary basis. Although not true random assignment, students with the highest grades in the course were mixed with students with the lowest grades in the course to make up the interview group. The numbers of students and times of interviews are shown in Table 3. These interviews on perceptions were video recorded and then transcribed and coded in a manner similar to that described by Lofgren (2013). The coding schema was created following Coffey and Atkinson (1996). The goal was to look for patterns in nontraditional students’ perceptions of an effective science curriculum. The theme/code connections that unfolded became the main results from the interviews.

**Students’ Attitudes toward Science**

Students’ positive attitudes toward science at the completion of the inquiry-based course ($M = 0.27, SD = 0.54$) were significantly higher than those of the students in the traditional course ($M = 0.0, SD = 0.47$) ($P = 0.04$). Pre- to post-survey attitude changes were greater in the inquiry-based courses than in the traditional courses on every question regarding a favorable attitude toward science. Figure 1 shows the three questions with the greatest difference between the two courses in positive attitude change from the beginning of the course to the end.

**Students’ Reactions**

The coding schema generated from focus group interviews was used to display more clearly students’ perceptions of an effective science curriculum (Figure 2). The comparative groups were viewing science curriculum through the lens of their past science courses and the lens of the traditional or inquiry-based science course.
in which they were enrolled. Regardless of the course, the three main themes emphasized by students with regard to effective instruction were connection, interaction, and application. Students felt that an effective science curriculum was one that connected their real-life experiences with the content. One student said, “When you gave real-life connections to help simplify the material, we understood better.” Students described how computer animation helped them picture the content in new ways, and they also emphasized the benefit of holding the course together with a big overall idea that they could relate to. Another student commented, “That’s what I liked — how everything related. You connected everything back to homeostasis in our body.”

Further, students described an appreciation for interaction in their science courses that involved an enthusiastic instructor who personally engages students and group/class discussion rather than straight lectures. A think-pair-share strategy was used in the inquiry-based course for partners to plan laboratory procedures. Think-pair-share was also used once the lab partners obtained their data. They were asked to communicate what they had discovered with other groups and challenge one another's conclusions based on the data obtained. One student said, “You know when you did the pair and share, it was nice, because when we finished, we had learned through the comparing.” In addition, reasonable accountability was appreciated. Another student said, “With projects, it helps to split it up into sections that are due on different dates so one can progress little by little.”

Lastly, nearly all students interviewed wanted application to be a major part of biology classes. These students generally agreed that shorter lectures or discussions with shorter experiments are more helpful than long, uninterrupted lectures or labs. One student said, “I want to listen a little bit, then get the chance to explore a little bit.” Students’ perceptions in the two different course styles deviated in that most of those in the traditional course felt comfortable sticking with more traditional forms of curriculum with lecture before exploration and cookbook labs. Many of the students who went through the traditional course had fear-based concerns regarding more open exploration. The common sentiments were “I think I would be confused on what we were doing” and “You need step-by-step to kind of refer back to if you’re stuck.” Students in the inquiry-based courses seemed to enjoy lab before lecture and embraced guided inquiry-based techniques. These students commented: “A brief pre-lab introduction and then let’s go for it” and “We felt more like scientists, because we had more control over the experiments.” Another said, “I didn’t like not having the step-by-step, but I do think it made me learn, it made me think.” Negative perceptions of too much lecture, or classes that are too open without timely instructor or peer support, were very apparent in comments from the inquiry-based students.

**Limitations/Considerations**

This study was an action research project with the major intent of improving D.A.K.’s biology teaching at the higher education level. It is not our goal to try to extrapolate these findings to all higher-education life science classrooms. This study had its strengths and weaknesses, and the results need to be treated contextually. For example, the study was done with small classes in a laboratory setting that met for extended periods twice a week. This situation is not typical, and thus the findings may not apply to larger lecture-hall classes that meet on a more traditional schedule. Further, having the instructor who taught the courses conduct the focus group interviews (even though final grades were already given) may have biased student responses. Finally, in an effort to validate the inquiry level of the lessons, only a sample of the classes were EQUIP assessed by outside evaluators.

**Discussion & Conclusions**

Positive attitude change toward science was significantly higher among the nontraditional students in the inquiry-based classes than among those taught via traditional methods. Thus, the data supported our hypothesis that the inquiry-based course would significantly generate a more positive attitude toward science. These results with nontraditional students support similar findings in the world of collegiate science education (Brownell et al., 2012). Whether in K–12 education (Spencer & Walker, 2015) or in higher education (Berg et al., 2003), students’ increased interest in science after experiencing an inquiry-based curriculum is likely based on the fact that “these methods encourage and enhance their natural curiosity and motivation for learning and connect science to students’ everyday life” (Spencer & Walker, 2015, p. 25).

Student interviews helped unveil nontraditional college students’ perceptions of an effective science curriculum. Although students were
enrolled in courses with different styles of instruction, the prevailing perceptions pointed toward balance. All interviews revealed that students do not want to abandon the traditional lecture but want shorter, more interactive lectures that connect the content to their lives and experiences. Proponents of inquiry-based teaching do not recommend abandoning all traditional methods. Lectures can be, and often are, important, even in inquiry-based classrooms (Marshall et al., 2009). For example, lectures can occur after students engage with materials to reinforce content, teach abstract concepts, or address misconceptions. Students who were given the opportunity to experience an inquiry-based course during this project appreciated it but wanted guided inquiry over open inquiry (minimal guidance). Further, many of these students commented on their increased interest in science. One student said, “Before this course, I could not stand science, but I loved the hands-on activities and the discussions, now I’m more apt to do more science classes; I did like your approach on teaching it.” Pre- to post-course survey results confirmed this common feeling. Instructors must find their own unique combination of teaching techniques to meet the needs of their unique students. Even though “inquiry methods are not a panacea for college student learning” (Neuby, 2010, p. 4), inquiry-based teaching holds great promise, and the research thus far has indicated that it is worth embracing.

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