Involving Undergraduates in Research and Publishing: A Holistic Approach

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Abstract

The purpose of the study was to determine if undergraduate students could develop scenario based science labs for local middle schools, teach the actual labs developed, and use the results of the experience for publication in a targeted journal. The labs were technique based, but were taught using inquiry methodology. College students with no experience in teaching revised a familiar college laboratory activity and taught it at a local middle school. Based upon the results of the lessons taught, the undergraduate students wrote an article for publication in a targeted, peer-reviewed science education journal, with several articles accepted for publication. Although the concept of lesson development, data collection and article submission were accomplished in one semester for four of the six projects, difficulties existed for undergraduate students in meeting the deadline for accomplishing all tasks within one semester. Time constraints with other classes, dependence on others in the group, and multiple revisions of the final article made the one semester timeline very difficult to manage.

Introduction

Research conducted by undergraduates can be a positive experience for both undergraduate students and faculty. Spencer and Yoder (1981) ranked liberal arts schools by the amount of undergraduate student research published. Based upon the number of articles, the top ten institutions had undergraduate students involved in an average of over 50 published articles per year between 1967 and 1976. Yoder and Spencer also counted the number of published research articles from 1981 to 1984 at the same institutions. After subtracting research conducted as a requirement for a doctoral degree and post-doctoral publications, Yoder and Spencer found that 45 percent of the remaining publications included undergraduate student co-authors (1987).

Undergraduate research classes often teach a specific method or technique and may be limited to upper classmen. For example, Froese, Gantz, and Henry (1998) had psychology students complete a class project of writing meta-analysis manuscripts. Students coded information from multiple, related sources and performed statistical analyses according to a prescribed method. Other programs have senior writing classes built around a capstone project that infuses research practices. Allen (1991) reported a geology capstone class that included peer review in the course requirements. In social science disciplines such as economics, senior capstone experiences that include writing and oral components have been advocated. Elliott, Meisel, and Richards (1998) developed a senior project analyzing a Nobel Laureate's work with reference to current economic or political issues. While these studies reflected components of synthesis and analysis, few included participation of undergraduates in data collection.

Few examples of undergraduate student research supervised exist in a formal setting that combine data collection, analysis, and scholarly writing. One example (Chamberlain, 1986) highlighted psychology students who conducted 29 true research projects and included undergraduate students in the data collection process. The sample sizes for the research projects conducted varied between one and 180 research participants for the studies examined. According to Chamberlain "student feedback on the course is strongly positive, both on completion, and up to several years later" (1986, p. 207). Nursing students also completed an in-class student research project (Cole, 1995). Cole added, "[c]linical faculty related that students were excited about the project, especially being involved as research subjects and assistants" (Cole, 1995, p.159). However, even these projects do not propose publication of results in peer-reviewed journals as the end goal.

Hakim (1998) suggested that undergraduate research experiences should include mentorship, originality, acceptability, and dissemination. Mentorship is critical since many undergraduate students do not have the scientific background necessary to develop their own projects. Careful selection of research topics by faculty or graduate students could overcome this limitation in the classroom setting. Carsrud (1984) found that when the academic department took a strong supervising

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role, graduate students developed an apprenticeship program for undergraduate students. In this program, undergraduates rated the graduate students more positively than faculty members in teaching ability. Undergraduates thought that one of the most useful parts of the program was the interest and concern shown by the graduate students (Carsrud, 1984).

The purpose of this study was to determine if college students could devise science laboratory-based lessons, teach these lessons to middle school students, and use the student responses to the lessons to attempt publication in peer reviewed science education journals. College students, with no experience in teaching, revised and taught a college level laboratory activity lesson with which they were familiar at a local middle school. These lessons and lab activities focused on using a technique, such as electrophoresis, to solve an instructor-given problem. The instructor-given problem was presented as a scenario. Data was collected concerning the middle school students' perceptions of the techniques and the scenario based presentation, and their reactions to the undergraduate student instructors. The data was gathered using written surveys. Specifically, the study focused on three central issues:

1. What are undergraduate students' perceptions of their first publishing experience that used data gathered during a middle school teaching experience?

2. Can middle school students be taught effectively to use advanced techniques commonly used at the college level to answer problems? Or, do these students perceive themselves as having difficulties with using the techniques or equipment?

3. What are the reactions of middle school students to undergraduate instructors teaching science lessons and laboratory activities in a scenario based setting?

Materials and Methods

This study took place during the fall semesters of 2000 and 2001 and the spring semester of 2001. The primary author and "mentor" was a teaching assistant for courses taught in the Agronomy and Biology Departments of a Midwestern university. Undergraduate participation was voluntary and not a requirement for any class. Undergraduate students who participated responded to an announcement made in their required biology courses inviting them to participate in a "publishing club." Some students received academic credit for their research projects as a separate, stand-alone research credit. Others, with the approval of their course instructors, substituted their research project for a writing requirement in a biology class in which they were concurrently enrolled. Nineteen undergraduate students were involved in one of six different projects.

The primary goal of mentoring was to help undergraduate students in their first publishing attempt. Some students chose to revise a class laboratory experiment from the previous semester, while others revised a laboratory experiment taught earlier in the semester in which they were enrolled (Table 1). Undergraduate students picked general lab topics and modified the college laboratory activity as an introductory lesson and lab activity appropriate for middle school students. The four topic areas used for developing the lesson plans were graphing student-generated data, protein electrophoresis using agarose gels, cell staining and viewing with microscopes, and plant tissue staining. The revised lessons and lab activities were taught at a local middle school. Most lessons were taught over a two-day period to multiple sections of students.

Undergraduate students participating in the study met with the mentor for approximately one hour each week. Undergraduate students were encouraged to write problem solving labs in which a scientific technique or a piece of equipment was used. The mentor served as a "safety net" for the students. By helping students revise protocols, teach a section at the middle school if scheduling did not allow an undergraduate the opportunity, and proof drafts, the mentor was able to ensure that all projects were completed. The process of writing for the undergraduate students was continual. Some students completed three to four revisions before the final draft was submitted to the target journal. Besides short lectures given on survey techniques, appropriate statistical analysis, and graphing data, meetings with undergraduate students were discussion-based. The students were given sample articles that served as templates for the target journals. Table 1 illustrates

Table 1: Summary of Undergraduate Projects

Project Topic	Number of Undergraduate Students Involved	Number of Middle School Students Taught	Semester	Target Journal for Publication
Seedling Identification	3	99	Spring 2001	"American Biology Teacher"
Seed Tissue Stain	1	94	Spring 2001	"Science Activities"
Gram Stain Bacteria	1	89	Fall 2000	"The Science Teacher"
Protein Electrophoresis	7	119	Fall 2001	"Science Activities"
Viewing Red Blood Cells	4	91	Fall 2001	"Science Activities"
Tissue Printing	3	94	Fall 2001	"American Biology Teacher"

the referred journals targeted for submission.

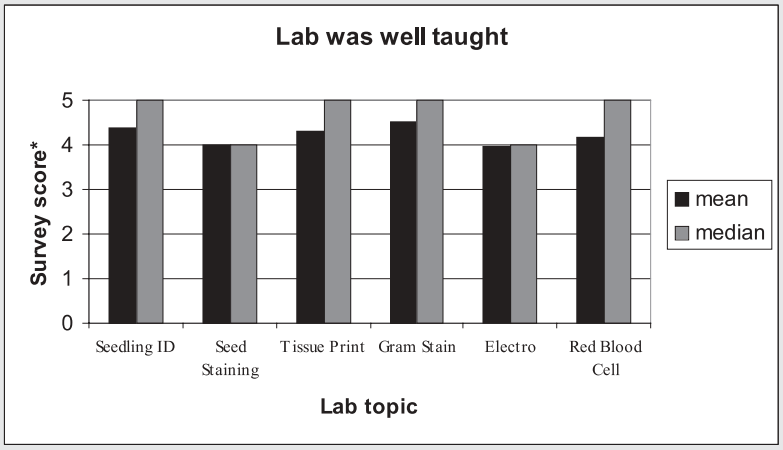
Almost 600 middle school students were taught in each undergraduate project (Table 1). To collect data on student perceptions of the undergraduate student lab experiments, students completed surveys after the lab activity was taught. Responses were measured using a Likert scale. Students were asked to respond to the statements using a five point scale with one representing strongly disagree, two representing disagree, three representing neutral, four representing agree, and five representing strongly agree. The number of survey questions varied with the laboratory activity, but statements related to how well middle school students perceived the teaching and enjoyment of the lab activity were included in all surveys. In general, each survey included the statements "overall, the lab was well taught," and "overall, I enjoyed the lab." In addition, undergraduate student perceptions were collected through the use of a survey at the end of each semester. The Institutional Review Board governing the use of research on human subjects where the research was conducted approved the research practices used in the study.

All lessons and laboratory activities were written in an inquiry fashion for middle school students. Undergraduate students highlighted key background information for the middle school students on the general topic of the lesson. The various techniques involved and the equipment to be used were demonstrated. Finally, a scenario or question was presented for the middle school students to solve. Due to the inquiry nature of the presentation, in-depth lecturing was avoided. Middle school students attempted to solve the problem in small groups, using equipment or scientific techniques to gather their own data. Inquiry education requires components of evidence presentation and communication to be present in each lesson. The middle school students who drew pictures of their results on an overhead projector or chalkboard fulfilled the evidence presentation component of the lessons and lab activities. The communication component occurred as middle school student results were discussed at the end of the lab activity.

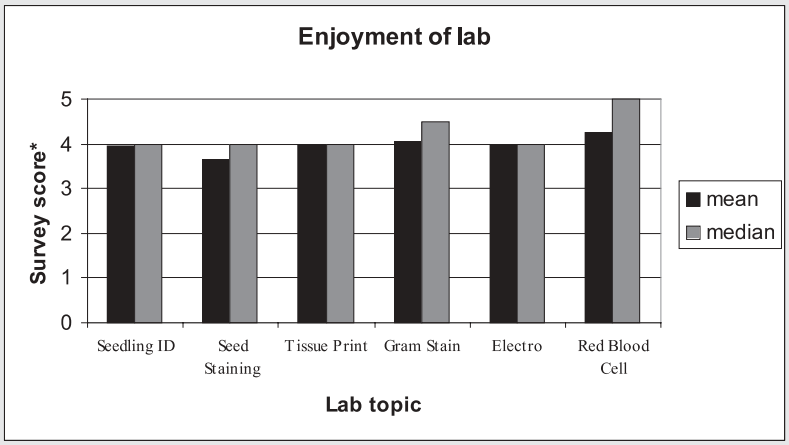
Finally, undergraduate students were surveyed for their perceptions of the research and publishing activity during the fall semester of 2001. Fifteen of a possible 17 undergraduate students returned the survey.

Results and Discussion

Regardless of the specific lesson and laboratory activity, middle school student perceptions were remarkably similar (Graphs 1 and 2). Lessons and lab activities were taught at two different schools to middle school science students. All lessons were taught to multiple sections throughout the day. Most class periods were 45-60 minutes in length with class sizes averaging approximately 20 students. Given the varied background and experiences of the undergraduate students, the results were positive. Most middle school students rated the undergraduate lessons and laboratory activities as enjoyable. The mean and median for student perceptions were approximately four indicating strong agreement that the lab activities were well taught. Most middle school students rated teaching by the undergraduate



Graph 1: Middle school student perceptions of a laboratory activity taught by an undergraduate student. (*Based upon a 5 point Likert scale with 5=strongly agree; 4=agree; 3=neutral; 2=disagree; 1=strongly disagree)



Graph 2: Middle school student perceptions of their enjoyment of the respective lab activity. (*Based upon a 5 point Likert scale with 5=strongly agree; 4=agree; 3=neutral; 2=disagree; 1=strongly disagree)

student as good. The data were skewed in each graph with the medians higher than the means, indicating a non-bell shaped data distribution.

Middle school students seemed to have little problem following instructions from undergraduate students inexperienced in teaching. Given the survey results, this implies that the middle school students felt comfortable with the instruction they received and that the middle school students were not frustrated with the techniques or equipment. Some laboratory activities were technically advanced for middle school students. For example, students used an oil immersion lens to view bacteria, made agarose gels to separate colored proteins, and examined tissues in seeds.

Of the six projects selected for lesson development, data collection, and article submission to peer reviewed science education journals, all six articles were submitted for publication. At present, five have been published while the authors are awaiting official notification on the status of the sixth article. Not all articles were selected within one semester. Two articles were not accepted until revisions were made. In both cases the authors were not notified of the article's acceptance until two semesters later. And, although the concept of lesson development, data collection, and article submission were accomplished in one semester for four of the six projects, difficulties existed for undergraduate students to meet the deadline for accomplishing all tasks within one semester. Time constraints with other classes, dependence on others in the undergraduate groups, and multiple revisions of the final article made the one semester timeline very difficult to manage. With time allotted for resubmissions and publishing, it may take a year or longer from the time an article is submitted until it can be seen in print.

Results of the undergraduate survey were encouraging (Table 2). One hundred percent of the students who returned a survey thought the experience was beneficial. Many students indicated they would participate in the publishing club activity again. It is especially encouraging that the students liked the informal club aspect of publishing, and all students had fun.

Some negative feedback came from the undergraduate survey. One student in particular thought the objectives were not clear. Given that the majority of the students preferred the informal aspect of the club, problems with directions and clear objectives were predictable. The club also met once a week at 8:00 p.m.. Some students considered this too late. However, the majority of students' short answer survey responses were positive. Examples included "I liked the experience of teaching and interacting with the students", "I liked having several opportunities to improve the paper before the final draft", "It was a great learning experience", and "I liked knowing what is needed in a paper in order for it to be considered to be published" as responses given to the statement regarding what students enjoyed most about the opportunity.

Table 2: Results of undergraduate student survey. Total number of students returning survey was 15 of a possible 17 of those involved in Fall semester 2001.

Question	Number of Undergraduate students responding "Yes"
1. The publishing club was worth it to me.	15
2. If my schedule allowed it, I would participate again in future semesters.	14
3. If biology offered it, I would be interested in taking a 300 level "Publishing class" similar to the club for a letter grade.	12
4. I liked working in groups.	14
5. The mentor sent too much e-mail.	1
6. The mentor was clear in the objectives	9
7. The mentor was clear in the "grading" substitutions for Bio 232	15
8. The mentor got comments back to me quickly	15
9. The mentor offered individual help if asked.	15
10. I have a better appreciation for what it takes to get published	15
11. I liked meeting informally on Wednesday night	13
12. I used the packet from the second week.	9
13. I would prefer a more structured club that includes lectures.	0
14. Overall, the experience was beneficial to me.	15
15. Overall, the experience was fun	15

Writing skills among the undergraduate students varied widely. Some wrote concisely and had little difficulty with scientific writing. Other students became upset when most of their first draft was deemed not useable by the mentor or needed major revisions. In addition, evidence of the degree of communication between the students and the mentor was obvious by the end of the semester. Over 200 e-mail messages were sent from the mentor to the undergraduate students in the fall semester of 2001, and over 100 messages from the 17 undergraduates to the mentor during the same semester.

From a mentor's perspective, a secondary benefit for the undergraduate students was the ability to make their own chemical reagents and try different procedures. The undergraduate students made several mistakes in revising protocols but they learned from their mistakes.

Funding for this publishing club was mainly by a

grant through the host university's School of Agriculture and from monetary gifts from a local corporation. A benefit to revising college laboratory experiments was that the undergraduate students involved could use excess materials directly from the accompanying teaching lab. As a result, costs were kept to a minimum. Only consumable items such as chemicals, reagents, seeds, soil-less mix, and microscope slides needed to be purchased from the club's account. Most projects could be completed for less than two hundred dollars. It was learned that in the short term, undergraduate projects could be funded through the associated department and through corporate sponsors.

Summary

Based upon the findings of this study it can be concluded that undergraduate students gained from the experience of teaching, conducting research, and publishing the results. A few of the undergraduate students were dual majors in science education and a second field but most were not education majors. Their effort to teach middle school students was outside of their career field. Despite this, the undergraduate students found the experience to be positive and beneficial. Based upon the findings from the undergraduate survey, students benefited from the club format utilized in this study. In addition, throughout the process it was evident that close supervision and constant feedback were essential to the success of undergraduate students in their attempts to publish research articles. Finally, it can be concluded that middle school students can effectively perform sophisticated procedures utilizing advanced scientific equipment. The undergraduate student responsible for teaching each lesson and laboratory activity made it possible to introduce more sophisticated equipment and techniques beyond what is found in most traditional middle school science classrooms.

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