Instrumentation Class Develops Interdisciplinary Skills[1]

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Abstract

In an agronomy and horticulture program, scientists use many tools. Professors with New Mexico State University's Horticulture Department have developed an instrumentation class that introduces students to instrument use and measurement for testing hypotheses. This Graduate Level class teaches communication and cognitive skills and interdisciplinary research team methodologies. Each week, the first class period introduces the instrument's theory, while the second period includes a hands-on demonstration. Students write one-to-two page discussion papers about each instrument. A semester project requires students to produce a hypertext Internet document on an instrument covered in class that explains the operation theory and describes how the instrument works, it's limitations and accuracy as well as data processing. Six of 43 students said more time should be spent using the instruments and that some instruments did not apply to their needs. While the course introduces students to science outside their expertise area, some did not see the value of this teaching effort. Students learned cognitive skills, as demonstrated by the sophistication and clarity of the hypertext documents they produced.

Introduction

Scientific research requires measuring environmental variables to see how they change through space and time. Graduate students often lack the expertise to use the laboratory and field equipment needed to conduct their research. They also lack knowledge of how to use instruments to collect information to test a hypothesis. An instrumentation class introduces students to the instruments' theory, use and measurement limitations for testing a hypothesis. Graduate and undergraduate science classes need to incorporate teaching strategies that are modeled on the way scientists conduct scientific investigations (Allard and Barman, 1994).

In addition to learning to use tools and techniques, new students are increasingly asked to participate in team projects. In fact, the current scientific environment often demands of interdisciplinary team work to develop and test hypotheses involving the biosphere (Satyanarayana, 1994; Mervis, 2002). Interdisciplinary team communication requires that team members understand all of the tools and have communication skills to listen and interact effectively.

Graduate schools offer courses that teach students how to conduct research. However, with greater emphasis on interdisciplinary research, they also should address skills for working in teams and developing independent and interdependent research methodologies. They should cover the communication and cognitive skills needed to be successful research scientists in a changing environment. Consequently, instructional strategies in graduate classes that incorporate cognitive activities must include practices with feedback and attention to schema, which is the flow chart of a system, process, or state variable (Lyle and William, 2001). Schema theory views organized knowledge as an elaborate network of abstract mental structures that represent one's understanding of the world. Cognitive science research suggests that learning should be goal-driven and situated in a context (Ram, 1999). In an instrumentation class, instruction about instrument use must be presented in the context of using the instrument to make measurements to test a scientific hypothesis. An example is using time domain reflectometry to measure soil moisture to understand how a decrease in soil moisture might affect crop water use and photosynthesis.

Graduate schools have developed interdisciplinary programs to encourage students to learn how to work on a scientific team. At New Mexico State University, the Department of Agronomy and Horticulture developed a doctoral level instrumentation class to better train students in scientific equipment use and team research. The course is described in the graduate catalog: "Use of instruments used in research in all areas of agronomy, including gas chromatography, high performance liquid chromatography, neutron soil moisture probe, and other instruments." The first objective is to introduce graduate students to the instruments and

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vocabulary used in different disciplines. The second objective is to teach graduate students how to improve their cognitive and communication skills in order to function in a team research environment.

In an agronomy and horticulture program, scientists use many tools, which cannot all be covered in one course. Using the Internet can broaden the scope of the material. Virtual instruments can be used to teach instrument theory and operation when access to a physical instrument is not available for all students. Virtual instruments are built to represent the schema of a physical instrument (Waller and Foster, 2000). Examples include an electrophoresis simulator (Craig, 2002) to teach the principles of electrophoresis; a voltage simulator (Bothun, 2002) to teach Ohms law; and a series of electrical circuit simulators to teach basic electronic principles (Svoboda, 2003). This paper describes how a graduate-level instrumentation class can be used effectively to teach communication and cognitive skills and interdisciplinary research team methodologies.

Instrumentation classes require significant resources and, consequently, are not offered at all universities. Most chemistry departments offer some instrumentation class, and a large number of engineering schools, ranging from mechanical to aerospace, offer such a class. An Internet search on August 10,2003 revealed no instrument classes that require the students to produce hypertext documents that describe the instruments and teach cognitive and communication skills. All of the classes had single instructors. Instrumentation classes usually are not taught in agriculture colleges, thus no literature was available about how to design and implement such a class.

Materials and Methods

NMSU's Department of Agronomy and Horticulture was formed in 1986, when the crop and soil science department merged with the horticulture department. This meant faculty with different interests were housed in one department and graduate students hailed from diverse academic backgrounds. The average teaching appointment of the faculty is 25%, with a 75% research appointment. The department offers five bachelor's degrees, three master's degrees, and one doctoral degree with a current enrollment of 105 undergraduates and 60 graduate students. The three main emphasis areas are ornamental horticulture, environmental and soil science, and genetics and crop breeding. The department currently consists of 20 professors and is primarily a research organization, where knowledge of other disciplines is essential to maintaining a cohesive unit. The instrumentation class includes students from all areas of the department. The class is taught by a group of instructors from within the department and from other departments within the university. Instructors teach about an instrument (Table 1) that they have a lot of experience using. The class is organized and run by the instructor of record who does the grading, presents several instruments and coordinates all lectures. The class presentation for each instrument consists of 1.5 hours of theory and 1.5 hours of laboratory application. Faculty teaching material for each instrument is both traditional lecture material and Web- based hyperlink instruction. (Hypertext versus knowledge management, 2003) All material is posted on the class Web site. The first week of class instruction focuses how to create hyperlinked Web-based material.

Table 1. Instruments and departments housing the faculty currently team teaching Soils 620, Instrumentation in Agronomy.

Instrument	Faculty Department
TDR probe	Agronomy and Horticulture
electrophoresis	Agronomy and Horticulture
gas chromatograph	soil water and testing laboratory
autoanalyzer	soil water and testing laboratory
LI-6400 System for photosynthesis measurement	Biology
biological oxidizer	Entomology, Plant Pathology and Weed Science
Campbell Data loggers	Agronomy and Horticulture
pressure bomb	Agronomy and Horticulture
high performance liquid chromatography	soil water and testing laboratory
Geographic information systems (GIS) technology	agriculture experiment station
The Global Positioning System (GPS)	agriculture experiment station
Palm Computer	Agronomy and Horticulture
GIS	

Grades are determined by the quality of the one-to-two page discussion papers written about each instrument turned in weekly and a hypertext document on a selected instrument. The weekly reports and the hypertext documents are returned for additional revisions until they are acceptable for public presentation. A teaching assistant helps grade the weekly reports. The assistant gives guidance to the students until an acceptable document is ready to be e-mailed to the instructor for final approval.

The one-to two-page discussion papers contain:

- Introduction with operation theory, application and unique usage
- Objectives including the instrument's advantages and shortcomings, how it operates, and what knowledge is required
- Results and discussion, including where to find information (links or books) and a summary of results

Students also are required to produce a Web-based hypertext document about using a particular instrument. They can work in groups for this assignment. A hypertext document is a nonlinear way to present information through links that allows readers to determine the order that information is presented, thereby allowing them to follow their own path. (Hypertext, 2003).

Originally, 15 students in the first class taught were required to produce the student hypertext Internet document on five of the instruments covered in class. In subsequent classes after the students produced hypertext internet document of all instruments presented in class, they were allowed to select instruments not covered in class but used their research areas. When a new instrument was added to the class syllabus, the students taking that class were encouraged to select that instrument for their student hypertext Internet document.

The hypertext reports contain:
- Operation theory
- Description of how it works
- Limitations
- Accuracy
- How to process data
- Documentation with photos

These documents serve as users' guides that provide basic information about how to operate the instruments. They contain photographs or artwork to facilitate understanding and enough hyperlinks for easy reading. Hyperlinks also were included to point users to supplemental information available on the Internet.

material the first time. Usually, one-quarter of the students had to rewrite their assignments at least twice. A few students had to revise their discussion papers three times. When one student was unable to do the work at a satisfactory level he was given an appropriate grade for the work completed.

Revising the reports forces students to reevaluate their thought processes, which develops their cognitive and schema skills. The teaching assistant also needs good cognitive and schema skills in order to grade the papers and determine when students have reached a satisfactory scholarship level. The reports must be written logically and concisely. The description of how the instrument works needs to follow schema theory. Occasionally, the instructor of record needs to work with the students directly to develop an adequate document. Each semester one student emerges as a better writer than the rest, producing a discussion paper that was complete, concise, logical and well-written. This was the standard by which the rest of the papers were judged.

To date, students have posted hypertext documents on 16 instruments (Table 2). The documents include the authors' e-mail hyperlinks, so that Internet users can ask additional questions. The students are encouraged, but not required, to work in groups to write the hypertext documents. They usually decided to work in groups of two to four.

Table 2. Hypertext instruments produced by students in Soils 620, Instrumentation in Agronomy.

Instrument	Number of authors	Currently taught in class	url: http://weather.nmsu.edu/Teaching_Material/soil698/
Electrophoresis	2	Yes	electrophoresis/index.html
Gas Chromatograph	4	Yes	Student_Material/gchp5890GCHP5840A\index.html
Biological Oxidizer	2	Yes	Student_Material/biologicaloxidizer/oxidiz~3.htm
Photosynthesis (Li Core closed system)	4	Yes	Student_Material/Photosynthesis/
HPLC HP 1090 Chromatograph	2	Yes	Student_Material/hplchp1090/
Spectrophotometer	3	No	Student_Material/spectrometer/index.htm#n
Pressure Plate Extractors	2	No	Student_Material/pressureplate/pressure.htm#t1
Atomic Absorption Spectrometer	2	No	Student_Material/AA/Portaweb.htm
Soil Nitrate Nitrogen "Quick Test"	1	No	Student_Material/soil-nitrate/Soil-Nitrate-Nitrogen.htm
Absorbance Micro Plate Reader	2	No	Student_Reports/Automatic_Soil/html/project620main.html
Chlorophyll Fluorometer	1	No	Student_Reports/Flourometer/mcf.html
pH Meter	1	No	Student_Reports/PH_Tester/SOIL-620-PROJECT.htm
Atomic Absorption Spectroscopy	1	No	Student_Reports/Spectroscopy/report.htm
SPINLAB Stelometer	1	No	Student_Reports/STELOMETER/stelometer.html
Autoanalyzer	3	Yes	SOIL698\Student_Material\AutoAnalyzer\index.html
Neutron Prob	2	No	SOIL698\Student_Material\neutronprob\link.htm

Results and Discussion

Requiring students to revise their weekly assignments until they are coherent and logical, means that all students can earn an “A,” as long as they are willing to revise their work. In many cases, this is a new concept for students who are not accustomed to being responsible for rewriting their work. This approach to grading gives students a taste of the real world. No students turned in acceptable written

Sometimes they decided to produce the document on their own and, consequently, their assignments lack the depth of a group activity. Some students do not feel comfortable in a team activity and likely would not make good team members in future research activities without additional guidance. In the team, generally one student is better at computers and putting together the hypertext document and another is better at writing and graphics. When the group size increases to four students, one or two often do not pull their weight. However, everyone is graded as a group. A lecture on group dynamics before the groups are formed may help produce more productive members.

The hypertext document is reviewed throughout the semester and suggestions are given about how to improve it. Some groups produce more complete documents with better graphics than others. In the first draft, some documents show a high degree of cognitive skill by the organization and hyperlink structure. Others that show a lack of communication skills are completely revised and resubmitted for critique. In some cases, the final documents still indicate low cognitive skills. However, they are accepted because of class time constraints.

The students form their own groups based on common interests. They are instructed to elect one student as team leader. If the group cannot agree on a team leader, one is assigned. That person leads the group to determine the structure and content of the hypertext document. The team leaders' interpersonal skills and overall abilities seem to influence the final product's quality.

Creating hypertext documents forces students to think using a schema methodology to organize knowledge. Creating hypertext documents has become easier with Microsoft Word. However, tools only make the cognitive thought process easier to execute not easier to conceive. In many cases, the hypertext document did not display on the computer server exactly as it looked in the Word document. Fixing this problem requires cognitive skills. In some cases, students cannot fix the problem, and a computer science student comes in to help the team. Thus, help from computer science students has made teaching this course considerably easier. Support for a computer science student should be part of every department's budget to help noncomputer science students become more literate in computer use.

The team teaching approach to the class requires nine professors to participate. Because the professors do not get teaching credit for team teaching the class, they must believe in the value of this class and generally be altruistic. The university has a structure to reward teachers of record for outstanding teaching, but has no method to reward teachers that give two to four lectures in a class as part of a team-taught class. The faculty came from not only the Agronomy and Horticulture Department but also the Biology, and Entomology, Plant Pathology and Weed Science departments. These departments work together closely, and faculty serve on each other's graduate student committees.

Student evaluations indicated that the level of teaching expertise was not uniform. Some instructors assumed basic knowledge behind the theory that all students in the class did not possess. Sometimes students have trouble following the theory section, which is presented as a lecture. Because no textbook is used, it is imperative that the students review the theory material on the Internet before class. When they fail to do this, they have more trouble understanding. Sometimes, an instructor teaches at too advanced a level. The instructor of record tries to bring the faculty member back in line with the students' level of understanding. Often, the students are too intimidated to ask for clarification.

When first taught in 1996, the class size was 15 students. However, as the course was taught more regularly, it had an enrollment of five to eight students (1996, 15; 1997, eight; 1998, nine; 2000, five; 2002, six). A class size of about eight is ideal. More than eight seems to cause problems during the laboratory period, because sufficient time for each student to practice on the instruments is not available. The enrollment in 1997 and 1998 represented the ideal class sizes. The faculty got tired of teaching the course every year, and the class went to an alternate year teaching rotation with a class size of five to six students.

Past hypertext documents posted on the Internet help students write the weekly instrument reports. The Internet information serves as a textbook for the class. The instruments that are taught change with time as some professors decide not to teach the class, participating professors leave the institution, or the instrument is replaced by something newer and better. For example, the neutron probe has been replaced with a TDR (Time Domain Reflectometry) to measure soil moisture. But a hypertext document about the neutron probe is still available on the Internet site.

Team teaching results in a more informative and comprehensive class, but a lack of administration recognition for this effort may limit the number of classes that can be taught in this manner by an individual department. Also, team teaching requires that all professors pull their weight and that the instructor of record be able to communicate with the rest of the team, coordinate the class presentation, show up at all presentations and spend time working with the other instructors to get their teaching material on an Internet server. The instructor of record learns a tremendous amount when team teaching such a class, but the instructor needs good social skills to convince the other faculty to participate. The instructor of record also should teach several sessions of the class on different instruments to make sure that other faculty do not feel put upon.

Class success is demonstrated by hypertext document use. The number of hits on this class site is not tracked but the web site receives 6000 hits a day and 20% of those are for the teaching directory, which has class material posted for five classes. The author has responded to at least 30 e-mail questions about the hypertext documents on the instruments. The high ratio of access to emails indicates that the hypertext documents are clearly written requiring little clarification.

Conclusion

The instrumentation class generally received good student evaluations on team teachers' familiarity, knowledge, interest and enthusiasm for the subject, and for this organization. Six out of 43 students said that more time should be spent using the instruments. This could only occur by decreasing the number of instruments presented. As expected, some students said that some instruments did not apply to their needs. The objective is to introduce students to science outside their expertise area and to teach communication and cognitive skills and interdisciplinary research team methodologies. All students learned these skills as demonstrated by the level of sophistication of the hypertext documents they produced using a team approach. The faculty continue to volunteer to team teach the course, even though they do not get credit for it. This continued support speaks highly of the faculty involved.

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