PROJECT- AND GROUP-BASED LEARNING OF *JUNIOR WRITING IN BIOLOGY*

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Writing in Biology, part of the Junior Writing Program, is inherently a project-based learning course. After a Science, Technology, Engineering, and Mathematics Teacher Education Collaborative (STEMTEC) workshop, the course was thoroughly revised. Each of six projects was modified to increase student-active and group participation. Base groups with a balanced experience constitution are established using voluntary ordering and random assignment. A walk-around during the initial meeting serves to establish bonding within the base groups. Random groups are used within exercises to stimulate student interaction and familiarity with ad hoc group cooperation. Digital images of, and by, students are used to encourage student interaction and name recognition. A website with the entire course plan is available at an archival site to complement and help elucidate the course.

Introduction

In the University of Massachusetts Amherst Department of Biology, the Junior Writing Program [1] is a University wide program and a degree requirement for undergraduates, and is implemented as the course *Biol 312: Writing in Biology* [2,3,4]. It is assigned to faculty who are assumed to have their own outlook on what the Junior Writing Program requirements should be. Indeed, the University has been flexible in allowing each department to define the guidelines for teaching its own majors the writing skills important to its particular discipline.

In that framework, I have been teaching *Writing in Biology* at least once a year for the past twelve years, with the exception of a sabbatical year spent off campus. That twelve years spanned the development of the World Wide Web and microcomputer resources on campus and in my department, and these have had a dramatic influence on the ease and direction of teaching courses. In Spring 1996, I instituted the first use of a home page for my *Writing in Biology* course [2], and I then participated in the Science, Technology, Engineering, and Mathematics Teacher Education Collaborative (STEMTEC) [5] Cycle II workshop in the summer of 1998. STEMTEC has had a fundamental and far reaching influence on my teaching approach to this course, and perhaps also on my teaching style in general. I must preface this endorsement of

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STEMTEC with the warning that I was an early convert to using computers in education, including early attempts to use the University Computing Facilities to teach biometry using the APL language with the teletype terminals available to us in the 1980s. Thus, some of my efforts to implement and encourage my students to use computers is wedded to my own career-long use of and devotion to mathematical approaches and computer implementations of data collection and analysis. For a scientist, that cannot be bad, in my eyes. Whether my degree of emphasis on computer technology for undergraduate education is appropriate, is itself debatable.

Using strategy I learned in STEMTEC, I derived very practical methodology for implementing group-oriented learning as well as project-based learning approaches. This methodology fit in very well with my earlier feelings that the most intense learning experiences were those with hands-on contact on a learning focus. On the other hand, my earliest teaching approach was wedded to my college and graduate learning experiences, where the majority of my professors spent their class time lecturing. The incongruity between how I had best learned as an undergraduate—"hands-on" experience—and how I was teaching my students continued to perplex me until I attended a STEM colloquium on teaching methods (spring of 1998). A talk entitled, “Teaching Human Biology through Medical Cases,” by Dr. Merle Bruno caught my attention. This peek at an enlightened approach led to my participation in STEMTEC Cycle II in the summer of 1998.

In this paper, I will describe how the *Writing in Biology* course has developed with the aim of making its methodology available to others teaching similar courses. It is sometimes hard to imagine students learning without the inspiration of their professor at the head of the class. This description of my progress in teaching *Writing in Biology* is an attempt to redefine my own role as director in a classroom and whose students are involved in managing their own learning experience.

Materials and Methods

The methods used in teaching *Biol 312* (Table I) can be precisely described if not precisely applied. I will discuss each method to explain its utility and implementation in the course. Some of the methods were acquired during the STEMTEC Cycle II workshops and some were developed through an evolutionary process in the classroom.

Table I. Methods used in teaching *Biology 312:Writing in Biology*
Six formal student projects (60% of grade).
ad hoc assigned projects (40% of grade).
Course home page, e-mail list, calendar of events, syllabus and notes.
Base group implementation.
Random groups used ad hoc.
Blacklist Errors establish a code which should not be violated.
Digital images of students increases student identification.
'E-mail 3 then me!' to encourage student-student interaction.
Mini-lecture organization.
Case-based organization.
One-minute essays e-mailed to instructor.
Laboratories are used to complement the projects: A. Careers Day held along with Vita/Résumé project. B. Excel workshop associated with Technical Report project. C. Library and Informational Database searching.
Overall focus on student ownership of a "Term Project."
Terminal symposium of student projects.
Peer comments and grading of Term Project talk.
Students develop Rubric for grading projects.

Six Formal Student Projects

The learning experience in *Writing in Biology* revolves around six formal projects (Table II) which represent 60% of the student's final grade. Completing the six projects involves the core communication skills that I decided need to be developed to an acceptable level of proficiency in any student who wants to be considered a modern biologist. These are described below. Students are given sufficient time (at least two weeks) to finish each project and in most instances, have the opportunity to resubmit it once and get re-graded. The new grade is averaged with the old, therefore pressure exists to get it right the first time. Also, the right to redo a project is absolute only if the project is submitted on time, thereafter it becomes negotiable.

Table II. Six Formal Projects of *Writing in Biology*	
Project	**Special rules**
Centered Abstract	Hard copy, electronic, and redoable
Curriculum Vitae	Hard copy, electronic, and redoable
Technical Report	Electronic only, and redoable
Annotated Bibliography	Electronic only, and redoable
Popular Essay	Electronic only, and redoable
Poster / Talk	Poster or talk, one time only

The Centered Abstract - This project is used as a method of introducing the student to the concept of being in total control of a finished writing product which must fit in the constraints specified by a conference at which they will be presenting their ideas. They are given basic guidelines to follow: (1) sources of subject matter (*Scientific American*, *New York Times*, or *Science Times* essays on biological subjects for the past six months); (2) instructions on placement of the abstract within a prescribed space on an 8-1/2" x 11" page; (3) instructions on required and optional formatting; (4) must be turned in as hard copy in the specified format and as an attachment or insert to e-mail in a limited number of formats (flat text, RTF attachment, URL pointer).

Curriculum Vitae - Students are made authors of their self descriptions. This allows students to describe themselves in their own best light. It produces a document which they may find difficult to assemble at a later time under pressure. At this time, they can begin defining a look back on their careers and assemble information which will be a foundation for their future. This project must be turned in as a hard copy and as an attachment or insert to e-mail in a limited number of formats (flat text, RTF attachment, URL pointer).

Technical Report - Every science student has been called upon at least once to produce a lab report, yet it is rare that one gets to spend time on the format of an ideal form of such a document. The skills learned in this process could have major consequences for the professional advancement of students in their disciplines. Students who are doing independent study in a university lab are encouraged to use this Technical Report project to develop their final report for their independent study. This project must be submitted in an electronic form with one or more of a limited number of formats (RTF attachment, URL pointer).

Annotated Bibliography - Writing without intellectual rigor is worthless. In this project, students learn to use modern library resources including on-line catalogs and reference gathering from databases such as Medline and Web-of-Science. The difference between a core reference from a refereed journal and a URL from the World Wide Web is defined. Electronic processing of searched for information must be performed to bring it together into a consistent format of a bibliography. Capturing essential information from a reference in an annotation limited to two sentences develops the skill of interpretation and summarization. This project must be submitted in an electronic form with one or more of a limited number of formats (RTF attachment, URL pointer).

Popular Essay - While scientists need to be able to understand technical information, professional scientists also need to be able to communicate their expertise to the public. The popular essay allows students to translate, for popular consumption, their expertise gleaned from reading technical journals and analyzing graphs and charts. If students truly understand their subject, they will easily convey it in plain language understood by the layman. This project must be submitted in an electronic form with one or more of a limited number of formats (RTF attachment, URL pointer).

Poster/Talk - Written and spoken communication are quite different and require separate skills. In this project, the students learn how to present their topic to fellow students either as five minute talks (+ three minute discussion) to the entire class or as posters which they explain to a small audience in a simulated poster session setting. This project includes an abstract that must be submitted electronically by a deadline. It must be presented live at a symposium session scheduled at the end of the term using either the physical poster with a presenter or a five minute talk format using overhead and/or *PowerPoint* projections. The students grade all the presentations according to a rubric which they have helped produce. The students also vote for a single top presentation that has no bearing on the final grade.

Ad Hoc Assigned Projects

Class assignments are meant to be completed in a short prescribed time, perhaps within the laboratory period in which they were assigned. They involve immediate hands-on learning or cooperation within a group to accomplish the task assigned. When they are to be graded, students must have a tangible result that can be assigned a grade. The immediate objective of the assignment may be trivial, while the skills learned through the process of group activity, cooperation, and communication may be the ultimate objective of the assignment. The types of ad hoc assignments include one-minute essays and random-group activities.

One-minute essays e-mailed - The availability of student computer stations in the University Microcomputer Labs and Biological Computer Resource Center (BCRC) [6] allow one to stop a learning segment and inject a one-minute essay which is e-mailed directly to the instructor. In another version, the minute essay is e-mailed to another student who then must respond with commentary or criticism.

Random group activities - In order to allow for variety in student interaction, several ad hoc group assemblages were used. Several methods of ad hoc grouping were used including, nearest neighbor pairs, nearest birthday pairing, and jigsaw grouping (a disassembly of the base groups sending delegates to select focus groups). The objective is a greater mixture of interactions between more students in the class. Typically, the groups created were assigned a task that required or would be aided by cooperation within the group.

Walk-around - During the initial meeting of the class, there is often little concrete to do that falls within the project-based nature of the course since no projects are yet established [7]. In getting the students acquainted with their base group, as well as group dynamics, a standard walk-around student activity was devised. The students, in their base groups, first walk around five to six stations, each with an initially large blank poster with a controversial question posed. The group discusses the question and adds some written response to the sheet using a colored marking pen. After five minutes at each station, the groups rotate to another station. The class is next randomized into six different groups who go to one of the stations and evaluate the responses the base groups had added to the posters. Then, a representative from each group presents the conclusions of the poster. This walk-around activity gives the base group and the class as a whole an opportunity to converse and get to know each other in a semi-relaxed atmosphere. The leader or designee takes time during the rotations to take pictures of students and their groups for use in other class projects

Course Home Page, E-mail List, Calendar of Events, Syllabus and Notes

It became efficient to present this course in this format because of the availability of easy communication over the Internet as well as the promulgation and availability of computers and software for communication. The convenience of having supportive documents and instructions on-line and being able to communicate in multiple ways (instructor ⇔ student ⇔ student) allows for a different dynamic in the learning process. The work of the classroom extends to wherever there is a computer terminal on the Internet.

By 1996, the Department of Biology had made an investment in a computer resource center, the BCRC, which included an electronic classroom with 25 computerized student stations. In addition, a SPARCstation 20 was provided to serve as a server to integrate the lab with other ancillary equipment, such as printers, slide and flatbed scanners, and cameras. The SPARCstation also provided a powerful Unix box separate from the department's workhorse that could be used as a web server devoted to teaching projects. This investment was a conscious commitment by a department to embrace the electronic aids to teaching.

In addition, a full-time faculty position was funded to provide an education professional whose research interests and expertise lay in the application of technology to teaching. Without the foregoing commitments of the Biology Department, I would have found it difficult to make the changes in my teaching approach that are listed here.

Even with all the physical support by the University and the Biology Department, establishing an effective course delivery would be difficult if aspects of its delivery were not made routine for the student as well as the instructor. For that, we biologists are indebted to the director of the BCRC. He adopted and managed a system of software that provided a uniform Internet interface for all Biology Department course offerings (whether it was used or not). Links to a course syllabus and a course e-mail list make information and communication about the course available to the student at a click of the mouse. A calendar of events with hyperlinks to the project descriptions allows students to know more precisely what is expected of them to make progress. Workshops are scheduled to help faculty make use of the internet utilities available to them.

These improvements in teaching technology do not happen without support from a committed administration. One can not underestimate the importance of a department chair and college dean who manifest their commitment to improved teaching technology in an enlightened way.

Base Group Implementation

Students were randomly distributed according to expertise into base groups, four students to a group. This was accomplished by first asking students to divide into three levels of experience in information technology (IT) methods, including word processing, spreadsheet analysis, and Internet skills. Then these groups were placed in a long line that counted off 1-6. This created six groups, each having high to low IT skilled members. The base groups would provide a nucleus within which group cooperation and individual roles could be practiced. Leader, recorder, skeptic, and reporter roles provide each group with the opportunity to cooperate in carrying out class assignments in which division of labor would benefit the group as a whole.

A Blacklist Errors Document Establishes a Professional Code Not to be Violated

To be a professional biologist, major errors in communication should be avoided. Highest on that list is plagiarism, a professional form of cheating. However, the concept of plagiarism is presented in its professional context where scientists need to preface their own contributions with the citation of ideas contributed by their science forebears. Professionals must be able to reflexly recognize when ideas they are presenting are not their own and give proper credit to the authors. Thus, one avoids being labeled a plagiarist by using the research tools of the library to ensure respect of past contributors. Second on the communication blacklist are grammatical and spelling errors that lower respect for the communicator. A list of these key errors is posted and each error committed in an assignment or project is an immediate reason for grading down the student's work and reinforcing the elimination of that erroneous behavior.

Digital Images of Students Increase Student Identification

On the first day of the semester, digital images are taken of each student. The images are used to improve greater cohesiveness in the class. Teacher identification of the students is improved. The images are posted on the class web page, used in a group identification assignment, and are available for the students to enhance their own web pages.

"E-mail 3 then me!" to Encourage Student-Student Interaction

An e-mail list for the entire class as well as individual addresses for each student are listed and students are encouraged to e-mail the entire class and one another when they run into problems. Many students will reflexly e-mail the instructor for answers to questions. In an environment where e-mailing is encouraged, this can result in an overwhelming number of e-mails to be answered by the instructor. To encourage a more even distribution of e-mailing within the class, the ***"E-mail 3 then me"*** rule was established. This rule suggests that the students should address routine informational questions to at least three other class (or world) members before they e-mail the instructor. Points are given for posing and answering substantive questions to the entire class through the class e-mail list. These are awarded as bonus points at the end of the semester.

Mini-Lectures

In breaking out of the traditional hour-long lecture format of traditional university courses, the "lecture" and "lab" meetings of the course are broken into short mini-lecture segments. These mini-lectures are interwoven with evaluation and student-active segments in which the learning of the mini-lecture is consolidated by an assignment that practices the new skills.

Case-Based Organization

In a case-based approach, one supplies a rich problem plus the tools to solve the problem, to either individual or groups of students. The objective of this approach is to get students to be reflective of their current stage of development and to learn to choose the proper tools and use them in solving a problem they might run into in their chosen professions [8]. It is a teaching method being used in professional schools to get students involved in an approach as they might apply it in the real world [9]. Application of case-based methods to undergraduate science education is less common [10].

I have used the Goldenrod Gall case [11,12] as a theme in one laboratory to create the rich fabric for students to investigate. This particular case-based example requires a wet/dry lab learning facility that allows the students to manipulate biological material and simultaneously record observations on computer terminals.

Most university wide computer classrooms are not designed to accommodate this type of special learning experience. This is a reason for designing computer classrooms at the departmental level (here, the Department of Biology) so that the peculiar requirements of a discipline may be accommodated during the planning stage.

Laboratories Complement Projects in Tool and Skill Development

The six formal projects are rich in detail as projects in themselves, and need explanation and help to be properly approached by the students. The projects can be enriched by independent exercises that are assigned in laboratories run in parallel with the projects. For example, a Careers Day was held at the time of a Vita/Résumé project; and, an *Excel* workshop was held paralleling the need of such tools for the Technical Report project. The primary concern remains the development of critical skills in each student.

It is hoped that the assignments and enrichment exercises will develop a professional sense of differences in value of: (1) primary references from peer reviewed journals; (2) reviews of the field by experts in their field; and, (3) reviews by professional writer commentators; (4) commentary obtained in non-peer reviewed URLs.

Students Develop Rubrics

The basis for grading of two of the six formal projects is discussed and modified by the students using random small groups. A student-developed rubric establishes what is expected and what would constitute loss of credit for the two projects at a time when the students should be preparing to carry out the project. Owning the rubric allows students to focus on the fairness of various reasons for loss of credit and focus on the objectives of the project.

Student Ownership of Term Project

While an atmosphere of availability of support for all types of technical issues is encouraged, each student is expected to become the local expert in their Term Project. Ownership of that project is used as a confidence building tool. Students are encouraged to speak about their projects at several points in the semester to develop their ownership of the topic. Any duplication of projects is turned into pressure to differentiate the approach taken by the superficially similar topics.

Terminal Symposium During which Students Share their Term Project in a *Presentation*

A symposium is prepared at the end of the semester in which students provide a final abstract on their term project and give a 5-minute talk with additional minutes for questions and discussion. A student photographer takes digital images of the proceedings to give the students an image of how they appeared on stage and to apply a level of pressure on their performance. When there is not enough time to present all projects as talks, the overflow is allowed to use a poster session format.

Peer Comments and Grading of Term Project Talk

Students participate in the grading of the abstract and oral part of the Term Project talk.

This is one of the formal projects for which the students helped to develop the rubric. The preparation of the rubric allows them to contribute more effectively to the grading process.

Results

The content of *Writing in Biology* has changed in the twelve years that it has been offered in this format (Table III). While it was always a project-based learning experience, the way *Writing in Biology* is taught has changed dramatically. Initially, a large amount of time was spent in the traditional mode of expert-professor transferring information to *tabulae rasae* students. I now recognize that most of that lecture time and "expert vs. empty-vessel to be filled" attitude was a misuse of time. While students in project-based learning regimes benefit from being overseen by an expert [13], the majority of students can rarely retain and digest the material provided in long lectures by such an expert. Now, more emphasis is put on students experiencing hands-on solutions to their own communication problems, using the information resources that are available and only one of which is a professor. Communication among the students is encouraged by the formation of formal and informal groups whose objective is to cooperate and communicate. Tools, similar to the ones they might use to solve problems, are provided and they have instructions, group partners, and local experts to consult in how to use the tools. All students can advance at their own pace using the available resources, but all students are also judged against minimal standards specified in the Blacklist Errors document.

The major global factor in the change of approach to teaching *Writing in Biology* has been the increased availability of IT; in particular, the personal computer, the Internet, and e-mail. These tools have allowed the teacher to expand the experiences that can be presented to the student in a learning environment. Before, communication was hampered by the need for face-to-face communication or often through scribbled handwriting. Digital personal computers provided a way of recording and transmitting, first by printed output, then by e-mail and finally by attachments of digital documents, including images, to e-mail. The Internet allows lecture notes to be provided on-line. In addition, the introduction of the Hypertext Markup Language (HTML) allows 'hyperlinks' within the notes to provide further enrichment of the lecture material by rapid (one mouse click) linkage to ancillary information. This ancillary material may be developed locally by the instructor or may be available on the web (e.g., the U.S. government has financed the free availability of bibliographic, genomic, and taxonomic databases via the Entrez search engine). Teaching students how to access this rich resource which is expanding every week, is empowering them to join the new IT century. Not teaching them to access this resource may lead to a new level of illiteracy, information age illiteracy.

While global factors establish the limits of what is possible, often local factors limit what can be accomplished. The major local factors in the changes introduced in *Writing in Biology* have been the institution of the Microcomputer Resource Facilities by the University Office of Information Technology (OIT), the development of the Biological Computer Resource Center (BCRC) by the Biology Department, the hiring of support staff, the progressive ethernet wiring of our department and campus, and institution of the STEMTEC organization. IT started in earnest in the Biology Department in 1988 when our then departmental electronics specialist, George Drake, was encouraged by our forward looking Dean Fred Byron to install ethernet wiring in our building, the Morrill Science Center. At that time, Chris Woodcock and I were bemused by our new ability to e-mail each other and George from our desktop computers. We were more impressed with being able to store data and access it on a disc drive attached to our Unix based minicomputer which was a floor away from my office computer. It was challenging to take advantage of the subsequent exponential increase in resources that were made available by these foregoing factors.

Table III. History of significant facts and actions contributing to the evolution of *Biol 312: Writing in Biology* (as taught by JGK)

1988	Prehistory and Infrastructure	The Biology Department is wired with ethernet. Faculty gets e-mail.
		University establishes PC based lab classrooms.
		Writing in Zoology under JGK begins using the University PC classrooms.
1994	Necessary commitment of funds	Howard Hughes Foundation funds a Macintosh based Biological Computer Resource Center (BCRC).
1995	Individual effort	JGK learns HTML programming, as well as the Macintosh platform.
1996	New Investment	JGK uses HTML to establish the first website for *Writing in Biology* .
		A director of the BCRC was hired with Biology faculty member status.
1997	Providing Tools	BCRC director implements a home page for every biology course. STEMTEC Program is established to stimulate teaching improvements in science and technology.
1998	Synergy	JGK participates in the STEMTEC Cycle II workshop.
		JGK implements group- and project based approaches to *Biol 312.*
		SARIS report finds 65-70% of UMass Amherst students use computers.

Many new as well as older professors found it difficult to take advantage of these opportunities given the pressures to maintain expertise in their own research specialties. The recognition of this fact by the Biology Department led to hiring a professional director of the BCRC in 1996 to implement mechanisms which would help the faculty include IT methodology in their teaching. The current director was identified by a committee, cognizant of our growing need for expertise in the areas of IT, instructional technology, and instructional software. Without the thoughtfully constructed resource that our BCRC director provides, I am sure that progress in transforming the teaching of biology at our university would be considerably less advanced. Unfortunately, the decisions for designing and acquiring the BCRC facility were carried out while I was on sabbatical and the committee went entirely with Macintosh computers. This required that I, a dedicated PC user, learn the then substantial differences involved in using the new computers. In the ensuing years, the differences in software and file compatibility have decreased and divisive pressures on the students (who are also mainly PC owners) have subsided. This is a familiar story, and a reason it often takes substantially greater effort to innovate techniques. Reduction to routine practice often takes several years. In that respect, the IT and teaching technology advances need to be encouraged by an understanding administration that values the efforts put in these new directions.

The implementation of *Writing in Biology* evolved over several years. In the initial years, 1988-93, the availability of microcomputers or word processors was not universal among students, particularly students at a state university, drawn from all economic levels. Only a few public microcomputer labs of about twenty computers were available for a population of over 20,000 students. Personal computers were not yet an essential part of each student's personal property on campus and the few that had computers were not yet connected to the Internet, itself a new concept on campus.

When I started using the University Microcomputer Labs for teaching skills in *Writing in Zoology*, I considered the use of the microcomputers an optional enrichment and did not feel comfortable in absolutely requiring students to hand in all their writing projects typed or printed. That meant teaching *Writing in Zoology* involved the pain of reading often horribly handwritten assignments. Two classes of students developed, those with and those without easy access to a microcomputer and printer. This contrasts with the subsequent gradual development of easy access to university-wide microcomputer facilities with ancillary printer output capabilities.

It is interesting how back then, the perceived major controversy over who would pay for all that paper was resolved. It was remarkably decided that the cost of a few reams of paper was less important than encouraging the use of the new technology. "If you make it next to free, they will come!" It is (was) an important transition to the paperless society. Making this technology easily available to the students enabled me to require students to submit writing assignments printed and, more recently, as attachments to their e-mail or posted on their personal web pages. Each step moves closer to the paperless and minimal energy use society which is making our country more productive. Receiving their digital homework allows me to use spell checkers and grammar checkers to filter the assignments prior to reading them for intellectual content. What a difference twelve years has made!!

The technology, of course, has gone through its own painful development. Early e-mail utilities did not have convenient editors with spell-checking capabilities and this led to a decline in grammar and spelling skills since everyone was supposed to accept the poor construction that attended the new way of communication. Advances in e-mail utilities now allow me to demand the same careful preparation of e-mail messages as I demand for essays.

STEMTEC Contribution

By far the greatest change in the format of the *Writing in Biology* course was implemented after I took the STEMTEC Cycle II workshop in the summer of 1998. Previously, I did not use grouping of students at all in my teaching of this course. The approaches introduced by the workshop resulted in introducing base groups, random groups and jigsaw groups as ways of introducing cooperation, organizational role play, and communication between students. Prior to my STEMTEC experience, grading was dependent solely on six formal projects. After STEMTEC, I implemented new features such as graded ad hoc class assignments which both engaged the students and gave them a reason for coming to class. Most of student work on formal projects could still be completed by using the already implemented on-line descriptions of the projects. To encourage students to come to workshops which I designed to enrich their formal project implementation, I linked the workshop with the project using grading. I linked related workshops with projects; i.e., participation in a committee based career search was linked with their formal CV preparation project. I linked a spreadsheet workshop to parallel their formal Technical Report project in order to provide the skills for accomplishing their formal project. However, it was the short, graded, ad hoc assignments during the workshops that required their attendance to carry out if they valued the 40% of their grade dependant on class assignments. Thus, it was an unanticipated combination of student active exercises plus ad hoc testing that had a positive effect on class attendance.

Grading the Project- and Group-Based Course

Some of the formal projects and ad hoc assignments fall into the traditional grading scheme of quality points given for how close one comes to the ideal response described in a rubric for the project. Before STEMTEC, the rubrics were loosely defined by the instructor and sometimes not well explained to the student. By involving the student in assignments in which they constructed, modified, and presented proposals for modifying a project rubric, through interactions within a small group, both student and instructor became more cognizant of the objectives of the projects and what were legitimate bases for grading. However, it is in general harder to grade the various ad hoc assignments that are spawned during the class periods. Rubrics for these assignments cannot be spelled out too completely since there is often only a short time given for their completion (e.g., a one-minute essay on a subject to be transmitted immediately by e-mail to the instructor). Deadlines for submission are often not met and some credence must be given to the reasons for tardiness as well as credit given to those who meet the deadlines. In addition, many of the class assignments use groups to accomplish the goals. How does one gauge the performance of individuals within the group? When a group with a missing member during a given week carries out an assignment, does the entire group benefit or suffer from the assigned grade? These problems often need to be dealt with in a very individual way that may cause some questions from students.

Advantages of the Web Page Based Course

In the past, one's image of progress in the development of a course was almost totally based on memory and perhaps notes about how things went that semester and one's grade book. Now, biology course web pages are routinely archived each year by the BCRC director providing a detailed history of the electronic course material [2,3,4], and, if designed into the site by the instructor, includes examples of student work [14]. Previous years' results can be a basis for current course projects. Students can view the results of prior classes. Archived pages make updating easier for the instructor and attention can be given to enrichment in succeeding semesters. Instructor-archived assignments and course web pages at critical times during the semester can be a record of student progress within the semester and can help in initial grading, as well as resolution of controversies at the end of the semester. At some point, when enough years of archived courses are accumulated, this archive could be a subject of study by educational research specialists on the effectiveness of various teaching approaches. In fact, the problem of evaluation of the effectiveness of teaching innovations and technology is one of the most vexing problems in educational funding.

The Future of *Writing in Biology*

I hope that *Writing in Biology* will persevere in its student centered objective of producing biologists who are well trained in communicating with their fellow biologists and the world in general. Accomplishing this objective will require the continued cooperation of faculty, administration, and taxpayers to keep our technology close to the forefront of IT. This is particularly challenging in an atmosphere of pressure to reduce taxes without reducing educational services. The electorate must understand that you rarely get more than you pay for. The Howard Hughes Foundation grants that were used to enrich our biology educational environment carried a stipulation that the University carry on some of the innovations that were funded by this charitable trust. This means that some of the burden of maintaining our new IT facilities and educational approaches will fall upon the federal and state taxpayer or tuition payer. Unfortunately, too much attention is being paid to glorifying individual teachers who expend superhuman effort for their students. As admirable as these individuals are, education cannot depend upon having such great teachers of extraordinary dedication. In fact, given the low wages that teachers are generally paid, we must be able to use teachers of average intelligence and dedication to carry out the majority of our educational goals. Science suggests that there are methods which, when applied correctly, should give us a desired result. *Writing in Biology*, taught using the formula presented here, is an attempt to allow the students to learn their needed skills in a learning environment that is optimized for their success. Since the majority of work expended in the learning process is by the student, we should be able to design and apply a teaching methodology which allows the students to learn at an optimal rate. We become engineers of the learning process, applying good organizational skills to keep the learning environment well stocked with the correct learning tools and opportunities for our students. This may be a big difference from how we originally envisioned passing on our interests to our students (overwhelming them with our intellect), but we must come to the realization that the old forced feeding approach has not been working well and a new direction is called for. Using the formula provided here, we use the old trick of convincing the student that their learning was their own idea. I know that I learn best that way.

The future for any course should include experimentation with new features. Given the importance of IT and computers in modern society and the recent development of Learning Goals by the Biology Department which include teaching more math skills [15], I am experimenting with adding a project or exercise to the *Writing in Biology* course which uses the new, free, computer programming language, J [16]. I am hoping that it would at least be useful to give our students a taste of what using a modern computer language is like and give them a chance to learn how to communicate with or to their own computer.

Application of this Model to Other Courses

Aspects of the *Writing in Biology* model as taught by me certainly could be extended to sections taught by other biology instructors as well as Junior Writing Program courses taught in other science disciplines. Many of the techniques and problems described are not in any way limited to the discipline of biology. In fact, a collaboration of several science faculties teaching the Junior Writing Program course might benefit from consolidation of effort and sharing of resources.

Application of this model to teaching of other subjects is under development by this author. One obvious application is to a laboratory course that is also inherently project- and group-based. Combining the Technical Report and the Poster/Talk projects into the traditional lab report aspect of a laboratory course are natural progressions that are under way. Insertion of ad hoc assignments would improve lab group member tardiness and absences. Given the usual time constraints in labs, some aspects of group organizational improvements in e-mail communication could make the laboratory experience more positive for students. Clearly, the benefits of having all protocols and informative hyperlinks organized within a course website is applicable to any laboratory course. ■

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