The Implementation and Efficacy of Scientific Literature within an Introductory Biology Lecture Course:

A Study in Pedagogy, Curricula, and Standards As They Apply to Post-Secondary Science Education

by

Shaun Allen Tomaszewski

Submitted to the Faculty of the

University Honors College, University of Pittsburgh in partial fulfillment

of the requirements for the degree of

Bachelor of Philosophy

in the areas of Microbiology and Neuroscience

University of Pittsburgh

2009

Docendo discimus

Δ

UNIVERSITY OF PITTSBURGH

University Honors College

This thesis was presented

by

Shaun Allen Tomaszewski

Defended on

April 3rd, 2009

and approved by

Susan Godfrey, PhD, Biological Sciences, School of Arts and Sciences

Kathy Humphrey, PhD, Administrative and Policy Studies, School of Education

Sandra Bobick, EdD, Biology, Community College of Allegheny County

Thesis Director: Laurel Roberts, PhD, Biological Sciences, School of Arts and Sciences

The Implementation and Efficacy of Scientific Literature within an Introductory Biology Lecture Course:

A Study in Pedagogy, Curricula, and Standards As They Apply to Post-Secondary Science Education

Shaun Allen Tomaszewski

University of Pittsburgh, 2009

The current study involved students enrolled in the Fall 2007 Biosc 0150 and Spring 2008 Biosc 0160 lecture sections of a single Faculty member. Most students were incoming freshmen, and their prior exposure to the natural sciences varied. A single recitation section was used as the experimental section, taken from each lecture section. In addition to regular instruction, the students enrolled in the experimental section were also assigned readings from peer-reviewed journals. The performance of these students was then tracked, as it was expected to vary, and compared to that of the students enrolled in the control recitation sections. There was found to be a significant difference between the achieved mean course grade of the experimental section and the control section, for the Biosc 0150 lecture section, but not in the Biosc 0160 lecture section. Important trends, though, were noted in both semesters and are examined herein.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

I would like to first thank Laurel Roberts for her continuing support of educational research and thereby past, current, and future educators. She has served as a personal, academic, and professional inspiration and will continue to do so for myriad students anon. I would also like to thank the members of my thesis committee; Sandra Bobbik, Susan Godfrey, and Kathy Humphrey. Their varied support throughout my undergraduate career has driven me into a career of education and service. Finally, I would like to thank the University Of Pittsburgh Department Of Biological Sciences for allowing this curriculum research to be done and for further allowing that research to serve as the foundations of this Thesis.

1.0 INTRODUCTION

A Need for Change

The education of America is a particularly interesting and worthwhile topic to study academically. The current movements witnessed in primary and secondary education[1,2,5,6] serve to remind both educators and the general public that a clear vision is both lacking and needed, and more importantly, that a clear direction is needed to ensure the primacy of the American education system within the global economy.

The current cultural and social dynamics of life have affected the manner in which we communicate and have thereby affected the manner in which we educate. Throughout the past century, there have been dramatic alterations to the dimensions of communication. Spatially, the dimensions of communication have expanded such that individuals can communicate with and develop relationships with people in every corner of the globe. Temporally, the dimensions of communication have contracted to levels unimaginable even a decade ago. With the advent of text messaging, Facebook, and Twitter, one can have a multimedia conversation with multiple people in disparate parts of the world instantly.

Educators and the pedagogical paradigms in which they operate are becoming more and more aware of the rapid strides being made in the fields of information technology and communication processes[3,10,11,14,17]. Educators today are increasingly willing to apply cutting edge methods to their curricula[3, 9, 10, 11, 12, 14], but some teachers and professors continue to be satisfied with more conventional techniques[4, 8, 10] that can stifle many students' cognitive potential[7, 10] and don't allow for a truly "learner-centered" environment[13]. Further, today's students *expect* various forms of information technology to be used both within the classroom and within the curriculum[17]. In order to witness sweeping technological reform, though, the general public must be willing to support developing information technology infrastructures that will facilitate increased communication efficacy and thereby increase education efficacy within academe at all levels. It is common knowledge, for example, that a math problem performed on a Smartboard holds students' attention more so than does that same problem performed on a traditional chalkboard. As a society, it is crucial that the American people look at the crumbling middle schools and colleges within their communities with indignation. As educators, it is essential that we take advantage of, and incorporate into our curricula, modern technologies such as electronic literature databases.

A Call to Arms

It is the opinion of the author that there currently exists a major shortcoming in Biology education at the University level. Bogged down with worries of preparing students for standardized tests, instructors are often left pressed for time and thereby are left unable to teach cutting-edge information or to instill essential traits or skills. Among many students, there is a desire for content knowledge that is both current and meaningful. And herein lies the Catch-22 of any introductory survey course: How does an instructor provide his students with new and relevant information while still ensuring an adequate level of preparation for the standardized tests they will need to take and pass for admission into graduate and/or certification programs? In addition to teaching content, there must also be a renewed focus on developing traits within students that are essential to their functioning as scientists. Such traits include curiosity and the ability to acquire novel information beyond that which is presented within the lecture hall or the textbook through databases either unknown to the introductory student or perceived as reserved for "real scientists"[15, 16].

The Nature of Introductory Survey Courses

The current study takes into consideration the curricular and pedagogical dilemmas instructors face while developing the materials for lecture-based introductory survey courses within any discipline. Whether one is teaching history, physics, biology, or jazz, the dilemma becomes: How can such a vast body of material be covered in a meaningful manner in such a short period of time. The information gleaned from research within the biological sciences, more so than any other scientific discipline, is rapidly growing both in scope and depth.

The expansion of the knowledge base that is available to scientist operating within the various sub-fields of the biological sciences is a welcomed phenomenon from the standpoint of the experts operating therein, but it is often to the chagrin of many students, especially introductory students. It is extremely easy to overwhelm introductory students with information. As has been mentioned, biology is unique: unique in its breadth and depth, but also unique in the amount of expertise biology instructors expect from their students. Further, biology is somewhat unlike chemistry and physics, in that advanced technical or mathematical skills are not necessary to understand the majority of cutting edge material. Undoubtedly, a working knowledge of statistics and calculus is important for some biology courses, but the overwhelming majority of information, especially material examined in an introductory course, is taught without mentioning its formulaic foundations.

Bringing the Field into the Lecture Hall

The use of scientific literature within the classroom setting is rare within foundational introductory courses having an enrollment comprised primarily of freshmen students, and although previous studies have examined similar issues centered on the use of literature in the undergraduate curricula[16, 18, 19], none have dealt solely with large-enrollment foundational introductory courses with such enrollments. Certainly, instructors of such classes savvy to current developments within the various fields might discuss those developments during lecture, but teaching from the data contained within research articles, especially current articles, is relatively unheard of when dealing primarily with freshmen introductory students. This generalization holds true for such courses taught at the University of Pittsburgh.

The use of literature within the curriculum becomes more common as the natural science student progresses in his or her academic career. The majority of instructors who do use the literature within the lecture setting do so in one of the following ways; through the use of classic original research papers, current review papers, current original research papers, or an amalgamation thereof.

Table 1. Costs and benefits associated with the use of various types of scientific literature within the introductory lecture setting.

Literature Type	Associated Costs	Associated Benefits	Associated Difficulty Level
Classic Original Research Paper	•Presence of possibly out-dated or refuted information	•Students can gain a sense of the seminal hypotheses and evidence that gave rise to current biological concepts and paradigms	•Students generally find the classic papers easier to follow due to their more general findings and the lack of specialized vocabulary. •These articles are often more difficult for the instructor to obtain via electronic means
Current Review Paper	•Actual length of the article is often an immediate turn-off to students (especially intro-level students)	•Provides students with a general appreciation of the current concepts and paradigms of the field	•For students, the level at which review articles are written is easier to approach than original papers.
Current Original Research Paper	•Written at a very high and specific level of expertise •Replete with acronyms	•Allows students to see elasticity of scientific knowledge •Allows students to become especially versed in specific content areas	•Current research articles are often times very difficult for students (especially intro-level students) to read and digest. •For the instructor, the use of this article type requires much student preparation.

There is merit in implementing the literature into foundational introductory course curricula. Although it's difficult for students to understand the data therein when they are first reading articles[18], as experience gleaned from the current study has shown, a learning curve is eventually established, allowing students to tackle more difficult materials. As a result, students become more scientifically literate and perform better on exams. There is also a need to implement literature across the entire term, not periodically. In a section of Biosc 0150 taught during the fall of 2006, a singular article[*]

* See Appendix A for citation

was employed to discuss various biochemistry topics. The article was an original research article about the bacterial copper chelator methanobactin. The article was horribly received by students and ended up consuming valuable class time, in order to facilitate appropriate discussions of its content. Many lessons were learned from the methanobactin incident; primary among them, though, is that students must be empathetically considered when choosing an article. Further, a single article does not provide students with the confidence they need to read more scientific literature[18]. This confidence is an essential quality to instill in students, for it will allow them to increase their scientific literacy through independent searches of electronic journal databases[21].

2.0 EXPERIMENTAL DESIGN

At the University of Pittsburgh, there are four "types" of introductory Biology courses. The first being the non-majors course which provides a basic overview of key biological concepts members of society could encounter and/or utilize in their daily lives. The second type is the general intro course sequence taken by majors and non-majors alike. This "foundations" sequence provides the working knowledge base of future scientists, clinicians, and academics and is focus of the current study. The third type of course is a novel combination of the general introductory lecture course and the practical lab-based course. The last type of first-year biology course is the lecture-based honors sequence. This is a small-enrollment course and is primarily intended for students interested in careers in the biological sciences.

Fall of 2007 Biosc 0150, and Introduction

During the fall of 2007, there were multiple lecture sections of Biosc 0150 being taught. Each lecture section typically has an enrollment of 200-300 students. The lecture section discussed here was taught by a single lecturer holding a PhD and serving as a full-time Faculty member within the Department of Biological Sciences at the University of Pittsburgh. The course had an enrollment of 270. The students enrolled in the course varied in age, academic background, experience within the field of biology, and school affiliation. Although the majority of students were freshmen enrolled through the School of Arts and Sciences, some were nontraditional students enrolled though the College of General Studies. Post-Baccalaureate students and students coming from one of the University's many allied health programs also comprised a growing minority. The academic and field-specific backgrounds of the students also vary widely. For some freshmen, the only experience they will have had with natural sciences will be their high school biology. Others are senior chemistry majors, having worked for years in lab-settings.

The varied backgrounds of the students being taught make for a difficult audience. The core question becomes: How can lectures be designed so that the student with effectively no previous experience in biology is not overwhelmed by the material needed to keep the more seasoned student minimally engaged? Does one simply truncate the needs of the outliers and teach to the modal student? Or, is there some net that can be cast broadly enough in order to capture the attention of all students?

Fall 2007 Biosc 0150, Study Design

In an attempt to address the aforementioned issues, it was posited that scientific literature be incorporated into the course curriculum. The lecture section described above (enrollment= 270 students) was subdivided into 4 recitation sections by the University Registrar according to students' schedules. One recitation section (n= 70) was randomly chosen to serve as the experimental group of the current study. The exam scores of all students were tracked, and the scores of those in the experimental recitation section were segregated from those of the control sections.

For each week during which an exam had not been scheduled, scientific literature was chosen and assigned to students that dealt indirectly with material being discussed in the larger lecture setting. For example; when discussing enzymatic function at an early point in the semester, an article reviewing ribozyme functionality was chosen by the undergraduate teaching assistant. Information from the articles assigned to the experimental recitation section was never placed on an exam. Rather, articles served as a means to more actively and deeply explore the information and concepts presented during lectures and also served as springboards for future material. The ribozyme article, like many of the articles employed throughout the course of this study, was a recently written review article.

Accompanying the first and second articles was a set of assigned questions (Appendix B) meant to guide the students' reading. In return for completing the assigned questions, students received course points. Thereafter, students were required to develop two discussion questions for which they received credit. These discussion questions formed the basis of recitation discussions and were explicitly developed by the students in an attempt to tie material presented during lecture to the information contained within the assigned articles.

Spring 2008 Biosc 0160, an Introduction

This particular lecture section (enrollment= 194 students) was co-taught by two lectures, both holding PhD's and both having full-time Faculty positions within the Department of Biological Sciences. One of the lecturers who taught the Biosc 0160 lecture section described herein also taught the aforementioned lecture section of Biosc 0150. Their teaching styles were somewhat different, though complimented each other nicely.

Just as in the Biosc 0150 lecture section described above, accompanying the lecturers were a small group of undergraduate teaching assistants. It was their job to facilitate exam review sessions, answer any questions students might have about the material being covered, and lead weekly recitation sections.

Spring 2008 Biosc 0160, Study Design

The lecture section (enrollment= 194 students) was subdivided into four recitation sections by the University Registrar according to students' schedules. One section (n= 21) was randomly chosen to serve as the experimental section. The exam scores of this section were tracked and segregated from those of the control sections.

Unlike in the experimental section of Biosc 0150, the experimental section of Biosc 0160 chose the articles they read from a set of 2-3 articles chosen by the undergraduate teaching assistant. These article choices were presented to the students following a topical introduction to their content by means of a current event news article. The students then voted on which articles they wanted to read. Articles were employed less frequently in the experimental recitation section of Biosc 0160 than in Biosc 0150, due to student concerns over their comprehension of the articles' material. As in Biosc 0150, information contained within the recitation articles never appeared on an exam. A listing of all articles used in both Biosc 0150 and Biosc 0160 can be found in Appendix A.

Data Analysis

The exam scores and final course grades of students enrolled in the experimental sections were compared to those enrolled in the control sections for both Biosc 0150 and Biosc 0160. Simple statistical analyses such as mean comparisons and z-score comparisons were used to compare the sections. Histogram plots and regression analyses were also used. Sections were normalized using percentages rather than counts for all calculation. All calculations were performed using Microsoft Excel.

3.0 EXPERIMENTAL RESULTS

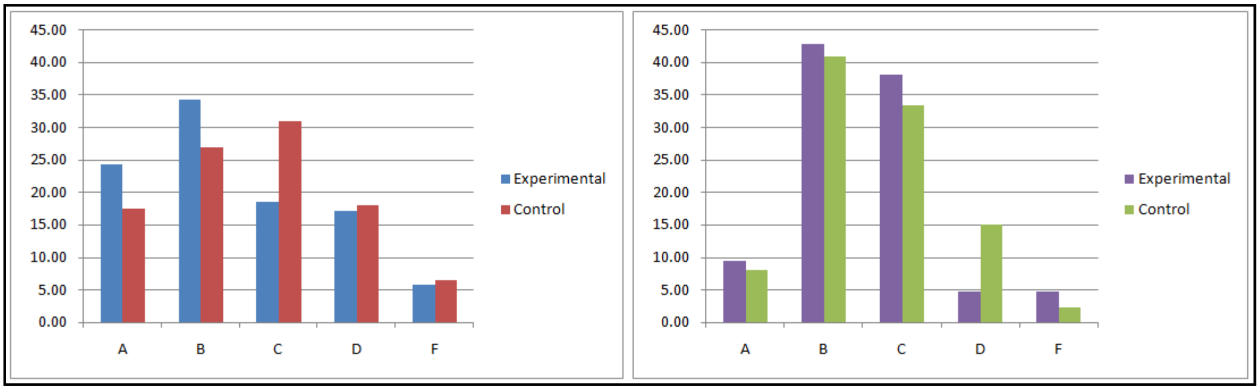


Figure 1. A graphic representation of grades within Biosc 0150 (left panel) and Biosc 0160 (right panel). The ordinate represents % of respective sample. For Biosc 0150, $n_{experimental}$ = 70 and $n_{control}$ = 200. For Biosc 0160, $n_{experimental}$ = 21 and $n_{control}$ = 173.

Table 2. Sample proportions of grades received by students in Biosc 0150 and Biosc 0160.

	A	B	C	D	F
Biosc 0150 Experimental	24.29%	34.29%	18.57%	17.14%	5.71%
Biosc 0150 Control	17.50%	27.00%	31.00%	18.00%	6.50%
Biosc 0160 Experimental	9.52%	42.86%	38.10%	4.76%	4.76%
Biosc 0160 Control	8.09%	41.04%	33.53%	15.03%	2.31%

Table 3. Sample proportions of success levels achieved by students in Biosc 0150 and Biosc 0160. A grade of A or B was deemed successful, C was deemed average, and a D or F were deemed unsuccessful.

	Successful	Average	Unsuccessful
Biosc 0150 Experimental	58.57%	18.57%	22.86%
Biosc 0150 Control	44.50%	31.00%	24.50%
Biosc 0160 Experimental	52.38%	38.10%	9.52%
Biosc 0160 Control	49.13%	33.53%	17.34%

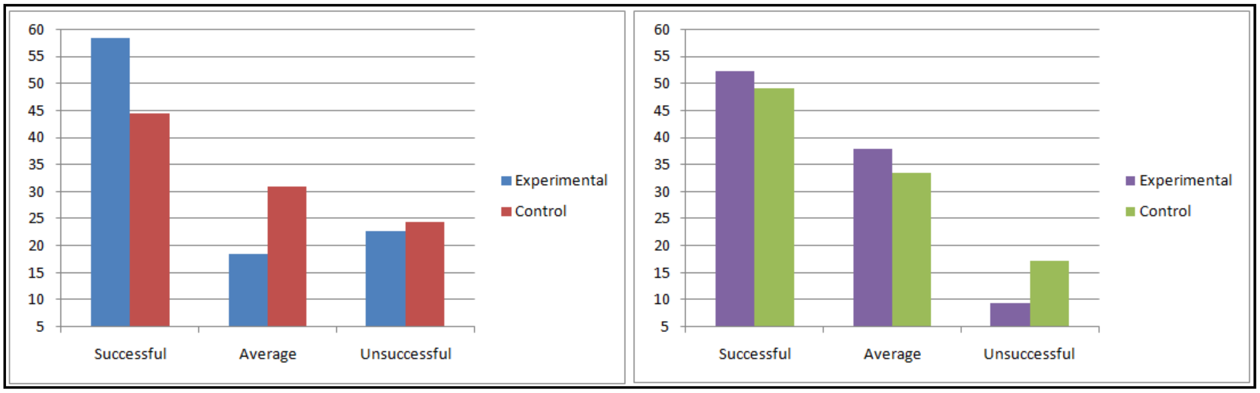


Figure 2. A graphic representation of performance within Biosc 0150 (left panel) and Biosc 0160 (right panel). Performance bins represent grades of A or B (Successful), C (Average), and D or F (Unsuccessful). The ordinate represents % of respective sample. For Biosc 0150, $n_{experimental} = 70$ and $n_{control} = 200$. For Biosc 0160, $n_{experimental} = 21$ and $n_{control} = 173$.

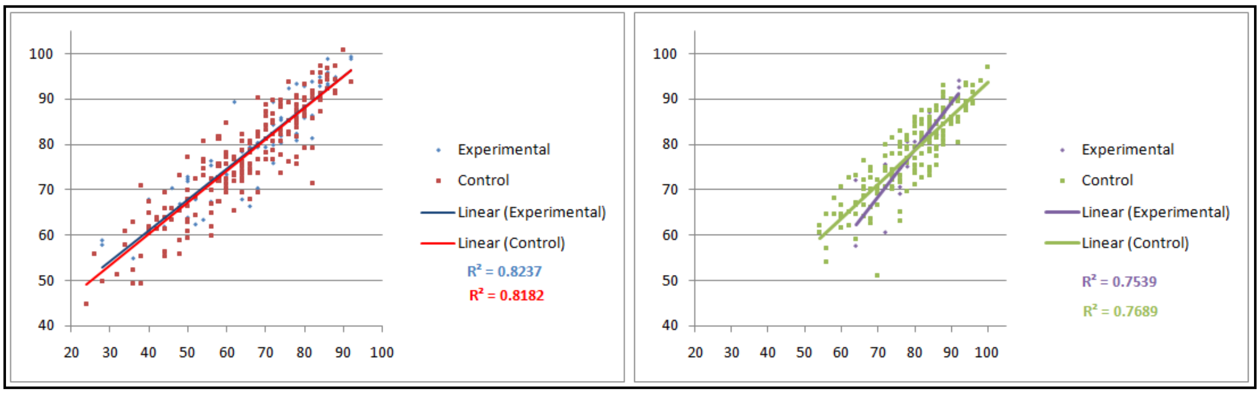


Figure 3. Scatter plots examining the correlation between performance on the final exam (abscissa) and overall curved course grade (ordinate). Biosc 0150 is shown in the left panel, and Biosc 0160 is shown in the left panel.

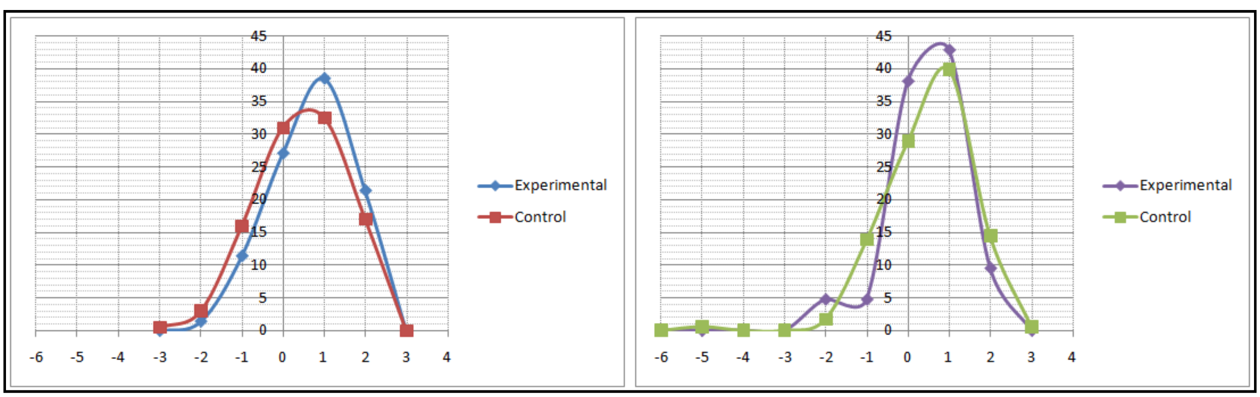


Figure 4. A comparison of curved course grade distributions for Biosc 0150 (left panel) and Biosc 0160 (right panel). Calculated z-scores (abscissa) were paired with sample proportions (ordinate) to derive these histogram plots.

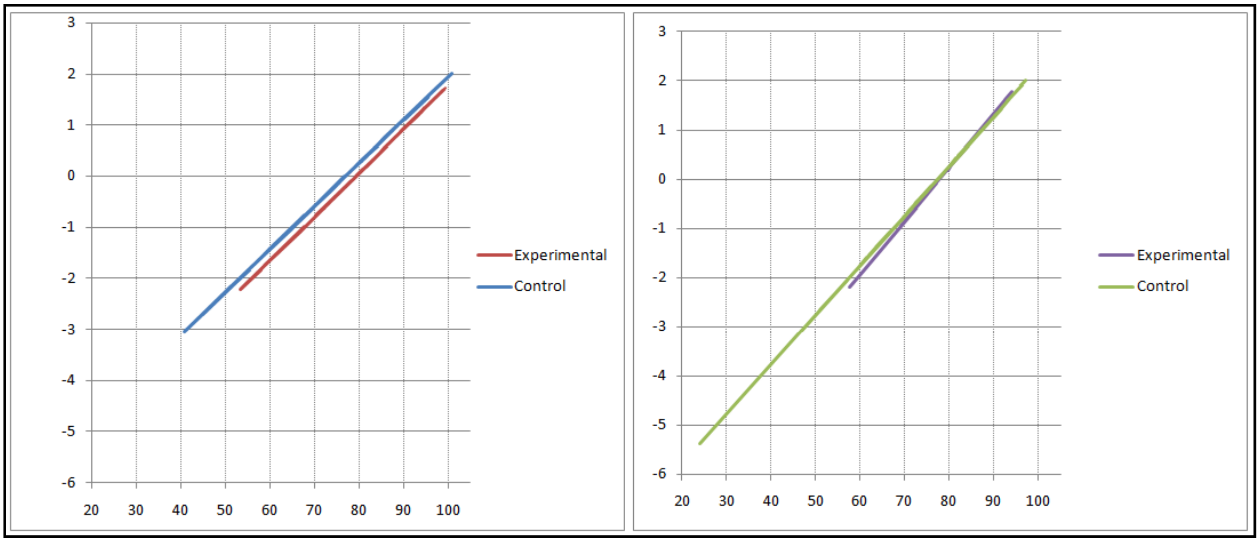


Figure 5. Line plot of curved course grade (abscissa) and calculated z-score (ordinate) for Biosc 0150 (left panel) and Biosc 0160 (right panel).

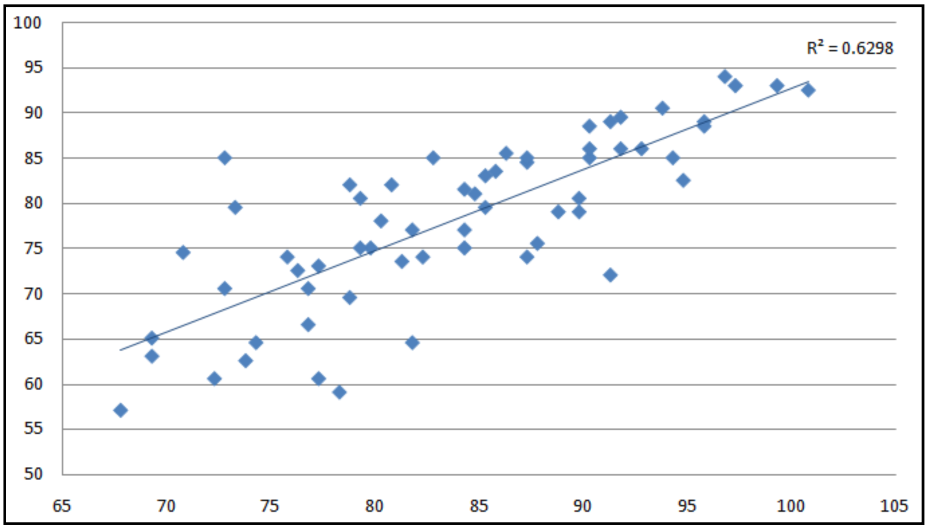


Figure 6. Scatter plot of Biosc 0150 curved course grades (abscissa) and Biosc 0160 curved course grades (ordinate). Line of best fit is also shown with accompanying R^2 value.

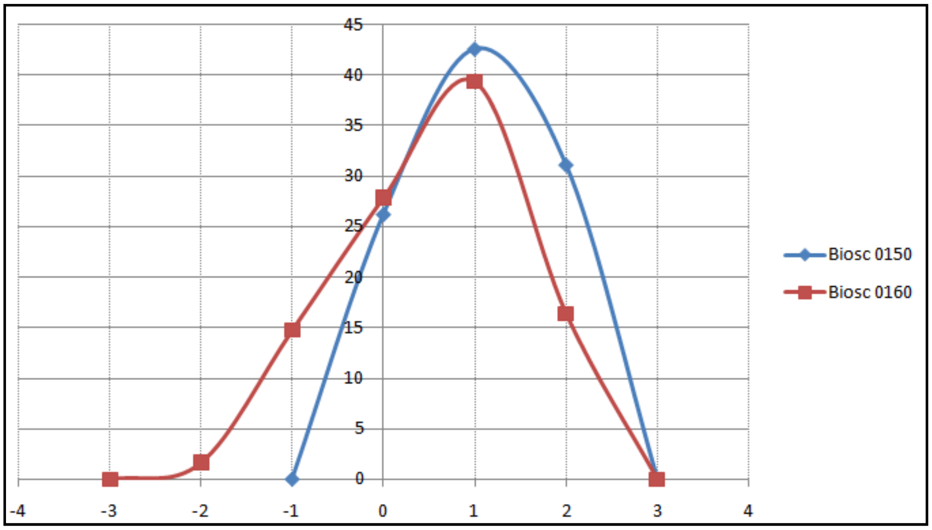


Figure 7. A plot using calculated z-score (abscissa) and sample proportion (ordinate) comparing the course performance of students taught by the same Faculty member in Biosc 0150 and Biosc 0160.

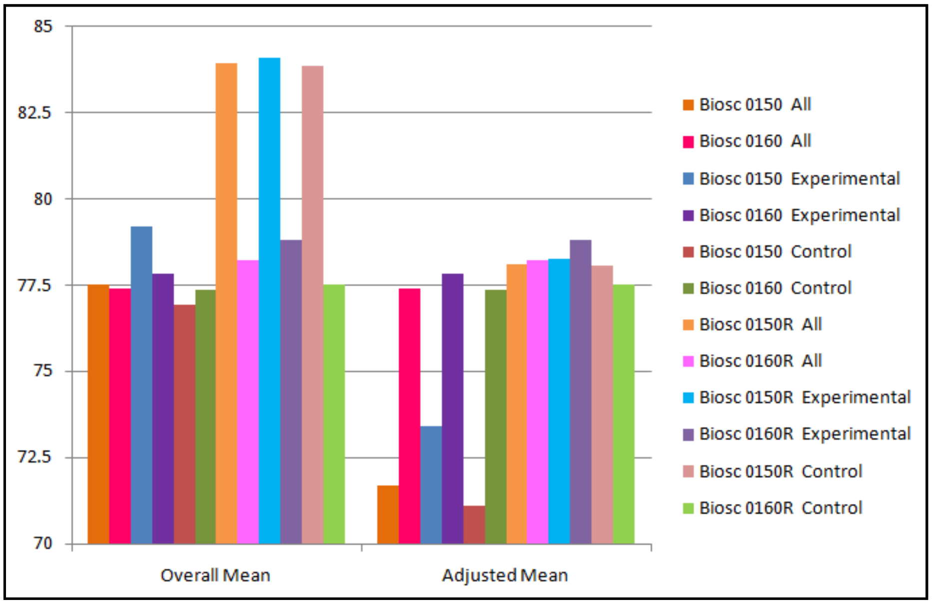


Figure 8. A summary of course performances as measured by percentage achieved. Adjusted means are lacking the course curves (+5.8085% for Biosc 0150 and +0.00% for Biosc 0160).

Table 4. A summary of course performances. Adjusted means are lacking the calculated course curves (+5.8085% for Biosc 0150 and +0.00% for Biosc 0160).

	Overall Mean	Adjusted Mean
Biosc 0150 All	77.51%	71.70%
Biosc 0160 All	77.40%	77.40%
Biosc 0150 Experimental	79.20%	73.39%
Biosc 0160 Experimental	77.84%	77.84%
Biosc 0150 Control	76.92%	71.11%
Biosc 0160 Control	77.35%	77.35%
Biosc 0150R All	83.93%	78.12%
Biosc 0160R All	78.24%	78.24%
Biosc 0150R Experimental	84.09%	78.28%
Biosc 0160R Experimental	78.83%	78.83%
Biosc 0150R Control	83.88%	78.07%
Biosc 0160R Control	77.53%	77.53%

Table 5. Mean exam scores for Biosc 0150. *= final course curve of +5.8085% not yet added

	Exam 1*	Exam 2*	Exam 3*	Exam 4*	Final Exam*
Experimental Section	69.60%	68.98%	74.04%	69.27%	67.36%
Control Section	67.38%	67.96%	71.00%	65.62%	64.34%

Table 6. Mean exam scores for Biosc 0160.

	Exam 1	Exam 2	Exam 3	Exam 4	Final Exam
Experimental Section	77.89%	74.49%	72.98%	76.51%	79.05%
Control Section	76.56%	71.40%	72.82%	78.04%	78.39%

4.0 DISCUSSION

The varied backgrounds of the students being taught make for a difficult audience. The core question becomes: How can lectures be designed and recitations organized so that the student with effectively no previous experience in biology is not overwhelmed by the material needed to keep the more seasoned student minimally engaged? Does one simply truncate the needs of the outliers and teach to the modal student? Or, is there some net that can be cast broadly enough in order to capture the attention of all students?

That net, as suggested by this study, could be scientific literature. Examining Figures 1 and 2 and Tables 2 and 3, it can be noted that more students performed well and fewer students performed poorly, if enrolled in the experimental recitation sections. This trend proved to be evident for both Biosc 0150 and Biosc 0160 lecture sections examined herein. The mean curved course grade for the control section of Biosc 0150 was just 76.92%, while the mean for the experimental section was 79.20%. This difference is statistically significant, at $\alpha=0.10$. Moreover, that difference represents a shift in the mean final course grade obtained by the experimental section from a "C" to a "B-." For Biosc 0160, the difference was not significant (experimental mean= 77.84, control mean= 77.35), with the mean curved course grades of both sections earning a "C+." Note, though, that upon examining the right panel of Figure 4, an interesting trend can be noted: Far fewer students in the experimental section performed below -1.0 standard deviations than did students within the control section. This can also be noted in the right panel of Figure 5; note where the two lines cross. In the right panel of Figure 5, experimental section abscissa values below the cross correspond to ordinate values that are lower than those associated with the same control abscissa values. This can be translated into the following statement: Even though the difference between experimental and control means was not statistically significant for the Biosc 0160 recitation sections, students enrolled in the experimental section were *still* less likely to perform poorly than those students enrolled in the control sections.

The relationship between final exam score and curved course grade illustrated in figure 3 is worth examining closely. Note that the lines of best fit for both the experimental and control groups of Biosc 0150 (left panel) overlay nicely, having almost identical slopes (0.681 and 0.695, respectively). A relatively strong correlation also exists for control (R^2=0.8237) and experimental (R^2=0.8182) groups. This strong correlation is lost, though, in Biosc 0160 (right panel). The lack of strong correlation between final exam score and curved course grade (experimental R2=0.7539 and control R2=0.7689) could possibly be due to extenuating factors such as rigorous final exam schedules with other courses in which introductory biology students are also enrolled such as Chemistry, Physics, Calculus, etc.

The histogram plots of Figure 4 exhibit the relationship that exists between z-scores, calculated from the population means and standard deviations, of Biosc 0150 and Biosc 0160 lecture sections and the sample proportions of the bin counts. It is interesting to note that the area contained under the four curves is equal: The areas are all equal to 100. The shapes, however, differ. For both Biosc 0150 (left panel) and Biosc 0160 (right panel), the experimental sections' histograms are tighter. If the means of the experimental sections were equal to the means of the control sections, then these tighter distributions would suggest that experimental students were less likely to get grades of either “A” or “F.” Note, though, that in addition to the tighter distributions of the experimental sections, their modes occur at greater abscissa values. Therefore, the data show that an experimental student was more likely to get an “A” and less likely to get an “F” than a control student.

The aforementioned relationship becomes especially evident in Figure 5. The left and right panels (Biosc 0150 and Bios 0160 respectively) are both line plots where curved course grades make up the abscissa and calculated z-scores make up the ordinate. Unlike the histogram plots of Figure 4, when calculating the z-scores for Figure 5, the lecture section (i.e. “population”) means and standard deviations were not used. Instead, the means and standard deviations used for Figure 5 were derived from each sample, thereby treating each sample as if it was its own population subjected to identical treatment (i.e. lecture environment) with the experimental variable being the use of scientific literature. The left panel is a plot of the values for Biosc 0150. Note that the experimental section’s distribution is much tighter and occurs at higher abscissa values. This indicates that grades of “A” were more likely to be earned by students in the experimental section than those in the control section (i.e. a course grade of 93% provided a lower z-score for the experimental section (~1.16) than for the control section (~1.36)).

Figure 6 ties Biosc 0150 to Biosc 0160. Of the 464 students enrolled in either lecture section, 61 of those students happened to have the same professor for both semesters. Therefore, the performance of these students can be tracked and analyzed across the two courses. Note that performance in Biosc 0160 is not strongly correlated to performance in Biosc 0150 (R^2= 0.6298). This discrepancy could be due to a wide range of factors such as the students’ course load, their differential interest in various subject matter, etc. The only clear connection between the two lecture sections is that students in the experimental sections were more likely to do well. In addition to Figure 6, Tables 4, 5, and 6 and Figure 8 illustrate this.

Another interesting trend can be noted if one examines the performance of students across Biosc 0150 and Biosc 0160, as illustrated by Figure 7. Note the expansion of the distribution as students went from Biosc 0150 into Biosc 0160. Even though these students performed better, on average, than their classmates who were taught by a different instructor for Biosc 0150 (x= 78.24 for students who had the same instructor across the two semesters and x= 77.40 for those who did not), they still tended to perform poorer in Biosc 0160 than they did in Biosc 0150. This is due to a self-selecting phenomenon. If one compares the students enrolled in Biosc 150 to those enrolled in Biosc 0160, an important difference is observed: The poorest performing students of Biosc0150 do not persist, thereby allowing a student whose exam scores (Tables 5 and 6) might have been 1.0 standard deviation below the class's mean in Biosc 0150 to now be 1.5 standard deviations below the mean in Biosc 0160.

In addition to the quantitative data presented in the Results section, more qualitative data can be found in Appendix C. A small sample of students' discussion questions can be found, along with concerns students had after reading the literature. For the majority of students, these concerns diminished after more articles were read throughout the semester.

5.0 CONCLUSION

The benefit to learning that scientific literature provides introductory students enrolled in foundation courses is clear. The incorporation of literature into pre-existing curricula is not a difficult task. It simply requires the instructor to be up to date in two particular areas: developments in the field that have relevancy within his course, and the role he must play in the academic development of his students. The former point is practical, while the latter is pedagogical.

The etymology of "educate" is interesting. The word is derived from the Latin *educare*, meaning to rear. When broken down further, into its components, it means quite literally to lead out into. Herein, educators can derive their most basic charge: to rear students (i.e. nurture their development) in a way that will lead them out (of ignorance and/or naiveté) into (a more enlightened paradigm and ethos).

This study showed that the implementation of scientific literature within a foundational introductory curriculum helped to better educate students. Using the literature and teaching from the data therein provided the students with a greater sense of and facility within the material. Further, in requiring the students to retrieve the articles on their own, during the latter portions of the semester, they developed a greater faculty in working with the literature and online journal databases, something that has been suggested to increase scientific literacy and foster their development as both academics and as scientists[5, 16, 18]. By the end of the semester, some of the students who were reluctant to read extra passages within the assigned textbook were logging on to electronic journals such as *Cell*, *Nature*, *Science*, and *The New England Journal of Medicine* to glean more in-depth information than they could by relying on course materials alone.

The results exhibited herein bring to mind some popular buzz words within primary and secondary education circles: Constructivism, standards, and technology. Out of the sweeping cognitive movement came constructivism, which essentially claims that students will discover information and concepts on their own, provided with an appropriate set of tangible materials. It is possible that the utilization of the literature within the curriculum, and the information literacy skills derived therefrom, provided the experimental section students with a sort of intangible constructivist environment[6]. Intangible in the sense that the materials provided them were not tangible manipulatives within a laboratory setting, but instead the practically infinite body of information that comprises the modern electronic journal databases.

These students were now able to navigate electronic journals and discover information on their own, and in doing so, they were unknowingly becoming better biology students[16]. This is an interesting phenomenon hence forth deemed "academic baggage." Academic baggage refers to the fact that, as one learns more about a particular topic and increases his expertise within a particular area (i.e. as one reads more high-level literature about that topic), he is required to carry with him the information gleaned from previous learning experiences, thereby accruing academic baggage.

Students will never meet standards that we (as educators) don't set for them [20]. The present study strengthens that claim. In trying to comprehend the information presented to them within the literature, the experimental section students were forced to recall all of the previous information acquired from lectures, recitation, peer study groups, and their text book. Further, during recitations and while developing discussion questions, students were analyzing, synthesizing, and evaluating the information available to them. These gerunds represent the core of higher-order cognition outlined in Blooms taxonomy[21]. I am certainly not claiming that course curricula that do not employ literature therein are not allowing for these cognitive processes[13], instead, I posit that scientific literature, and the discussion thereof, is another tool instructors may use to allow for these processes.

APPENDIX A

[ARTICLES CHOSEN FOR RECITATION]

Biosc 0150, Fall 2007

Tommassen, *Science*, **317**, 903 (2007)

"Getting Into and Through the Outer Membrane"

Joyce, *Science*, **315**, 1507 (2007)

"A Glimpse of Biology's First Enzyme"

Hay, *EMBO Reports*, **8**, 236 (2007)

"Calcium: A Fundamental Regulator of Membrane Fusion?"

Gracia, *Pharmacotherapy*, **24**, 1358 (2004)

"Cyanide Poisoning and Its Treatment"

Elliott, *Am. J. Clin. Nutr.*, **76**, 911 (2002)

"Fructose, Weight Gain, and the Insulin Resistance Syndrome"

Murray, *Nature Reviews Neuroscience*, **8**, 885 (2007)

"Cannabis, the Mind and Society: the Hash Realities"

Biosc 0160, Spring 2008

Cibelli, *The Journal of Regenerative Medicine*, **2**, 25 (2001)

"Somatic Cell Nuclear Transfer in Humans: Pronuclear and Early Embryonic Development"

Abu-Raddad, *Science*, **314**, 1603 (2006)

"Dual Infection with HIV and Malaria Fuels the Spread of Both Diseases in Sub-Saharan Africa"

Parker, *Pediatrics*, **114**, 793 (2004)

"Thimerosal-Containing Vaccines and Autistic Spectrum Disorder: A Critical Review of Published Original Data"

Duelli, *Nature*, **7**, 968 (2007)

"Cell-to-Cell Fusion as a Link Between Viruses and Cancer"

Warfield, *Journal of Immunology*, **175**, 1184 (2005)

"Induction of Humoral and CD8 T Cell Responses Are Required for Protection Against Lethal Ebola Virus Infection"

*** Biosc 0150, Fall 2006**

Kim et al. *Science*, **305**, 1612 (2004)

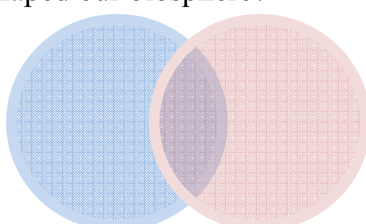
"Methanobactin, a Copper-Acquisition Compound from Methane-Oxidizing Bacteria"

APPENDIX B

[SAMPLE QUESTION SETS]

Biosc 0150 First Article Questions "A Glimpse of Biology's First Enzyme"

1. What was it that Crick speculated the function of the original ribozymes to be?
    - RNA-based RNA polymerases
    - Currently, no evidence of ribozymal polymerases…
2. How might in-vitro or "test tube" evolution take place?
    - Compare and contrast in-vitro evolution to the evolutionary process that has shaped our biosphere?



3. What are the differences between RNA and DNA at a:
    - Monomeric level?
        - Ribose vs. 2-deoxy ribose
    - Polymeric level?
        - Single vs. double stranded
        - Enzymatic activity
        - packaging
4. What properties of DNA *might* have made it better suited to act as the carrier of genetic information within earlier organisms?
    - i.e. why had RNA lost favor somewhere along the evolutionary tree?
        - RNA chemically more susceptible to alterations/ degradation
        - Talk about methyl cap, poly-A tail in euk's
5. What function does a ligase perform?
    - Joins nucleotide monomers to form nucleic acid polymers
    - Also used in DNA rep to join Okazaki fragments

6. Why is the Class I Ligase considered a Ferrari by this author, while three other noble ribozymes (LI Ligase, RC3 Ligase, and DSL Ligase) are given the lowly rank of "family sedan"?
    - Only *part* of this answer has to do with the rate at which the Class I Ligase does its job!
    - Speed, utility (Class I Ligase can only do one thing fast), reliability
7. In the second to last paragraph, the author states that: One must be careful in drawing conclusions about the reaction mechanism facilitated by the discussed ribozyme.
    - Easy: Why is this so? What is the specific reason for this cited by the author?
        - Crystal resolution limited to discrete temporal events.
    - Not so easy: Is the author's statement a valid one? i.e. if you are holding two things in your hands: the definite reactant in your left hand and the definite product in your right hand, can you not then speculate, with considerable certainty, the processes through which the reactant underwent to become the product?
        - Certainty vs. Probability
        - Particle momentum and particle position
            - Heisenberg uncertainty principle

Biosc 0150 Second Article Questions "Calcium: A Fundamental Regulator of Membrane Fusion?"

1. Before reading this article, what roles did you associate with Calcium in regards to the animal body?
    a. What function does Calcium serve in the neuron?
    b. What function does Calcium serve in the skeletal muscle?
        i. *The answers to 1.a and 1.b cannot be directly found in the attached article. Instead, simply refer to your Biology textbook or Wikipedia.
2. What role was Calcium shown to have in the various types of membrane fusion discussed in the article?
3. What were the effects that Calcium chelators had on vesicle trafficking?
4. How did exogenous Calcium affect the SNAP-25/Hrs interaction?
5. What role did Calcium play in SNARE-dependant membrane fusion?
6. Looking at Figure 1, which panel best represents the so-called "Calcium dependant coat stabilization" discussed on page 238?
7. How might Calcium requirements (or the lack there of) encode specificity into the secretory pathway?

APPENDIX C

[CONVERSATIONS WITH STUDENTS]

A Question Developed by a Biosc 0150 Student, Regarding an Article about Cyanide Poisoning:

> The article addresses the lethal dose of and the affects of cyanide in humans. However, when there is a spill as in China, the cyanide affects other systems as well. To be harmful to a river ecosystem, how would the lethal dose compare to 50-200 mg, the lethal dose for adults? Would that dose, then be harmful to humans who drink the water? If a smaller concentration of cyanide is lethal in a river ecosystem, then what should the highest allowed concentration be? Would it just take into account human suffering? River suffering is human suffering.

Questions Developed by a Biosc 0160 Student, Regarding an Article about Cannabis:

> Does the route of administration (i.e. inhaled, ingested, injected, etc) for cannabis influence the severity of its affects on the brain?

> Does the amount of cannabis taken by those thought to be psychosis-prone and those not, have an effect on their feelings of hostility and paranoia or feelings of "ease" (respectively)?

Concern from a Biosc 0150 Student about Her Ability to Read an Article:

> It's "Jane Doe," and I'm in the recitation tomorrow afternoon. And
> I know this is short notice, but the article you gave us to do was REALLY confusing and hard to understand. I did attempt to answer the questions the best I could...but just as a heads up...I did not really understand the article.

Concern from a Biosc 0160 Student about His Ability to Read an Article:

This is “John Doe,” the kid with the mac who "answered enough". Despite my active participation, I really have no idea what's going on (I'm just faking it). It is with that concern that I email you...

Biology is not my strong subject by any means and I'm feeling really lost. I recognize that it is only the fest two weeks of class, but I still feel like I should have a better understanding of the material. I hope you can offer me a few suggestions. I've started reading the book and I intend to catch up over the weekend including taking notes on it. I will also complete the homework for the other recitation sessions. Is there anything else you can suggest I do on my own? Would you be able to offer any other help, such as tutoring?

Anything would be greatly appreciated.

BIBLIOGRAPHY

1. Ball, Stephen, *Comparative Education*, **34**, 119 (1998)
2. Darlin-Hammond & Sykes, *Education Policy Analysis Archives*, **11**, (2003)
3. Anderson et al. *Proceedings of the 38th SIGCSE Technical Symposium on Computer Science Education* (2007)
4. Vannatta & Fordham, *Journal of Research on Technology in Education*, **36**, (2004)
5. Airey, Linder, *Journal* of *Research in Science Teaching*, **46**, 27 (2009)
6. Taylor, Fraser, Fisher, *International Journal of Educational Research*, **27**, 293 (1997)
7. Guthrie & Carlin, *Proceedings of the Tenth Americas Conference on Information Systems* (2004)
8. Reisman, *IT Professional*, **7**, 63 (2005)
9. Linnet et al. *Frontiers in Education* (2007)
10. Muir-Herzig, *Computers & Education*, **42**, 111 (2004)
11. Hays, *The American Biology Teacher*, **64**, 70 (2002)
12. Frydenberg, *Information Systems Education Journal*, **6** (2008)
13. Al-Bataineh & Brooks, *Community College Journal of Research and Practice*, **27**, 473 (2003)
14. Duhaney, *International Journal of Instructional Media*, **27**, 67 (2000)
15. Kirk, *Proceedings of the American Society for Information Science* (2003)
16. Bren & Boyes, *Practical Assessment, Research & Evaluation*, **7** (2000)
17. Rickman, *EDUCAUSE Quarterly*, **23**, 24 (2000)
18. Mulnix, *Cell Biology Education*, **2**, 248 (2003)

19. Bloom, *FASEB Journal*, **22** (2008)

20. Scherer, *Educational Leadership*, **59**, 14 (2001)

21. Seddon, *Review of Educational Research*, **48**, 303 (1978)

22. Porter, *New Directions for Higher Education*, **1992**, 45 (1992)