

Factors influencing academic performance of students enrolled in a lower division Cell Biology core course

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Abstract: Students' performance in two semesters of our Cell Biology course was examined for this study. Teaching strategies, behaviors, and pre-course variables were analyzed with respect to students' performance. Pre-semester and post-semester surveys were administered to ascertain students' perceptions about class difficulty, amount of study and effort put into the course, and professional goals. Chi-square (χ^2) tests of independence showed that completion of chemistry requirements, passing the laboratory component of Cell Biology, homework, and attendance were related to passing our course. Logistic regression showed that perfect attendance followed by GPA, were the most important factors associated with passing the course.

Keywords: undergraduate, GPA, attendance, lower division cell biology, pre-requisites, assessment

I. Introduction.

As educators, one of the most important goals of our teaching is to help students understand the course material. Equally important for science students, is the goal of obtaining a grade that will facilitate academic and professional advancement.

Numerous science education studies have focused on the question of which teaching strategies are best for improving students' learning and overall course performance. Some of these have emphasized the development of scientific inquiry as a way of increasing students' understanding of the content being taught in the course (Ebert-May et al., 1997; DebBurman, 2002; Wright and Boggs, 2002; Knight and Wood, 2005; Smith et al., 2005). For the most part, teaching strategies studies deal with what we can do to improve our students' content understanding. But very few of these studies provide insights about the type of experiences or factors the students must have before they enroll in our courses in order to succeed.

Several studies have ascertained if demographic factors, previous experiences, or background are associated with students' course performance. Some of these have examined the importance of previous GPA (Graunke and Woosley, 2005; Tai et al., 2005; Salaiman and Mohezar, 2006; Freeman et al., 2007; Klomegah, 2007), academic background and course pre-requisites (House, 1994; House, 2000; Tai et al., 2005), demographic characteristics such as gender (Graunke and Woosley, 2005; Salaiman and Mohezar, 2006), and students' own perception of their abilities (House, 2000; Klomegah, 2007).

Our study aimed to identify factors associated with students' success in a large, lecture and laboratory, lower division, undergraduate Cell Biology course. The following research questions guided our investigation:

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- (1) Which pre-course variables (such as GPA and completion of course pre-requisites) are associated with student performance in our lower division cell biology course?
- (2) Which in-class behaviors (such as attendance and completion of homework) are associated with student performance?

II. Methods.

A. Lower Division Cell Biology Course at San José State University.

Our biology majors enroll in a three-semester core biology sequence (Biology 1, Biology 2, and Biology 3). Each course has a lecture and a laboratory component. All core courses are taught every semester, with an average of 100 students enrolled in each course. The pre-requisites for the Cell Biology course (Biology 3) are completion of Biology 1 course and the first semester of the freshman chemistry sequence (Chemistry 1A at SJSU), both with a C or better. Co-requisites include Biology 2 and Chemistry 1B. A passing grade in the Cell Biology course is a C or better.

B. Course Design.

Two spring semesters (2004 and 2005) were examined for this study. The same instructor, author J.S., taught both semesters using the following learning cycle in each lecture:

Students read material before coming to class (*as presented* by Kitchen et al., 2003)→then students were posed with an engaging question at the start of the lecture (research-based, sometimes discrepant, 1 min)→small group (2-3 students) discussion followed (5 min, *modified from* Ebert-May et al., 1997)→Socratic approach lecture (25 min)→Another research question was posed (expanding on the first one, providing more evidence)→small group discussion (5 min) followed→the research question was answered by student groups or by the instructor (5 min) → quizzes (2 min), or exit tickets were completed at the end of lecture. The exit ticket contained the student's name, a concept they understood and a concept they had difficulty understanding from the material that was covered in lecture.

The final course grade for each student was calculated as follows: 4% for participation (daily quizzes in 2004, and exit tickets in 2005), 4% for a book report, 42% for three exams during the semester, 25% for a final, and 25% for lab performance (quizzes, homework, and two exams with a practicum component). Lecture exams contained questions involving the analysis of research data and problem solving. Students were requested to pick up their graded exams during office hours, or by appointment.

Although the class content, overall delivery, and assessment were the same in both semesters analyzed, several instructional strategies differed. In 2004 only, students were required to turn in answers to homework problems, had daily quizzes, and had access to digitally videotaped lectures on CD-ROM. In 2005 only, students were required to sign and adhere to a social/syllabus contract, homework problems were optional, videotaped lectures were not available, and exit tickets were collected. The social/syllabus contract was derived from the course syllabus and emphasized students' responsibilities in the class and for their learning.

C. Participants.

One hundred and eighty-four students from the 2004 and 2005 Cell Biology class participated in this study. Twenty students (eight from 2004 and 12 from 2005) did not participate. Participation in this study was not required for course credit. Twenty-three percent and seventeen percent of the 2004 and 2005 participants, respectively, were graduate or post-baccalaureate students, the rest were undergraduates.

D. Data Collected.

University transcripts were collected during the first week of the semester. The transcripts were used to gather information regarding prior GPA, completion of pre-requisites and co-requisites, and grades obtained in the pre- and co-requisite courses. The instructor kept a record of students who had turned in homework assignments, taken quizzes, and used videotaped lectures for the 2004 class. Attendance for 2004 was determined by the collection of daily quizzes. In 2005, students were required to sign a social/syllabus contract and the contract was collected during the first week of the semester. Attendance for 2005 was determined by the collection of daily exit tickets. For both 2004 and 2005, students' grades for each exam, the laboratory component, and the overall score were recorded. Pre and post surveys were administered to ascertain students' perceptions about the class difficulty, and amount of study put into the course (Appendix 1).

III. Results.

Data were taken from class records kept by the instructor or from the pre-instruction and post-instruction surveys completed by the students. We used chi-square test of independence for results reported here, unless otherwise noted. Passing/not passing was used as a measure of success in order to simplify the analyses. Passing was defined as earning a C or better. Chi-square examined whether two categorical variables, such as Passing/Not Passing Cell Biology and completion of prerequisites, were related. In addition, direct logistic regression was used to analyze the association between three variables (completion of Biology and Chemistry course pre-requisites, attendance, and GPA) and passing our Cell Biology course.

A. 2004 and 2005 classes had similar passing rates.

Table 1 shows demographic characteristics of the participating students from the 2004 and 2005 classes we used in this study. The participation rate for the 2004 class was 93%, and 78% for the 2005 class. The dropout rate was 7% and 3% for the 2004 and 2005 classes, respectively. This rate did not differ between 2004 and 2005, $\chi^2(1) = 2.387$, $p > 0.05$.

Table 1. Demographic Characteristics of the classes we examined in this study*.

Demographic Characteristics	2004 Class	2005 Class
Non-participating students	8	12
Participating students	107	77
Female	46	52
Male	61	25
Undergraduate	82	64
Sophomore	26	14
Junior	34	31
Senior	22	19
Post-baccalaureate	25	11
Graduate (M.A. or M.S.)	0	2
Students who dropped the course	8	2
Students who obtained an A+ to A-	19	20
Students who obtained a B+ to a B-	30	15
Students who obtained a C+ to C	20	17
Students who failed the Course**	30	23
Mean Course GPA (Std. Dev.)	2.97 (0.546)	2.99 (0.498)

*Data presented in this table include demographic information from participating students only. ** C- or below

There was a significantly higher proportion of males in 2004 compared to 2005, $\chi^2(1) = 10.834$, $p \leq 0.05$. The proportions of sophomores, juniors, seniors, post-baccalaureate, and graduate students did not differ between 2004 and 2005 $\chi^2(4) = 6.689$, $p > 0.05$. The proportions of students earning As, Bs, Cs, or below C did not differ between 2004 and 2005, $\chi^2(3) = 2.939$, $p > 0.05$. Unpaired t-test showed that the overall percentage of points earned was similar between the 2004 (79%) and 2005 classes (76%), $t(162) = 1.349$, $p > 0.05$. Moreover, the percentage of students who passed each class, approximately 70%, did not significantly differ between 2004 and 2005, $\chi^2(1) = 0.446$, $p > 0.05$. Because the statistical results for 2004 and 2005 classes did not qualitatively differ when analyzed separately, the data for the two classes were combined, unless otherwise noted.

B. Post-baccalaureates vs. undergraduates.

We compared passing rates in Cell Biology for undergraduates, graduate, and post-baccalaureate students. Post-baccalaureate students were more likely to pass Cell Biology than undergraduates, $\chi^2(2) = 7.026$, $p \leq 0.05$. Ninety-three percent of post-baccalaureate students and 69% of undergraduates passed the course. Two graduate students enrolled in the 2005 course, one passed (Table 1).

C. Are specific chemistry courses related to passing Cell Biology?

Students who took both Chemistry 1A and 1B, were more likely to pass Cell Biology than those who only took Chemistry 1A, $\chi^2(1) = 10.893$, $p \leq 0.05$. Fifty-two percent of those who only took Chemistry 1A passed while 80% of those who took both chemistry courses passed. Students who took Organic Chemistry courses were no more likely to pass the Cell Biology course ($p > 0.05$ for both analyses). The likelihood of passing Cell Biology, was not

increased by taking chemistry courses at SJSU, rather than at another institution ($p > 0.05$ for all analyses).

D. Are introductory biology courses related to passing Cell Biology?

Passing Cell Biology did not depend on whether students took both Biology 1 and 2 courses or only one of them, $\chi^2(2) = 0.750$, $p > 0.05$. The likelihood of passing Cell Biology also did not depend on whether students took Biology 1 and 2 at SJSU rather than elsewhere ($p > 0.05$ for both analyses). According to the post-survey, most students did not feel that the Biology 1 and 2 courses prepared them for the Cell Biology course, regardless of whether the students passed or failed Cell Biology, $\chi^2(1) = 0.978$, $p > 0.05$.

E. Attendance, Quiz Scores, Homework, and Effort.

Students who passed Cell Biology had better attendance records than those who did not pass, $\chi^2(4) = 32.821$, $p \leq 0.05$ (Fig. 1). Attendance was classified as either perfect, very good (99-90% of lectures attended), good (89-80%), fair (79-70%), or poor (69% or less).

Forty-four percent of students who passed had perfect attendance and 27% had very good attendance. Only 7% of those who passed had poor attendance.

Quizzes were given in the 2004 class only, and scores on the quizzes were categorized as perfect, very good (99-90% correct answers), good (89-89% correct answers), fair (79-70% correct answers), or poor (69% or less). Passing the class did not depend on which quiz score category the student was in, $\chi^2(4) = 1.120$, $p > 0.05$.

Homework was assigned in the 2004 class only, in which the amount of homework completed was significantly related to passing Cell Biology, $\chi^2(4) = 38.885$, $p \leq 0.05$ (Fig. 2). All students who did not complete any homework failed the course. Ninety-seven percent of the students who completed 100% of the homework passed the course. Forty-two percent of the students who completed 50% of the homework passed the course. All students who completed 25% of the homework passed the course, although most in this group earned a C.

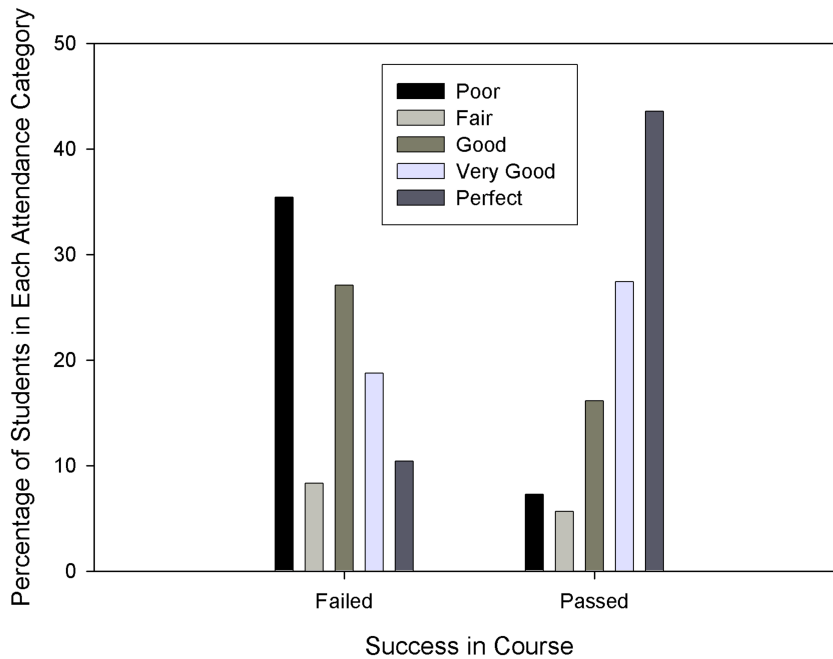


Figure 1. Students’ attendance records were compared to examine if they were related to students’ ability to pass the course. This graph depicts combined data for 2004 (n =107) and 2005 (n = 77). In 2004, attendance was kept by the collection of daily quizzes. In 2005, it was kept by the collection of “exit tickets”.

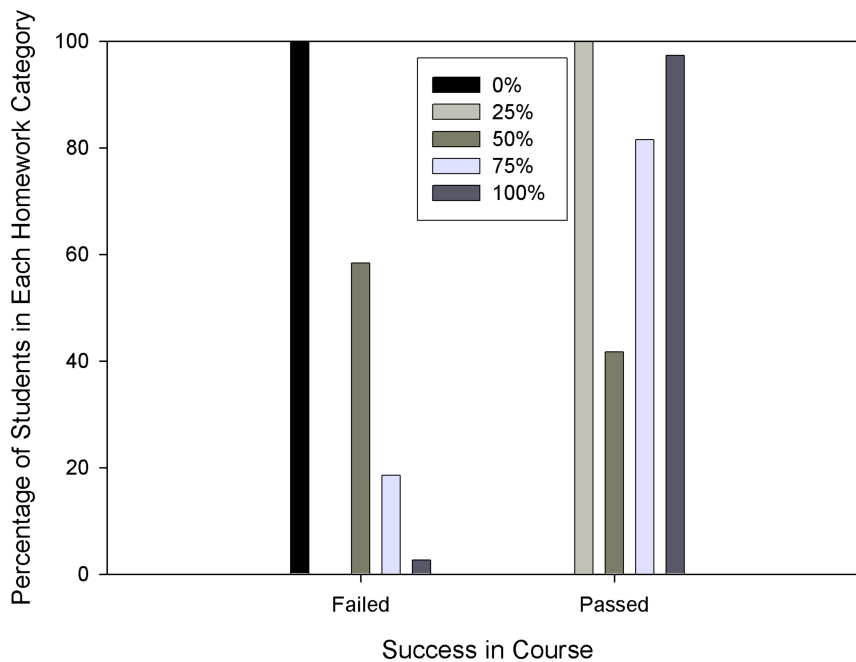


Figure 2. In 2004 only, students were required to turn in solutions to homework problems. Completion of homework was related to passing the course, $\chi^2(4) = 38.885, p \leq 0.05$. Bars depict the percentage of homework completed.

F. Association between the laboratory grade and passing Cell Biology.

Students who passed Cell Biology were more likely to have earned a passing grade in the laboratory as well, $\chi^2(1) = 55.670$, $p \leq 0.05$. Of those who failed the laboratory, 79% failed the class. Of those who passed the laboratory, only 14% failed the class.

G. Association between GPA and passing Cell Biology.

Unpaired t-test showed that students who failed Cell Biology entered the course with a significantly lower GPA (mean = 2.71, standard deviation = 0.440) than those who passed Cell Biology (mean = 3.09, standard deviation = 0.519), $t(155) = -4.252$, $p \leq 0.05$. Moreover, a higher GPA was significantly correlated with a higher percentage of points earned in the course, $r(150) = 0.460$; $p \leq 0.05$.

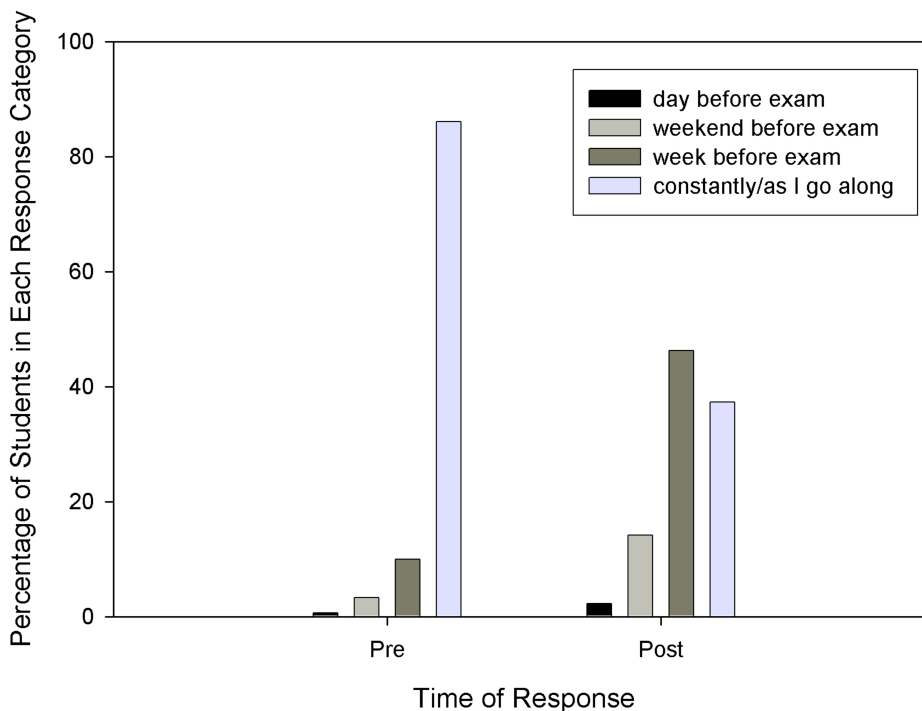


Figure 3. Students self-reported study habits. Students' responses to pre/post survey questions regarding when they expected to study (pre-survey) or actually studied (post-survey) for exams were compared to whether they passed or failed the course. Data for the 2004 and 2005 classes were combined for this analysis.

H. Relative importance of prerequisites, attendance, and GPA.

Direct logistic regression was used to compare completion of course pre-requisites, attendance, and GPA as correlating factors of passing the Cell Biology course. All were coded as dummy variables except for the continuous variable GPA. GPA ($p = 0.046$), perfect attendance

($p \leq 0.001$), and very good attendance ($p = 0.011$) associated significantly with passing the class. The odds ratio for GPA was 2.509, for perfect attendance was 32.530, and for very good attendance was 5.394. In other words, the odds of passing the class were increased by 2.509 for having a high GPA, were increased by 32.530 for having perfect attendance, and were increased by 5.394 for having very good attendance. The prediction success rate for this model was 70% correct.

I. Videotaped lectures on CD-ROM.

CD-ROMs containing digitally recorded lectures were offered to students in the 2004 class only. Passing the class was not related to using the CDs, how often they were used, or when they were used ($p > 0.05$ for all analyses).

J. Study habits.

Expected and actual study habits differed, $\chi^2(3) = 72.655$, $p \leq 0.05$ (Fig.3). The amount of study anticipated by students during the pre-survey was not related to passing the class; the same was true of the amount of study reported in the post-survey ($p > 0.05$ for both analyses).

The types of strategies that students anticipated would help them pass the course differed from what they reported helped them in the post-survey, $\chi^2(4) = 21.317$, $p \leq 0.05$. Fifty-three percent of students reported “*attending lecture*” and 36% reported “*gaining a conceptual understanding of the material*” in the pre-survey whereas in the post-survey, 50% reported “*attending lecture*”, 26% reported “*reading the required material*” (up from 8% in the pre-survey), and 20% reported “*gaining a conceptual understanding of the material.*” Passing the class was not related to how students ranked their study strategies in the post-survey, $\chi^2(3) = 3.723$, $p > 0.05$.

IV. Discussion.

In this study, we examined associations between several variables and passing a lower division cell biology course.

A. Passing our course as a measure of success.

We used passing the course as a measure of students’ success since we did not have a significant sub-sample size for each grade group. Passing the course indicates a level of success as it implies a degree of content understanding as well as a grade that allows students to remain in the major. At SJSU, students must earn a grade of C or better in Cell Biology in order to be allowed to enroll in upper division Biology courses. In addition students can only repeat this course once, if they obtained a non-passing grade. For some students, a C in this course is a realistic measure of success. For others interested in pursuing an advanced graduate or professional degree, a grade lower than A may represent failure.

B. Attendance associated with passing our course.

Our direct logistic regression showed that the most significant association for passing our Cell Biology course was perfect attendance. Our data showed that attendance was critical even when students had access to videotaped lectures. That is, watching the lecture passively at a later time did not supplant being in the classroom and participating in lecture discussions. Sixty-three percent of the students who used the videotaped lectures had poor attendance. These students missed the two group discussions that occurred during lecture, since the videotapes did not capture the discussions and strategies the students used to answer the questions. Some of the students who came regularly to lectures used the videotapes to reinforce the material, and to fill in gaps of their lecture notes. Attendance may have been important since modeling of research problem solving occurred during lectures. Similarly, Freeman et al. (2007) showed a positive relationship between attendance and classroom performance. Devadoss and Foltz (1996) found a strong positive relationship between prior GPA, attendance, and overall grade obtained in class. Furthermore, Durdeen and Ellis (1995) found that lack of attendance had a negative effect on performance only after missing four classes or more. Others have shown that attendance affects GPA of elementary school (Heberling and Shaffer, 1995) and high school (Brodbelt, 1985) students.

C. Previous GPA associated with passing our course.

A higher GPA prior to enrolling in our course was also associated with passing the course in our study. Perhaps students with higher GPAs had previously developed study skills and habits that prepared them for conceptual learning, data analyses, and research-based problem solving, and as a consequence were able to depend less on teacher-driven instruction.

Although previous GPA is the result of many different variables, researchers have used it in studies where associations or predictors of academic performance or success were determined (Bean and Bradley, 1986; Graunke and Woosley, 2005; Salaiman and Mohezar, 2006). For instance using a linear regression model, Freeman et al. (2007) showed that previous GPA could be used as a predictor of students' grades in an introductory biology course sequence. Tai et al. (2005) argued that grades are a valid measure of success, since they can be viewed as a summative assessment of students' performance in a course. Tai et al. (2005) examined course pre-requisites, past grades, and answers to survey questions to examine factors that influence success in college chemistry. They found that high school background, grades, and pedagogy had the greatest effect on helping students perform well in college chemistry.

D. The laboratory component.

Laboratory exercises are one of the few places in college science courses where students can use hands-on experiences to learn concepts (Tanner and Allen, 2004). These activities may be important for students that depend on kinesthetic means for learning the material. Our laboratory exercises allow students to manipulate materials to develop understanding of key concepts as they are introduced to the same topics in lecture. In addition, our laboratory exercises followed closely the content covered in lecture. For instance, a bacterial lipid TLC laboratory activity was done during the week when the cell membrane composition was covered in lecture.

The laboratory component might have been an important instructional tool, as most students who performed well in this component passed the course. However, we can not exclude the possibility that the association we found between passing the laboratory and the course is not directly related to the lab activities per se, but to the characteristics of the students themselves, as the total number of points earned in the class was correlated with the total number of points earned in the laboratory ($r(162) = 0.839, p \leq 0.05$). That is, students who performed well in the lecture also performed well in the lab.

E. Study habits.

Our students showed changes in attitude regarding expected and performed study habits. Most of the students (86%) reported the expectation of studying constantly (as “*I go along*” in the pre-survey) before the course began. At the end of the course (post-survey), that percentage dropped to 37%. It is possible that although most students expected to spend a large amount of time studying, their commitments to other courses or outside work prevented them from doing so. This is a reasonable explanation since most of our students must work outside of the university to support their education.

Students’ perception of what study habits are needed to perform well in a class depends on the strategies used in previous courses and on the experiences provided by the current class (Bartling, 1988). Post-baccalaureate students came to class with well-developed study strategies. Traditional undergraduates taking our class have only experienced one or two college biology courses before they enroll in Cell Biology. In our course, undergraduates were exposed to modified lectures and an emphasis on conceptual understanding over memorization of definitions and facts. Thus, most of these students needed to adjust to a different way of learning the material. One of the biggest obstacles for the students who struggled and failed the course was their inability to adjust to a different teaching and examination style. An example of an exam question is included as Appendix 2.

F. Lessons learned.

More than 75% of the students surveyed thought that effort should be counted as part of their overall grade. However, the majority of students could not suggest how the instructor should assign points for students’ effort. We think that their notion that instructors could assess effort, weigh it fairly, and accordingly, add points to their overall grade is derived from their earlier academic experience in elementary, middle, or high school.

Most of the students complained about the high expectations and the difficulty of exam questions when they were taking the course. Before the 2005 class, students thought that the course expectations and the exam questions were unfair. Bean and Bradley (1986) suggested that college students equate course material difficulty with being unpleasant, and not necessarily with being challenging. The unfairness perception as it relates to course difficulty changed after we implemented the social/syllabus contract. Several of the students enrolled in the 2005 class came to the instructor’s office, a semester or a year later, to thank him for preparing them for more challenging courses. They told him that one of the most important lessons they learned in the course is to accept and deal with a challenge, and not think that course difficulty is unfair.

It became clear that students defined studying “*constantly*” as spending two-to-three hours, three-to-four times a week on course material. The strategies used by some of the students

during the studying times included reading the book, typing their lecture notes, group discussion after class, and solving homework problems. We learned that once students were comfortable with the teaching strategy and the type of exam questions, their study habits changed.

Our biology freshman core is currently being restructured at SJSU. One of the authors of this article (J.G. Soto) is involved in the development and implementation of the new course sequence. Some of the strategies that will be implemented include the use of a social contract, the completion of two semesters of Chemistry freshman sequence, and the incorporation of problems in a workshop/discussion section.

G. Taking responsibility for their own learning.

We observed a shift in students' perceptions about their own learning responsibility as we read their comments to the exit tickets. As the 2005 semester progressed, in about 70% of the exit tickets collected for the concept they had difficulty understanding, students wrote comments like "I need to go over the material on my own," or "I need to re-read the assigned material before I can formulate good questions" (paraphrased by the authors). As science educators, we feel that allowing students the opportunity to feel that they are responsible for learning and doing well is the best possible outcome of the teaching strategies we used in our course.

Appendices

Appendix 1. Bio 3 Pre- and Post-Survey

Two last letters of last name _____ Student ID Number: _____

Major: _____

Your participation on this survey will not affect your final grade in this class. This survey is designed to help us understand how we can help you do better in Bio 3.

Circle the appropriate answer.

1. Are you a:
 - a) Sophomore
 - b) Junior
 - c) Senior
 - d) Undeclared
 - e) Post-baccalaureate
 - f) Graduate Student
2. Are/were you a transfer student?
 - a) Yes
 - b) No
3. Are you currently enrolled in a chemistry course?
 - a) Yes
 - b) No
4. If the answer to question #3 is yes, then you are currently enrolled in:
 - a) Chem 1B 32
 - b) Organic Chemistry I
 - c) Organic Chemistry II
 - d) Biochemistry 1
 - e) Other _____

5. What is the last chemistry university course you took?
 - a) Chem 1A
 - b) Chem 1B
 - c) Organic Chemistry I
 - d) Organic Chemistry II
 - e) Biochemistry
 - f) Other _____
6. Did you take Chem 1A at:
 - a) a Community College
 - b) SJSU
 - c) Other _____
7. If you took Chem 1B prior to enrolling in this class, did you take the course at?
 - a) a Community College
 - b) SJSU
 - c) Other _____
8. After taking Bio 3, you expect to gain
 - a) A superficial understanding of cell biology concepts
 - a) A good understanding of cell biology concepts
 - b) An in-depth conceptual understanding of cell biology concepts
 - c) Other _____
9. Do you expect Bio 3 to be at the same level of academic rigor (*difficulty*) as Bio 1 and Bio 2?
 - a) Yes
 - b) No
10. I expect Bio 3 exams to gauge:
 - a) A superficial understanding of cell biology concepts
 - b) A good understanding of cell biology concepts
 - c) An in-depth conceptual understanding of cell biology concepts
11. Based on your previous experience in Bio 1 and 2, I anticipate studying for Bio 3:
 - a) the day before the exam
 - b) the weekend before the exam
 - c) a week before the exam
 - d) as I go along
12. Based on your previous experience in Bio 1 and 2, predict and rank the following strategies (in order of importance, 1 been the most important) as being more effective in obtaining a passing grade in Bio 3:
 - _____ attending lecture
 - _____ reading the required reading
 - _____ attending office hours
 - _____ completing the homework
 - _____ memorizing facts
 - _____ gaining a conceptual understanding of the material

13. Based on your previous experience in Bio 1 and 2, predict and rank the following strategies (in order of importance, 1 been the most important) as being more effective in obtaining an "A-A+" grade in Bio 3:

- _____ attending lecture
- _____ reading the required reading
- _____ attending office hours
- _____ completing the homework
- _____ memorizing facts
- _____ gaining a conceptual understanding of the material

14. Should effort be counted as part of your class grade?

- a) Yes
- b) No

15. What is your professional goal after you finish your degree/program at SJSU?

- a) Attending graduate (Ph.D) school
- b) Attending medical school
- c) Obtaining a degree in other health related professions (dentistry, pharmacy, etc)
- d) Obtaining employment in my area of expertise
- e) Undecided

Bio 3 Post Survey

Two last letters of last name _____

Student ID Number: _____

Major: _____

Your participation on this survey will not affect your final grade in this class. This survey is designed to help us understand how we can students do better in Bio 3.

Circle the appropriate answer.

1. After taking Bio 3, you have gained

- a) A superficial understanding of cell biology concepts
- d) A good understanding of cell biology concepts
- e) An in-depth conceptual understanding of cell biology concepts
- f) Other _____

2. Was Bio 3 at the same level of academic rigor (*difficulty*) as Bio 1 and Bio 2?

- a) Yes
- b) No

1) Rank in order of interest the topics you found more interesting in cell biology:

- _____ Gene Regulation
- _____ Cancer
- _____ Cell structure
- _____ Cellular energetics
- _____ DNA replication
- _____ Cell-cell interactions

2) What chemistry course do you think would have prepared you better for Bio 3?

- A) Chem 1B
- B) Chem 112A (Organic Chemistry I)
- C) Chem 112B (Organic Chemistry II)
- D) Other _____

- 3) In your opinion, did Bio 1 and 2 prepare you for Bio 3?
- Yes
 - No
6. In my opinion, Bio 3 exams assessed:
- A superficial understanding of cell biology concepts
 - A good understanding of cell biology concepts
 - An in-depth conceptual understanding of cell biology concepts
7. How much did you study for Bio 3 exams?
- the day before the exam
 - the weekend before the exam
 - a week before the exam
 - constantly
8. Based on your experience in Bio 3, rank the following strategies (in order of importance, 1 been the most important) as being more effective in obtaining a passing grade in Bio 3:
- _____ attending lecture
_____ reading the required reading
_____ attending office hours
_____ completing the homework
_____ memorizing facts
_____ gaining a conceptual understanding of the material
Other _____
9. Based on your experience in Bio 3, rank the following strategies (in order of importance, 1 been the most important) as being more effective in obtaining an "A-A+" grade in Bio 3:
- _____ attending lecture
_____ reading the required reading
_____ attending office hours
_____ completing the homework
_____ memorizing facts
_____ gaining a conceptual understanding of the material
Other _____
10. Should effort be counted as part of your class grade?
- Yes
 - No
11. If your answer yes to question #9, how should effort be assessed?
12. Did your professional goal change after completing Bio 3?
- Yes
 - No

The following questions pertain to those students who obtained digital copies of lectures on CD-ROM:

13. How many lectures did you obtain on CD-ROM format?
- 1-5
 - 6-11

- c) 12-17
 - d) More than 17
14. Did you use videotaped lectures to:
- a) reinforce material
 - b) replace attending lectures
 - c) complete notes taken during lecture
15. In your estimation, were the videotaped lectures a valuable learning resource?
- a) Yes
 - b) No
16. How many times did you listen and watch a videotaped lecture?
- a) Once
 - b) Twice
 - c) Thrice or more
17. When did you listen/watch videotaped lectures?
- a) after receiving the CD-ROM
 - b) a week before the exam
 - c) the weekend before the exam
 - d) the day before the exam

Appendix 2. Example of a Bio 3 exam question.

- 4) (10 pnts) X2 Syndrome, a congenital disease, is characterized by the failure of pancreatic cells to secrete insulin. Dr. Soto grew pancreatic cells from a X2 Syndrome patient *in vitro* and tested for the presence or absence of insulin precursor (mRNA) or protein in those cells. His results are shown on the following table:

Detected	Organelle
Insulin mRNA	Nucleus
Insulin protein (not modified)	rough ER
Insulin protein (modified)	rough ER, Golgi complex

Dr. Soto did not detect insulin protein in the media surrounding the pancreatic cells in culture. What organelle(s) or cellular structure(s) would you predict could be damaged (non-functioning) on those cells?

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