

MIND THE GAP: A STUDY INTO THE TRANSITION BETWEEN HIGH SCHOOL
AND COLLEGE BIOLOGY

by

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ABSTRACT

Instructors of college introductory level biology courses agree that the large majority of students enrolled in these courses are inadequately prepared for the course content and coursework. One of the reasons why students are not successful in entry level biology courses (usually required for majors) is that their high school biology course failed to thoroughly prime them for college level science courses. In this study, I examine the knowledge gap between high school and college biology courses and perspectives of students, high school teachers and professors. In particular, the emphasis of this research project is on the transfer of subject content knowledge. To measure the level of student preparedness, I used a survey/pretest hybrid composed of several background questions about students' high school biology experience as well as questions designed to test student understanding of fundamental biological questions. The online survey was administered to over 3000 students in 42 randomly selected universities across six geographical regions of the United States during the first week of their introductory biology course in college. An exit poll was used towards the end of the semester to obtain student perspectives regarding how well prepared they had been for the college biology course they were about to complete. Online questionnaires and phone interviews provided insight into high school teacher and professor perspectives regarding the gap in biology knowledge transfer. The low average score on the pre-test indicates that high school graduates are poorly prepared for college biology in terms of fundamental concept knowledge. Professors agreed with this and most students surveyed at the end of their first college biology course felt that their high school biology experience had not adequately prepared them for college biology or that their teachers or the curriculum they followed could have done more to prepare them. Findings from this study also show that a lack of communication between secondary and higher education biology instructors is an important factor contributing to the misalignment between high school and college biology. Increased vertical communication between the two levels of education would enable secondary school teachers to better prepare their students for the transition to introductory college biology and give professors a more accurate idea of the expectations they can hold their students to.

INTRODUCTION AND BACKGROUND

As a high school biology teacher, I'm always disappointed at how little subject knowledge the majority of students have retained from middle school life science. There seems to be a big gap both in terms of content and course expectations between middle school science and high school science. The first thing I do at the start of Biology I (General Biology) is give my students an assessment based on the National Science Standards for middle school grades to determine how much basic biology knowledge they have coming into my class. Every year I am surprised at how little they know about topics like the nature of science, the human body and the environment. I find myself lowering my expectations of students and re-teaching what I feel they should have not just been taught, but actually learned in middle school. This is counterproductive as the learning students achieved during earlier grades should be built upon in high school and consequently in college (National Research Council, 1990) in order for them to make any progress. As a high school teacher there is little I can do to ensure that students are equipped with adequate life science knowledge when they reach high school. However, I can make sure that they are well prepared for college level science courses.

One of my main instructional goals is for students to leave my course with a solid understanding of biological concepts, which they will be able to apply in their everyday lives and help them build the necessary foundation/background to tackle biology courses in college, especially if they want to pursue a science major. From my own experience and conversations with former students, I have always suspected that many high school

graduates are poorly prepared for college biology courses and have often wondered how well prepared my own students are. For this reason, I was very interested in taking a different point of view from the one I usually have in the high school classroom and assessing students once they are actually in college to see how much biology knowledge they have retained. Though there are some studies looking at how well prepared students are going into physics and chemistry entry-level college courses, there is little literature in relation to biology with the exception of some university or state-specific studies.

My research project was designed as a longitudinal study to investigate the degree of subject knowledge transfer that exists between high school and college biology courses. To do this I surveyed college freshmen starting entry-level biology courses in forty two universities across the United States during the first week of the fall 2010 semester. I also interviewed professors and high school biology teachers to get their perspectives on the transition from high school to college biology and ideas for strategies to improve the transfer of biology content knowledge. With this data I am able to directly measure students' level of retention of high school biology concepts conditional on their highest level of high school biology completed. While this study does not explore the link between these retention levels and performance in college biology courses, such links have been discussed in a number of related studies (Schwartz et al. 2009; Saxon et al. 2008; Wischusen & Wischusen, 2007; Marbach-Ad et al. 2006; Tai et al. 2006; Beltzer et al. 2003; Gibson & Gibson, 2003; Minchella et al. 2002; Uno, 1988). In general, these previous studies describe a positive and significant relationship between retention levels from high school science and performance in introductory college science courses.

Focus Question

There are many aspects to the gap between high school and college level biology (e.g. student preparedness to handle the workload, ability to work as independent learners, subject specific skills, and conceptual knowledge), I chose to study it in terms of transfer of conceptual subject knowledge. My project had as primary focus question “How well does high school biology prepare students for freshman level biology courses in college?” In addition, I also tried to gain a deeper understanding into the biology topics students are least competent in at the start of a freshman biology course, factors relating to the high school biology experience that might contribute to this gap between high school and college biology, and strategies that can be adopted at both the secondary and post-secondary levels to better prepare students for success in college and university science courses.

CONCEPTUAL FRAMEWORK

According to the most recent ACT College Readiness Report (ACT, 2009) only about one in four students (28 %) who took the ACT test in 2009 met the College Readiness Benchmarks for Science, the lowest percentage out of the four subject tests, following English (67 %), Reading (53 %) and Math (42 %). The gap that exists between high school science and undergraduate science courses has been well documented since the 1980s (Upcraft et al. (2005) as cited in Wischusen & Wischusen, 2007; Wischusen & Wischusen, 2007; Marbach-Ad, Ribke, 2006; Belzer, Miller & Shoemake, 2003; Gibson & Gibson, 1993; Dickie & Farrell, 1991; Uno, 1988). College faculty and administrators

are growing increasingly concerned with the inadequate level of preparation of students enrolled in entry-level science courses and are turning to these studies to try to understand the reasons for this and develop strategies to narrow the gap (Belzer et al., 2003; Gibson & Gibson, 1993). In biology courses in particular, the problem stems mainly from a lack of subject background knowledge and an inability to apply concepts that were covered in high school courses to their freshman biology courses (Marbach-Ad, 2006; Odom, 1995; Uno, 1988). Understanding this gap in knowledge transfer between high school and college science, and taking a more proactive approach towards narrowing it, would ensure a higher student success rate in undergraduate science courses, which would in turn yield a greater number of students graduating as science majors (Wischusen & Wischusen, 2007).

It is important to understand the type of gap that exists between high school and college in order to determine the degree to which high school science courses, in particular biology, are responsible for students' inadequate preparation for entry-level college courses. Previous studies have found that there is a wide array of factors contributing to creating this gap. These include: demographic factors (e.g. race, highest parental education), types and levels of science and math courses taken in high school, student attitudes and perceptions of college science, teaching methods in high school science (e.g. use of demonstrations, frequency of labs, emphasizing understanding or memorization), how rigorous the high school curriculum is and student recall of information (Tai, Sadler & Mintzes, 2006; Gibson & Gibson, 1993; Leonard, Fowler, Mason, Ridenour & Stone, 1991; Dickie & Farrell, 1991). A major contributing factor to this gap is that many students have not taken the necessary science courses in high school

in terms of number of courses, nature (laboratory or not) and subject area (many take two or three sciences in high school, but some only take one). As a result, students might miss out on necessary skills or content, which are important for succeeding in introductory courses in college. The problem here lies mainly on the fact that in most states there is not an alignment between high school science requirements for graduation and college admission science requirements. A study carried out by the National Association of Systems Heads in 2000-2002 showed that out of all 50 states, only Florida had full alignment between high school graduation and college admission course requirements for science. Seventeen other states had only partial alignment, and the 32 remaining states had no alignment at all (Somerville & Yi, 2002). Even in the instances where there is a full or partial alignment of the number and nature of high school science courses with college science requirement, the curriculum itself is usually not aligned and the lack of continuity means there is either an overlap and therefore repetition of material, or a deficit due to topics being left out.

Part of the reason why high school biology courses may not be as effective as they could be at preparing students for entering college level science is that there is a mismatch between high school teachers' perceptions of how well prepared their students are and the expectations of college professors (Wischusen & Wischusen, 2007; Sadler & Tai, 2000). In a 2006 study by Sanoff (as cited in Wischusen & Wischusen, 2007), over 40% of college faculty thought students were not prepared for college and this view was only shared by 10% of high school teachers polled (the other 90 percent believed their students to be adequately prepared). Most science professors are aware that many of their students are not adequately prepared for their course and might fail or drop out, but they

go on teaching without addressing the issue (Belzer et al., 2003; Sadler and Tai, 2001). They hold the belief that students in college should be able to take responsibility for their own learning and figure out how to succeed in their course. Many professors however, are on the opposite extreme and have no expectations at all of their students with regards to how much biology background knowledge they should have. They start teaching the subject matter from scratch as though students had never had biology in high school, consequently acting as though high school science courses are a total waste of time. Strategies must be adopted at the high school level to ensure that students leave foundation science courses with both a solid understanding of the subject and the ability to enter college level courses and effectively build on their existing knowledge.

It is important to study the gap that exists between high school and college science because often students enter courses required for science majors without the background knowledge or critical thinking skills needed to reach their full potential in, or even pass, these courses (Beltzer et al., 2003). As a result of inadequate preparation, a high percentage of students who enroll in entry-level science courses end up dropping the course and often change their major to enroll in less demanding programs of study (Tobias as cited in Marbach-ad. 2006; Minchella, Yazac, Fodrea & Ball, 2002; Gainen as cited in Sadler and Tai, 2001). The United States is already falling behind European and Asian nations in terms of the science education standard (National Center for Education Statistics, 2009). A greater emphasis on creating continuity between high school and college science would help raise science education standards and foster more competent science students (Gibson & Gibson, 1993).

The data collection methods used to measure the gap between high school and college science are as varied as the contributing factors and depend on which aspect of the disparity the study focuses on (for example, curriculum continuity, student perceptions, teacher expectations, etc.) Quantitative methods used include student surveys, pre-tests, entrance exams and self-assessments. Studies carried out at individual universities across the country measuring content biology knowledge transfer between high school and college have mainly used multiple choice tests and provided direction for the methodologies used in my study. In their examination of a K-12 Kentucky Science curriculum and its alignment with college courses, Saxon, Lennex and Duvall (2008) gave students at a regional Kentucky university a “readiness pre-test” to determine the level of preparedness of freshman enrolled in a biology entry-level course. The pre-test consisted of multiple-choice questions covering the main topics in high school biology as mandated in Kentucky’s science standards, integrated math and chemistry questions and tested student’s ability to interpret data. The mean score on the pre-test was around 66 percent, indicating a rather low performance. When pre-test scores were compared to final course grades, findings from this study indicated that the pre-test was fairly effective in predicting student achievement in the introductory course with “a higher readiness test score indicat(ing) a higher performance in the course.” Beltzer et al. (2003) used a similar pre/post-content test, a NABT/NSTA high school biology exam consisting of multiple-choice questions designed to determine student knowledge of subject matter after taking a supplemental study skills course. Multiple-choice questions however provide only a limited insight into students’ understanding of subject matter concepts. Odom (1995) used a two tier multiple-choice format to increase the validity of his Diffusion/Osmosis

Diagnostic Test. The first tier consisted of two, three or four answer choices; the second tier gave four choices for the correct explanation of the first tier answer, requiring students not only to make a decision on which answer to choose but also to give a reason for their choice. This type of two tier multiple choice assessment reduces the chance that a correct answer is due to guessing alone from 25% to 12.5% (Odom, 1995).

In terms of qualitative data, verbal and written inquiry data in the form of questionnaires and interviews provide the most common instrument for examining teacher and professor perceptions and attitudes regarding student preparation for college science. Conversations with educators and focus groups have also yielded valuable information regarding potential strategies for improving the transfer of knowledge between high school and college biology courses (Saxon et al., 2008; Belzer et al., 2003). An alternative method to the qualitative strategies listed above is an alignment instrument such as the one Herman, Webb and Zuniga (2003) used to examine the level of agreement between K-12 and the 12-16 curricula. The alignment instrument was given to separate panels of high school teachers and university faculty who were asked to rank math topics and subtopics in order of perceived importance in their courses. Gibson and Gibson (1993) on the other hand used a more quantitative survey instrument similar to a Likert scale to analyze student perceptions of how effective their high school science courses were in preparing them for college biology. The study, which was carried out at a university in Florida, found that among the freshman students surveyed: males, students who had taken the greatest number of science courses, and those who came from large high schools felt the most comfortable taking a college level science class. The topic students were least confident in of those presented in the questionnaire was Mendelian

genetics and in terms of skills, only small percentage of those surveyed were familiar with the format for writing scientific paper. This study was limited however, in that only a few concepts were assessed for understanding.

Perhaps the most important strategy used to ensure that all high school students leave science courses with a solid knowledge base of the subject is to adopt a minimum core curriculum with emphasis on foundation science concepts (Gibson & Gibson, 1993; Leonard, Fowler, Mason, Ridenour & Stone, 1991). General recommendations made in the *Project 2061 Report* (AAAS, 1989) for basic science curricula include: reducing the breadth of material covered to encourage greater literacy; getting rid of strict subject-matter boundaries in order to foster making connections and thinking outside the box; exploiting relationships between science, math and technology; and encouraging scientific ways of thinking (Leonard et al, 1991). The National Science Education Standards define six content areas that should be a fundamental part of every life science program (as described in Content Standard C): The Cell; Molecular Basis of Heredity; Biological Evolution; Interdependence of Organisms; Matter, Energy and Organization in Living Systems; Behavior of Organisms. The Standards call for a change of emphasis regarding student learning objectives with less emphasis on knowing scientific facts and information, and more on understanding scientific concepts and developing abilities of inquiry (NSTA, 2004; National Research Council (NRC), 2000; NRC, 1996; Albridge & Strassenburg, 1995; AAAS, 1993; NRC, 1990). In their concluding remarks, Saxon et al. (2008) also recommend that “students need a pre-college curriculum that provides the components necessary to learn the essential concepts which are required for successful performance at the college level biology” and that promotes the retention of said

concepts. Effective college preparedness pre-tests therefore must assess students' understanding of key concepts rather than recall of facts (Gibson & Gibson, 1993; Leonard et al. 1991).

Other strategies for increasing college readiness included in the ACT 2009 Report are: implementing fewer, but more concise, state learning standards which are geared towards college and/or career preparation; a rigorous high school curriculum that is the same for college-bound and work-bound students that is made up of three years of science (Biology, Chemistry, Physics), which allows students to widen their scientific knowledge base and be more prepared for college; clear standards for college and work readiness; alignment of high school and college curriculum; monitoring and early intervention to help students stay on track for college or starting a career; and making decisions based on research data.

Other works have produced important findings that point to additional, potential strategies for reducing the gap between high school and college science. For example, in a study looking at the role of high school physics as preparation for college physics courses, Sadler and Tai (2001) found that certain high school teacher decisions were linked to their students getting higher grades in college. These decisions included: explaining problems in several different ways, using no textbook at all or using it less, covering less topics in greater depth, performing fewer but more effective labs in class, being average or less than average in terms of friendliness, avoiding long explanations after demonstrations, emphasizing understanding over memorization, and using demonstrations and class projects selectively (Tai, Sadler and Mintzes, 2006; Sadler and Tai, 2001). Considering the findings of this and similar studies could help high school

teachers modify their approach in order to better prepare their students for tackling level science courses.

Colleges should also seek ways to reduce the gap in knowledge transfer, especially in the first weeks of the semester. Students enter freshman science courses with a wide range of subject knowledge backgrounds. Professors must assess subject matter knowledge early on and uncover the most common preconceptions about biology held among students. As educational psychologist David Ausubel pointed out: “The most important single factor influencing learning is what the learning already knows. Ascertain this and teach him accordingly” (Ausubel, 1968). Once professors have assessed the biology background students hold, strategies and support systems can then be put into practice to even out student differences in terms of content knowledge and subject-related skills. A number of programs are already in place in universities around the country to help students who are poorly prepared for college-level science coursework. Some of these general strategies are: remedial courses, supplemental seminars, course “tasters,” review packages, learning centers, and peer tutoring (Belzer et al. 2003; Wischusen & Wischusen, 2007).

At Tel Aviv University in Israel, a “primer” unit was used to bridge the gap between high school biology and their entry-level course, Introductory Cell Biology. The primer unit was a power-point presentation that covered the basic foundations of cell biology: macromolecules, their compounds and their functions within the cell. This primer was made available to students one month prior to the start of the course. The researchers found that students who used the primer were better prepared for the cell biology course and were also less intimidated going into the course than those who did

not use the primer. The primer also contributed to reducing the content knowledge gap between students who took advanced biology in high school and those who had not. The effect of the primer became less pronounced as the course progressed. Results from the third questionnaire given six weeks into the course showed no significant difference between those who used the primer and those who did not (Marbach et al. 2006).

A more common way to bridge the knowledge gap is offering supplemental seminar courses that run parallel to introductory science courses. At Purdue University in Indiana, an intervention involving a seminar course covering topics of interest to students in the life science fields was so successful that now all freshmen biology majors at Purdue take a required seminar course titled “Biology Resource Seminar,” aimed to develop student intellectual skills and to integrate freshmen into the department and the university as a whole (Minchella et al. 2002). The course introduced students to problem-solving strategies, undergraduate research, resources available to them within the department and university, biology-related careers, professional development strategies and opportunities for collaborative learning. The Biology Resource Seminar significantly increased student achievement (participants had higher final grades than non-participants) in Introductory Biology. The seminar course also improved student satisfaction and retention to the biology major and to the university.

Nordell (2009) found that even just a one hour study skills workshop early in the semester helped students be more successful in introductory science courses. Students who attended the study skills workshop after their first lecture exam performed significantly better on lecture exams, compared to students who did not attend one. It is important to note that higher achieving students are more likely to attend a study skills

workshop, while students who need the most help are the least likely to seek it out.

Professors, therefore, would need to take on the responsibility of encouraging students to make use of support strategies that are available to them.

Another strategy that had a positive outcome at Louisiana State University was a five-day intensive “boot camp” for biology majors held the week before the start of their first semester in college (Wischusen & Wischusen, 2007). The BIOS (Biology Intensive Orientation for Students) program was made up of content lectures, exams, learning styles assessments, study skill and strategies for test taking workshops, study hall sessions, group work and informal sessions. The study found that BIOS students did better on the first exam and also had higher grades in the introductory biology course as a whole. Students attributed success in biology courses to having received “part of the course ahead of time” through the BIOS. Other reported benefits of the BIOS program included: a change in student perceptions of what was required from them in college, improved data analysis skills, the development of more efficient study habits, greater confidence in fundamental biology concepts and decreased fear of lecture tests.

Addressing student misconceptions was mentioned earlier in this section as an important step towards giving students a strong start in introductory science courses (Odom, 1995; Ausubel, 1968). Other general strategies that professors can adopt for enhancing learning in biology in particular are allowing for more discussion time, teaching concept mapping to make connections between topics and build meaning, using a variety of teaching methods to reach a wider range of students, and allowing time for students to make predictions and analyze data (Odom, 1995).

High school biology, and also to a certain extent physics and chemistry, is failing to adequately prepare students for introductory science courses in college (Wischusen & Wischusen, 2007; Beltzer et al. 2003). In a 1988 study by Moore (as cited in Gibson & Gibson, 1993), U.S. high school students ranked last among 13 countries on subject knowledge. College faculty members are growing increasingly concerned with the lack of background knowledge, subject-related skills and critical thinking ability shown by students entering their biology courses (Beltzer et al, 2003; Gibson & Gibson, 2003; National Research Council, 1996; Leonard et al, 1991; National Research Council, 1990). As Beltzer et al. say in their 2007 study, professors are frustrated with their students “lack of preparedness” for succeeding in their courses and asking the question of what can be done “to reduce the number of students who fail introductory biology.”

Developing strategies to address and reduce the gap at the high school and the college level instead of accepting student failure in foundation science courses or ignoring any preparation they already had, would raise overall student achievement in the sciences. It would also increase retention rates in this subject, as more students would continue with their biology related majors and go on to graduate. Wischusen and Wischusen (2007) give a list of examples in which retention rates of science majors was increased when strategies were carried out to address the transition between high school and college science. For example, in Arizona State University, a “freshman bridge program” and seminar course increased retention of minority engineering students by 12% the first year it was implemented and a similar course for engineering majors at University of Connecticut increased retention by 10%. At Purdue University, the biology resource

seminar offered to freshman biology majors mentioned earlier in this section, resulted in a 12% retention increase after three semesters (Minchella et al, 2002).

Although there have been several studies measuring content knowledge transfer in biology between high school and college at the local level, there is a lack of longitudinal research involving this aspect of the transition gap across a number of universities throughout the country. In their 2008 report, Saxon et al. ask how public schools could work together with colleges to better prepare students and they suggest determining needs through “great scrutiny of the curriculum in conjunction with determination of college-entrance readiness.” Maybe an effective first step towards narrowing this gap between high school and college biology would be to have professors observe some high school science classrooms and high school teachers to observe some college lectures (Dickie, 1991) or to have secondary teachers (from both middle and high schools) sit down with college faculty to discuss their curriculums and progressions between them as in the Saxon et al. study (2008). Regardless of the method or instruments used to address this disconnect, all conclusions point to the fact that “incoming freshmen struggle with the transition between high school and collegiate academics” (Nordell, 2009). This is evident in the a noticeable gap between K-12 science and undergraduate science and he longer it is left unaddressed, the wider it becomes, as does the gap between competitiveness in science in the United States compared to other nations (Gibson D.J., & Gibson L. S., 2003; National Research Council, 1990). In one of the most frequently referenced studies on the subject, Uno (1988) lists “a lack of solid science background” as the number one reason why students have difficulty in college introductory biology. The instrument I

designed for this study aims to offer one way of determining student readiness for college biology by measuring their retention of biology content from high school.

METHODOLOGY

For this project, I used three types of subjects in education: students enrolled in introductory biology in college, biology high school teachers and college professors currently teaching or having taught introductory biology courses. The main source of data was the student survey/pre-test I created to determine the level of student preparedness upon entering their first introductory biology course in college. The first part of the survey consisted of five informational questions that asked about the student's biology background: (1) Have you taken any biology classes in college before the one you are taking now? 2) What is the HIGHEST level of biology you completed in high school? 3) When did you take your LAST biology course in high school? 4) How confident are you about your biology background knowledge? 5) Was your last biology class mainly focused on understanding, memorization or a mixture of both? The second part of the survey asked a total of seventeen questions testing student knowledge of basic biological concepts including sixteen multiple choice questions and one free response question (See Appendix A for survey questions) These subject matter based questions aimed to measure students' understanding of key concepts rather than their ability to recall facts from their previous biology course/s. The pre-test was designed around the six topic areas defined in Content Standard C of the National Science Education Standards (NRC, 2010; NRC, 1996). I decided to use a regular one-tier multiple choice format, rather than a two-tiered

format like the one used by Odom (1995) in order to be able to keep the survey as short as possible while still including questions that would cover all key concepts. Although this meant that the validity of the results would be slightly compromised due to a higher chance of guessing the right answer with the one-tier format (Odom, 1995) as discussed in the previous section, I hoped a shorter survey would increase the chances of students' willingness to participate, since it was optional and they were to complete it in their own time. Every question was designed to test for understanding rather than recall and thoroughly reviewed by several biology professors. I want to emphasize again that the instrument I designed is not meant to be used as an indicator of student performance/grade on the introductory biology course, but as a measure of the degree to which students have retained important concepts of high school biology based on the National Science Education Standards (National Research Council, 1996).

Over 3000 students from 42 randomly-selected universities across six regions of the United States completed the survey. The six regions were defined by geography, based on those used in Peterson's College Search (<http://www.petersons.com/college-search.aspx>): Mid-Atlantic, Northwest, Midwest, New England, South and Southwest. I used the Peterson's College Search website to generate a list of all 4-year higher education institutions in the United States offering a B.S. in Biology. I stratified the population into the six geographic regions, assigned each university a number and then used a random number generator to select the potential participating universities. Once the Chairs of Department agreed to take part in the research study, I contacted their introductory biology professors and they were the ones who provided students with the link to the online survey and asked them to complete it anonymously, voluntarily and

outside of class. The response period for each of the universities opened the day of the first class lecture and closed eight days later.

The only requirement for participation in the student survey was that they be currently enrolled in an introductory biology course and that they be over 18. The first question of the survey, which asked “Have you taken any other biology classes in college before the one you are taking now?” was included in order to be able to exclude the responses of students who were not new to college level biology courses. Given that the focus of the study is the gap between high school and introductory college biology, it was important to only consider the responses of students who were taking their first introductory biology course, whether they were freshmen right out of high school or sophomores starting the biology course sequence. At some of the universities, several introductory courses could be taken out of order, so although courses such as “Biology Concepts: Cells” and “Biology Concepts: Evolution” were both listed as introductory courses, they had a mixture of students: some were totally new to college biology and others were taking their second biology course.

The student exit poll (Appendix B) consisted of a question that aimed to obtain students’ perspective of how well their high school biology course prepared them for the college biology course they were about to complete. It was administered online during the last two weeks of the fall to the same classes that participated in the pre-course student survey. The link to the poll was provided to instructors who then passed it along to their students like they did at the start of the semester.

Table 1 shows the triangulation matrix for the data collection instruments I used in this project. In addition to gathering data from students, qualitative evidence was also

obtained from college biology professors and high school biology teachers. This part of the project aimed to provide information about the teacher perspective into the level of preparedness of students. Professors who had their classes participate in the student survey participated in this section of the study. High school teachers were recruited via online science communities and local schools. Both professors and high school teachers were asked to complete online questionnaires consisting of five questions designed to gather their perception of their students' level of preparedness upon leaving high school biology and entering introductory college courses (see Appendices C and D). I then interviewed a subset of these instructors to gain a more in-depth understanding into the survey results. Interviewees were all given letters as pseudonyms in the discussion to maintain anonymity. The interview questions can be found in Appendices E and F.

Table 1
Data Triangulation Matrix

Focus Questions	Data Source 1	Data Source 2	Data Source 3
<i>Primary Question:</i> 1. How well does high school Biology prepare students for freshman level Biology courses in college?	Student pre-course survey and exit poll	Professor questionnaire and interviews	High School biology teacher questionnaire and interviews
<i>Secondary Questions:</i> 1. Which Biology topics are students least competent in at the start of a freshman Biology course?	Student pre-course survey	Professor questionnaire and interviews	High school biology teacher questionnaire and interviews
2. What factors might contribute to this gap between high school	Professor questionnaire and interviews	High School Biology teacher questionnaire and interviews	Student exit poll

and college Biology?

3. What are some strategies that can be adopted at both the high school and university level to better prepare students for success in college Biology courses?

Professor questionnaire and interviews

High School Biology teacher questionnaire and interviews

Student exit poll

The research methodology for this project received an exemption by Montana State University's Institutional Review Board (as well as that of several of the participating institutions which required a separate review process) and compliance for working with human subjects was maintained.

RESULTS

Student Pre-course Survey and Content Test

The student pre-course survey had two aims: to gather background information about students' high school biology experience and to test their basic subject knowledge going into their first introductory biology course in college. The pre-course survey was completed by a total of 3021 students. Of these, I removed 357 response, belonging to students who had already taken one or more previous biology courses in college. This leaves a sample of 2664 responses from students who were enrolled in their first college biology course at the time of completing the survey. Given that the free response question is of a somewhat subjective nature, I analyze the multiple choice questions and the free

response question separately below. Based on the results from the pre-course student survey questions, I report the summary statistics on the average and the variance for the number of correct answers for questions number 6-22 (the biology content questions). To assess question 22 (the only open response item on the pretest) I created a code to classify student responses into two categories: “Correct”= can correctly explain the relationship between proteins and nucleic acids and “Incorrect”=do not understand the relationship between proteins and nucleic acids or are unable to articulate it clearly enough.

In addition to the summary statistics on the subject matter questions, I carry out several regression analyses that illustrate relationships between performance and the following categories of independent variables: highest level of biology completed in high school, grade in which students took their last biology course, whether student high school biology experience was focused mainly on understanding or memorization and student level of confidence in their subject knowledge going into the introductory course in college.

The mean point score for the sixteen multiple choice questions is 5.2 (33% correct answers, SD= 2.24). Figure 1 shows student performance on each of the questions, the text of which can be found in Appendix A.

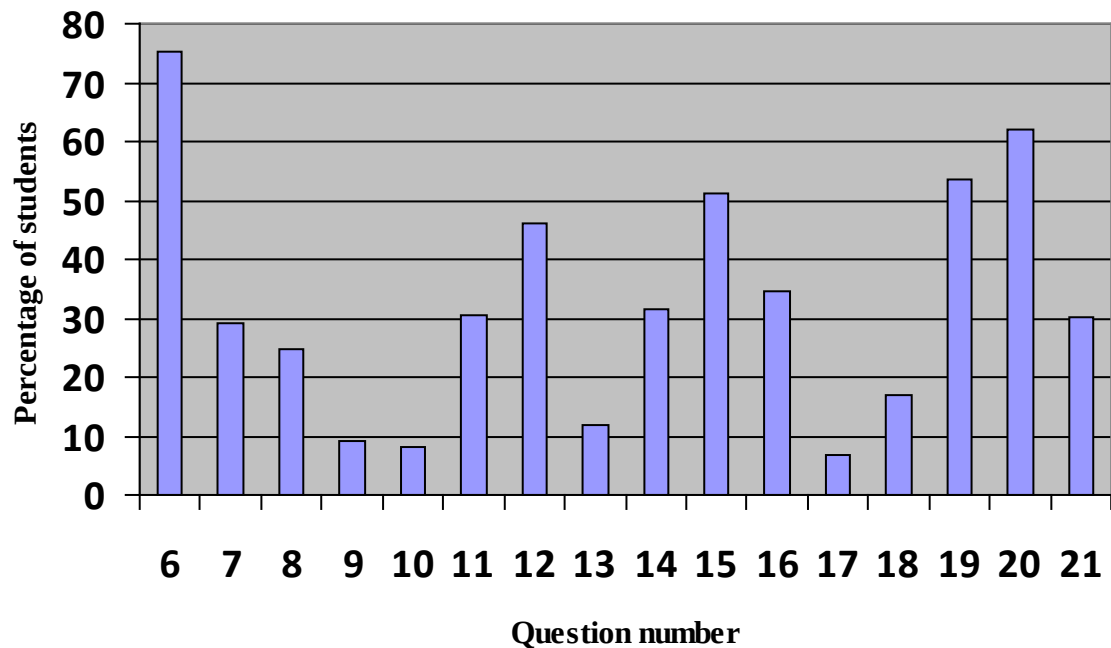


Figure 1. Percentage of students who answered each of the multiple choice questions on the pre-course survey correctly, (N= 2664).

There were twelve questions which more than half of the class answered incorrectly. I consider the topics these questions cover to be those which students are weakest in. These topics were genetics, cells, metabolism, ecology and evolution. On the other hand, the questions which over half of the class answered correctly suggest that students were strongest in human anatomy.

The last content question on the survey was open-response and designed to test students' understanding of the key principle of molecular biology known as "the central dogma of biology", the synthesis of proteins from the transcription and translation of nucleic acids. Only 272 students (10%) gave a correct answer to the question "Explain

the connection between proteins and nucleic acids”. The 10% is likely biased upward given that the number of identical answers suggests that many searched and copied the answer from the internet even though they were asked not to in the instructions. The other 2392 students answered the question incorrectly, incompletely or said they didn’t know the answer. Sample answers are contained in Table 2.

Table 2

Examples of incorrect and correct answers given by students to the open ended question “Explain the connection between proteins and nucleic acids”.

Correct	“Nucleic acids code for amino acids which string together to form proteins.” “Nucleic acids carry the genetic instructions needed to make proteins.” “Nucleic acids code for amino acids and amino acids use peptide bonds to form a long polypeptide chain called a protein.”
Incorrect	“Nucleic acids make up proteins.” “Proteins are the building blocks for nucleic acids.” “They both provide energy that the body needs to survive.”

The poor performance on this open-ended question, together with the low point average on the multiple choice content questions indicates that in general, students entering college biology recall very little information from high school biology.

I now discuss several predictor variables that might have contributed to variation in student performance on the pretest, starting with the type of biology course the student took in high school. The majority of students in the sample took some form of biology in high school. Only 40 students (2%) out of the 2664 did not take any life science courses in high school. Of those who did take biology: 55% (1475 students) completed Biology I

as their highest level biology class, 33% (871) completed some form of AP or Honors Biology¹, 8% (218) completed Biology II, 1% (35) completed IB Biology and less than 1% (25) took “Other” biology courses such as Anatomy and Physiology, Marine Biology and Genetics. This data is used to estimate a regression model to measure the effect a student’s highest level of high school biology has on student performance on the objective questions on the pretest (based on point scores). The regression results are shown below in Table 3. I suppressed Biology 1 and the estimates for the other courses included in the regression are interpreted relative to students who took Biology 1 as their last biology class.

Table 3

Regression results for last biology class taken on mean point score (number of questions scored correctly) for the sixteen multiple choice questions.

Independent Variables	Coefficient	Standard Error
Constant	4.77	0.06
AP / Honors Biology	1.24***	0.09
Biology 2	0.20	0.16
No Biology	-0.27	0.35
IB Biology	1.83***	0.37
“Other” Biology	0.83*	0.44

N.B. * indicates significance at the .1 level, ** at the .05 level, *** at the .01 level.

The coefficient for the constant term is the average point score for Biology 1 students on the sixteen multiple choice questions of the pretest, and this score is used as our baseline from which to measure the change in performance from varying levels of biology classes. Therefore the remaining coefficients are interpreted as the change in the

¹ Biology courses listed as “Other” by students which were advanced level courses (such as Advanced Biology and College Prep Biology for example) were combined into the “AP Biology or Honors Biology” category.

average score for each biology level apart from Biology 1. Students who took AP/Honors Biology, on average, scored 1.24 points higher than those students whose last biology course was Biology 1. This 1.24 points is a 26% increase (significant at the 99% level) relative to the baseline score. IB Biology also had a significant, positive effect (at the 99% confidence level) on student scores, raising the average by 1.83 points (38%). Moreover, the 1.83 point increase from IB Biology is statistically higher than the 1.24 increase from AP/Honors Biology (at the 95% confidence level).

The “Other” category also showed a significant, positive effect on student scores (at the 90% confidence level). These students scored 0.83 points higher on average than Biology 1 students, which is about a 17% increase. The reason for this may be that most of the courses students listed as “Other” (e.g. biotechnology, marine biology, molecular biology, genetics, zoology) were likely science electives taken after Biology 1, so they probably had two years of biology classes behind them. Biology 2 did not seem to have a significant effect on student scores relative to Biology 1, which was surprising given the presumed parallel with the “Other” category in terms of years of biology classes. Most interesting of all, however, was the fact that not having taken any biology in high school did not have a significant effect on student scores, neither positively nor negatively (at the 90, 95 or 99% confidence levels). This finding suggests that those students who did not take any secondary biology may be as ready, as measured by the pretest, for college biology as those who took one year in high school, which in turn makes the efficiency of having only one year of high school biology questionable as preparation for college biology.

The year in which biology was last taken in high school had a very strong effect on student scores on the pretest as reflected in the regression results on Table 4 below. Of the 2624 students who took some form of high school biology, 40% had biology last as sophomores, 24% had their only biology course as freshmen, 22% had biology as seniors and 14% took their last biology course when they were juniors. In this regression, the constant term is the average point score for students who last took biology as seniors in high school and this score is used as our baseline from which to measure the change in performance resulting from differences in when biology was last taken in high school. Therefore, the remaining coefficients are interpreted as the change in the average score for each different year biology was taken, relative to senior year. Students who took their last biology course when they were freshmen, sophomores or juniors in high school all scored significantly lower (at the 99% confidence level) than those who took a biology course as seniors. The average score for students who took biology as seniors is 6.27 as shown in Table 4. Those who last took biology as freshman scored an average of 1.31 points lower than those who took it as seniors, which is a 21% decrease in score; those who took it as sophomores scored 1.50 points lower on average (a 24% decrease); and those who took it during their junior year last scored 0.90 points less (a 14% decrease) relative to those who took their last biology course as seniors in high school. Interestingly, in this regression, not having taken biology in high school has a significant and negative effect (at the 99% confidence level) on student scores relative to students who took biology as seniors (they scored 1.27 points less on average which is 26% lower) but this is not dramatically lower than students who took biology last as freshmen or sophomores).

Table 4

Regression results for year biology was last taken in high school on mean point scores for the multiple choice questions

Independent Variables	Coefficient	Standard Error
Constant	6.27	0.09
Didn't take biology in high school	-1.62***	0.35
Freshman Year/ Gr. 9	-1.31***	0.12
Sophomore Year/ Gr. 10	-1.50***	0.11
Junior Year/ Gr. 11	-0.90***	0.14

N.B. * indicates significance at the .1 level, ** at the .05 level, *** at the .01 level.

I now turn to an analysis of how the focus of students' last biology class (recall, that the focus is categorized as "mainly memorization", "mainly understanding" or "a more or less even mixture of understanding and memorization" balance between the two) affects performance on the pretest. The results for this regression are contained in Table 5, the latter of the three categories being the one that is suppressed. Neither the biology courses with a focus on understanding, nor those with a focus on memorization had a statistically significant effect on student scores on the pretest relative to courses which focused more or less equally on memorization and understanding.

Table 5

Regression results for focus of last biology class taken on mean point score for the multiple choice questions.

Independent Variables	Coefficient	Standard Error
Constant	5.25	0.06
High school biology with a focus mainly on understanding	0.12	0.11
High school biology with a focus mainly on memorization	0.05	0.11

N.B. * indicates significance at the .1 level, ** at the .05 level, *** at the .01 level.

Next I discuss the effect student confidence seems to have on student performance on the pretest. The makeup of the student sample in terms of levels of confidence based on their biology preparation is illustrated in Figure 2.

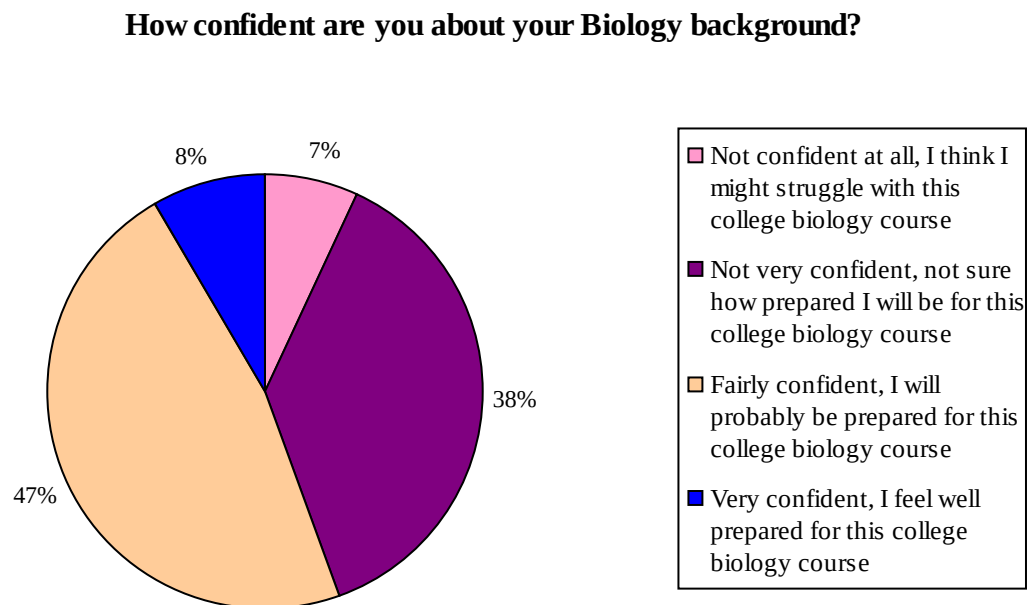


Figure 2. Level of student confidence at the start of their first biology course in college, (N=2664).

The level of confidence students felt seems to have an impact on their performance, with high student confidence having a strong, positive effect on student scores. Table 6 shows the results of the regression in which the “Not confident at all” response is suppressed.

Table 6

Regression results for level of confidence regarding preparation for introductory biology course on mean point scores for the multiple choice questions

Independent Variables	Coefficient	Standard Error
Constant	4.43	0.16
Not very confident, not sure how prepared I will be for this college biology course	0.32*	0.17
Fairly confident, I will probably be prepared for this college biology course	1.00***	0.17
Very confident, I feel well prepared for this college biology course	2.33***	0.22

N.B. * indicates significance at the .1 level, ** at the .05 level, *** at the .01 level.

Students who felt “Very confident” scored on average 2.33 points (53%) higher than those who were “Not confident at all” (significant at the 99% level)). Those who felt “Fairly confident” scored 1 point (23%) higher than those who were “Not confident at all”. Even those who were not very confident because they were not sure how prepared they were scored slightly higher (0.32 points, 7%) higher than those who claimed no confidence at all.²

² It is possible that the performance of highly confident students could be attributed to the fact that these students were also those who took higher level biology courses in high school and therefore had more solid subject knowledge. The results from a Pearson’s Correlation test suggest a strong linear correlation between student confidence and level of biology taken ($r(2662) = 0.29, p < 0.01$).

Student Exit Poll

The exit poll gathered student perspectives on their transition between high school and college biology. The poll was conducted online, among the same classes that were recruited for the pre-course survey towards the end of the semester. 1859 students answered the question “How well did your HIGH SCHOOL BIOLOGY course/s prepare you for the Biology course you took in college this semester?” The responses of 36 students who answered that they did not take Biology in high school were removed, the responses of the other 1826 students are illustrated in Figure 3. Findings indicate that 57% of the group felt that their high school biology had prepared them fairly well or very well, while the other 43% felt it had not prepared them at all for college biology or they couldn’t determine to what extent it had influenced their preparation. These results are compared to teacher perspectives about student preparedness at the start of the course later in the discussion.

How well did your HIGH SCHOOL BIOLOGY course/s prepare you for the Biology course you took in college this semester?

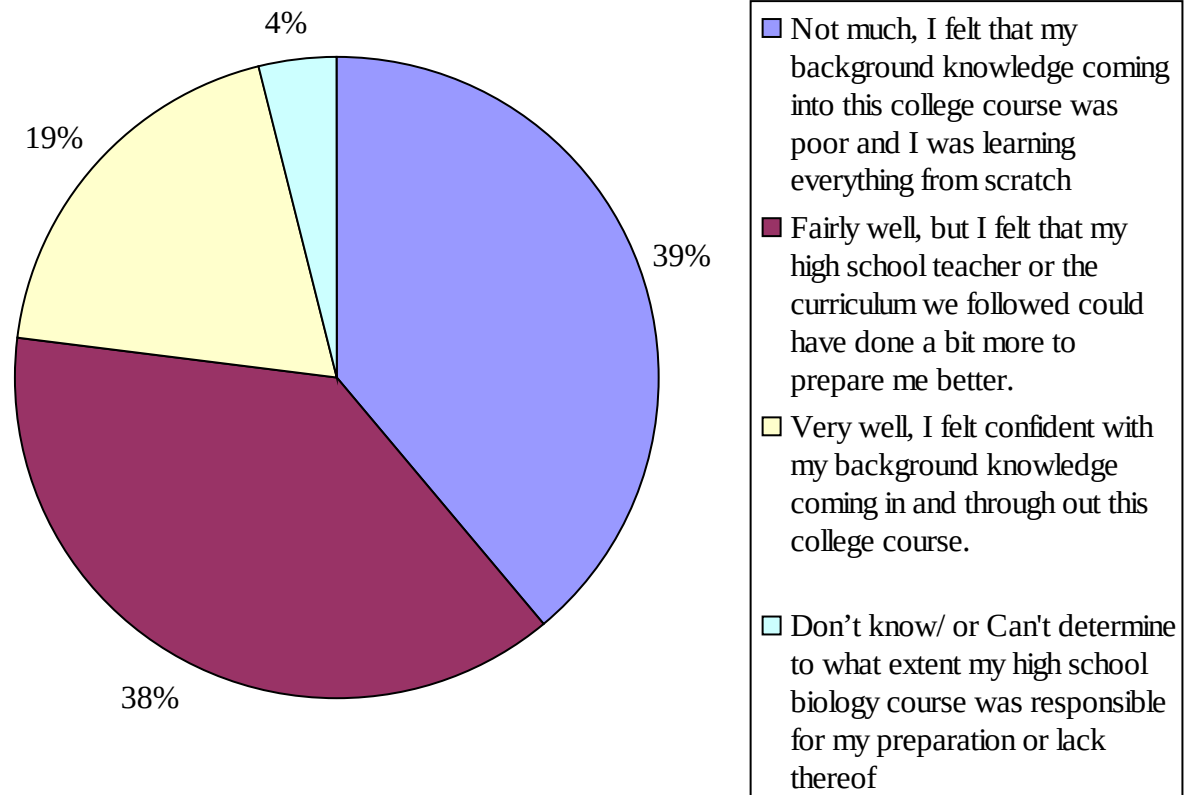


Figure 3. Results for the student exit poll question, answered online towards the end of their introductory biology course, (N= 1826).

High School Biology Teacher Online Questionnaire

The high school biology teacher online questionnaire was completed by 105 volunteers from online teaching communities and randomly selected high schools across the country.

One aspect of high school biology that might affect student preparation for college biology is whether the teacher focused on depth or breadth when covering topics. Of the group who completed the survey, 37% (39 teachers) said they focus mainly on breadth, 23% (24) on depth and 40% (42) try to find a balance between the two when teaching Biology I. While a question on this matter would have been too subjective to have students answer in their survey and it was therefore not possible to link this aspect to their performance, the response of professors about whether depth or breadth is more important in high school biology is interesting for comparison purposes and is discussed in the Professor Questionnaire section.

Another question on the survey looked at different teaching goals related to college preparedness and asked biology teachers how important these were to them. The summary statistics are shown below on Table 7. The means for all teaching goals are statistically different/ higher than "Somewhat important" at the 99% level, showing that on average, teachers consider all these teaching goals either "Important" or "Very Important". The highest mean, and therefore the goal teachers deem most important is "Providing students with skills for their everyday life". After that, "Helping students gain a solid background knowledge/ content for college biology" and "Helping students develop skills for Science college courses" are considered the most important.

Table 7

Total mean scores for Question 2 of the questionnaire which asked: “How important are the following teaching goals to you when teaching General Biology?” (0= not important at all, 1=of little importance, 2= somewhat important, 3= important, 4= very important), N=105, the number in parenthesis represents standard deviation.

Statement	Total Mean
1. Preparing students to meet school/ state requirements	3.06*** [1.03]
2. Preparing students for success in standardized tests	2.67*** [1.01]
3. Providing students with skills for their everyday life	3.48*** [0.84]
4. Helping students gain a solid background knowledge/ content for college biology	3.30*** [0.67]
5. Helping students develop skills for Science college courses	3.24** [0.73]

N.B. * indicates significance at the .1 level, ** at the .05 level, *** at the .01 level.

As illustrated on Figure 4 below, “Helping students gain a solid background knowledge/ content for college biology” is considered important or very important by 88% of the teachers. While 12% consider the goal only somewhat important and zero teachers believe that it was of little or no importance. Similarly, 87% said that “Helping students develop skills for college science courses” was either important or very important.

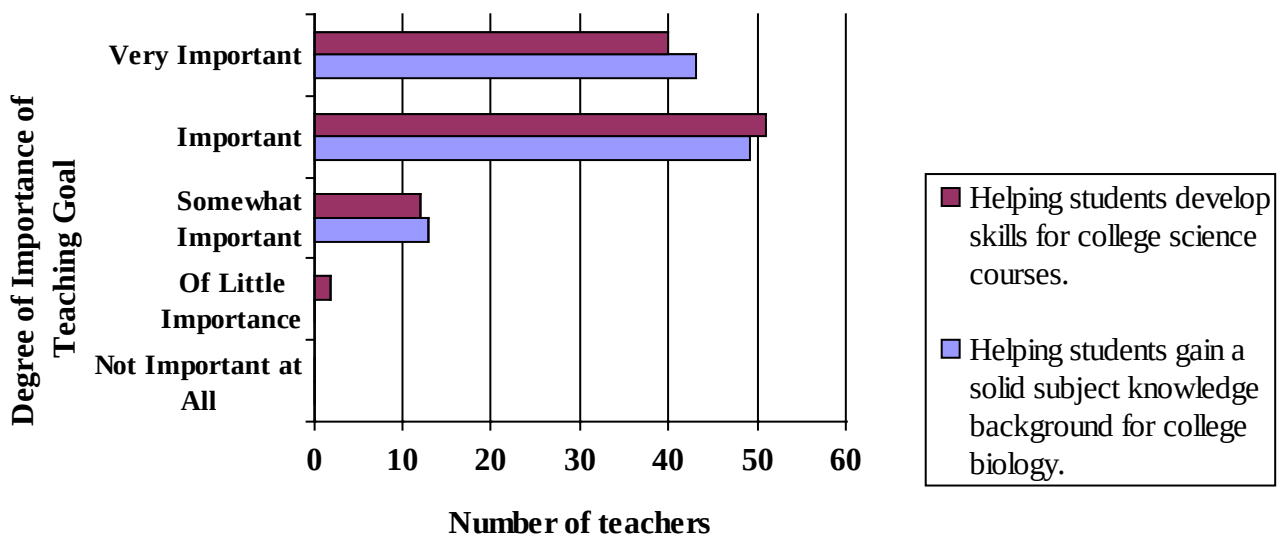


Figure 4. Degree of importance given by high school biology teachers to college preparedness teaching goals, (N= 105).

The high priority given to preparing students for college biology matched teacher perception of how well prepared their students would be for college upon leaving their course: 64% of teachers thought their average student is “Adequately Prepared” , 24% felt their average student is “Very prepared” and 12% that they are “Poorly prepared”. This part of the questionnaire could have been strengthened by asking more in depth questions about what teachers consider good preparation for college biology. Based on the additional comments given at the end of the questionnaire, it seems that teachers have very different ideas about what would constitute a good foundation for higher level biology. One teacher for example, said that “College professors teach you all you need to know, but a good foundation in research methods and general biology terminology is important.” Others found that more emphasis on skills like understanding experimental design, carrying out data analysis and being introduced to the type of lab equipment and

technology prevalent in college science would provide them the best foundation for success in higher level courses.

Given that many if not most secondary teachers and schools would consider an important goal of any subject to prepare their students for college, I was interested in finding out how many teachers and their students were involved in biology programs offered by local colleges or universities since this might help them understand what this goal should entail. Many of the teachers also commented on their survey that they would like the opportunity to work more closely with professors, for example, one said “I would appreciate dialogue with college biology professors to know what I can do to better prepare my students.” Results from the questionnaire showed that only about one third (34 out of 105 teachers) said either them or their students participate in some sort of university-run outreach program. Of those who said they did, less than half (12 out of 34) were actual partnerships in which there may have been some interaction/ communication with professors, the rest were teacher workshops offered by professional associations that just happened to be held at universities, stand alone public lectures on a specific biology topic that teachers might take their students to or campus tours. So we can conclude that only about 12 out of 105 teachers (11%) participate in a true partnership where there is the potential for information exchange/ communication with college faculty. Some examples given by teachers of their schools participating in university outreach programs or creating partnerships with local colleges were: having professors come to their classroom to do presentations and labs with students; inviting university graduate students as speakers come in to talk about their research twice a year and encouraging their students to participate in programs offered by neighboring higher education

institutions “geared towards tailoring interested high school students in the fields of engineering, science research, math, and technology”. One teacher also mentioned that their school offers biology courses in conjunction with their local college, in which “Students receive high school credit, as well as college credit and the curriculum is provided by college and comparable to AP Biology.”

With regards to specific content knowledge that would be useful to understand going into college biology, teachers were asked to provide the three key topics or concepts they want their students to leave their class understanding, those they consider the most important. Given this was an open-ended question, it was tallied with some liberty, using best judgment to group similar concepts together. Out of the concepts listed, the most frequently mentioned were: DNA and genetics (43 times), evolution and natural selection (42 times), ecology (42 times), and understanding the process of science and the impact of biology in the real world, and topics related to health and disease were mentioned over 20 times. All others listed (E.g. enzymes, protein synthesis, complexity of life and classification) were only mentioned once or twice.

It was interesting that several of the teachers made comments at the end of the questionnaire regarding the decreased emphasis they put on teaching biology content over critical thinking skills or appreciation for science in general. For example, one teacher said: “We are probably teaching more critical thinking skills but as far as content, we have watered it down to the point that often times topics get muddled [sic].” Another one reflected: “having them still be curious about science and well armed with the skills necessary to learn the material have taken more and more precedent over covering content for me the longer I teach and the more I realize what is most important.” For some, teaching content is a secondary priority, as one teacher said “I am big on kids learning how to be good students first and learning Biology second” and another pointed out “I want to make sure my students leave my class with an appreciation for

science [...] that they find joy in the study of science, they can “learn the details” in college.” On the other hand, there were many who are struggling in trying to cover as much content as possible, not by choice but by mandate. They expressed their frustration at being forced to cover a huge breadth of material in such a superficial and hectic manner, some of their comments are listed in Table 8 below.

Table 8.

Examples of high school teacher comments in the online questionnaire relating to the scope of the curriculum they teach.

Teacher 1	<i>“You will note my responses show high focus on standardized training for test prep rather than life skills or content background. I am NOT happy with my answers ... but they are honest. We are increasingly focused on "student achievement" over all other objectives.”</i>
Teacher 2	<i>“I do not believe that in NC our students are as prepared for college because of state mandated testing. Depending on the teacher...it seems that they usually are taught just the basics needed to pass the state test so that they can move on. We do not have the time to go into "detail" or if we do we do not have the time to cover the curriculum needed for the test. So we must choose.”</i>
Teacher 3	<i>“I am required to teach state standards as well as incorporate Texas mandated College Readiness Standards. The standards are broad and time constraints limit the amount of depth that can be addressed adequately. It is frustrating to say the least.”</i>
Teacher 4	<i>“Increasingly, the hands of educators are being tied by the districts which employ them... We are increasingly told what, how and when in regards to the concepts we teach.”</i>

Lastly, a major theme that emerged from the questionnaires was the idea that lack of tracking in the science classroom, i.e. “one class fits all” classes, may be doing students a disservice. Many of the teachers stated that one of the main reasons why they cannot put as much emphasis on college preparation is that “it is a huge challenge to prepare some for college, while at the same time teaching some with elementary level (and below) reading levels” or those who are

not college bound and have no interest in the subject. I thought one teacher in particular expressed this issue very well:

The United States must address the issue of mixed classrooms. Students should be tracked and placed in classes that will meet (their) future needs. Teachers are often forced to teach to the lowest levels of students, leaving behind the best and brightest of kids to boredom and mischief. This keeps teachers from addressing the educational needs of college bound students. They are under-prepared and pushed into a rut of mediocrity.

In general, the teacher questionnaire revealed that although the majority of high school biology teachers consider preparing students for college biology an important teaching goal in their introductory biology class, it is less so the earlier in high school it is offered and they face challenges that often cause this to become a much lower priority goal.

Interviews with High School Biology Teachers

The phone interviews provided more in-depth teacher perspectives about student readiness for college biology as they leave high school. Teachers have been given pseudonyms to maintain anonymity. Two of the teachers interviewed (teachers C and E) felt that their students would be well prepared for college level biology due to the broad nature of their courses and their focusing on understanding big ideas rather than discrete facts. This is a high priority teaching goal of theirs and they have gotten positive feedback from returning students about their preparation for college science courses. The other teacher I spoke to, teacher S felt that while this teacher's students would be adequately prepared for a laboratory course setting given the inquiry-based approach followed, they would be below average in terms of content knowledge. The main reason for this is that this teacher's course is taught at the 9th grade level, so the audience is much younger and therefore there is no emphasis on college preparation. The content is

thematic in nature rather than being a broad survey course, so there will be general biology concepts that they would not have covered.

Student motivation and family background are the factors with the greatest impact on student performance in these teacher's classes. Students who are self motivated, show curiosity and are able to see connections between what they are learning in class and their everyday lives are most likely to succeed academically. On the other hand, most of the students failing are those on free or reduced lunch, have parents who are unemployed or have family members in the military serving overseas. Many of these students don't have the opportunities (e.g. internet, time/ space to do homework properly), role models (many parents are uneducated) or support at home that they need to motivate them and help them push through in school in order to achieve their potential.

As mentioned earlier, the amount of emphasis teachers put on what they consider as preparation for college science seems to depend heavily on the year the course is taught and the type of students in the class. Becoming independent learners however, is something they all emphasize as well as developing subject specific skills such as how to analyze data, read scientific articles and think critically. They believe that this will help them greatly when they get to college. In terms of content covered, it depends on the curriculum determined by the school, district or state. Some high school biology courses that have more flexibility are based entirely around four to six big ideas, which are taught in depth. Teacher C for example listed their major themes as: "Container, Energy, Continuity and Evolution". Others like teacher E try to follow the National Standards on top of teaching what has traditionally been mandated by their district, essentially covering many topics in less depth or base their curriculum on that of a survey type local

community college course. Regardless of the scope of topics they chose to teach or is required of them, the teachers interviewed considered: evolution, cells, molecular biology and the scientific process as the most important topics they want their students to take away from their course.

They also shared some ideas about ways in which the transfer of content knowledge between high school and college biology could be improved. For example, that “it would be a good idea for teachers to connect with local colleges and participate in outreach programs, since most universities offer them,” that students should “practice data analysis often and get more lab experience,” and “teachers should talk among them more in order to establish common ground regarding what students should know, especially around sticky subjects like evolution and human reproduction.” Students can improve their preparation for college science by doing their homework regularly, listening to teacher feedback and acting on it, attending every lesson. For example, teacher C said that “both kids and parents should make school number one priority.” Additionally, students should focus on developing and practicing study skills. All three teachers interviewed agreed that colleges could provide more outreach programs to connect high school teachers with college faculty enabling collaboration between them or advertise those available better, and it was also suggested that professors be more aware of the National Standards so they can adjust their expectations of incoming students accordingly.

Biology Professor Online Questionnaire

Thirty three professors of introductory level biology courses completed the online questionnaire. About half were professors whose classes participated in the student

survey while the other half were recruited through announcements on biology teacher association newsletters. The main goal of the questionnaire was to determine how professors felt about student preparation coming into their courses. Figure 5 below shows that more than two thirds of biology professors feel that high school graduates are not well prepared for college biology.

Do you feel that the majority of high school graduates are well prepared to tackle college level biology?

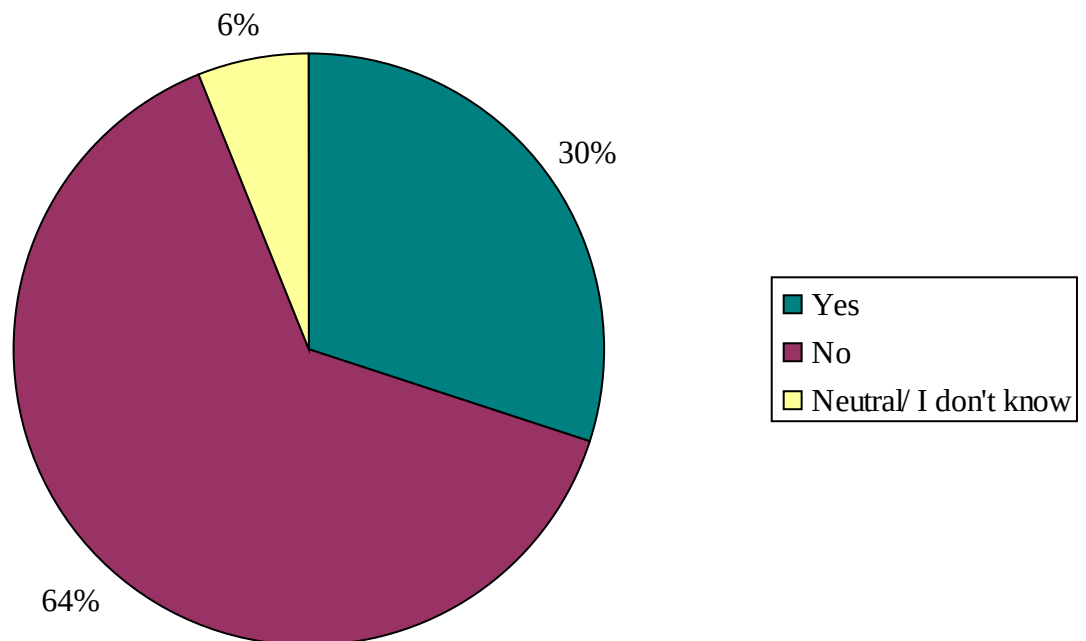


Figure 5. Biology professor opinion regarding student readiness for college biology, (N= 33).

Professors were asked about the expectations they have of incoming students in terms of biology background knowledge. The responses they gave varied widely. About half of the group said they expected no prior content knowledge at all, the other half said they expected only very basic chemistry or biology knowledge. Other responses included:

understanding basic scientific terms (such as “pH, reacts, forms, product, etc”), understanding that organisms are made of the same elements that make up the universe and being “able to write about life in complete sentences.” When asked specifically what three topics would be most valuable for students to understand coming into their class, the topics that were mentioned most frequently were: cellular biology, evolution and genetics. These are very much aligned with the topics deemed most important by the high school teachers who took the online survey and/ or were interviewed.

In terms of skills, professors again had very different expectations of students among them, from no expectations (about half of the group did not expect students to come in with any type of subject-specific skill) to higher level skills like ability to carry out chemical calculations. Many of the professors surveyed agreed that the problem of inadequate student preparation stems less from a lack of subject-specific skills and more from the fact that students are getting to college lacking basic literacy skills, as one of them commented: “A bigger problem is when students have difficulty learning what I teach because of poor study, math, and reading skills. We are finding that we need to teach these in order to help the students learn biology.” Other expectations mentioned included: statistics, unit conversions; lab skills (from taking measurements with rulers, scales and measuring cylinders to using microscopes, pipettes, pH meters, spectrophotometers); study skills; higher level writing skills; tackling comprehension-based questions; being open to new ideas; making and interpreting graphs, and being proficient with the computer.

Several of the professors felt that students’ preparation for college biology is inadequate mainly because they do not know how to assimilate information. One felt that

“students struggle most because they don't seem to know HOW to learn!” and when they get to college biology “instead of leaning continuously and trying to store the knowledge in their long-term memory and being able to actively recall it, students clearly learn only just before exams and passive, meaning they can answer multiple choice questions, but can't formulate answers actively.” Other professors attribute this mainly to an emphasis in high school science on memorizing facts rather than understanding, two examples follow:

Most bright students can get through high school biology by memorizing, but it comes as a big shock when that doesn't work in college.

A very important step in improving high school biology in transition to college (and in most college settings in general) would be to move away from rote memorization of hoards of facts and toward 1) scientific inquiry and 2) fundamental background concepts as a scaffold onto which the details can be subsequently tacked. If a student can cram for one night, memorize the list of facts for one exam, and forget them before they come to my university classroom, I will have to reteach.

Some of the professors who had no expectations of incoming students in terms of skills and/ or content knowledge explained that the variability between their students' high school experience is the reason why it is unrealistic to have high expectations of them. As one professor put it: “The major issue is that the students in my class have had very different high school experiences... This means I have to teach the course based on no background knowledge.” Some factors that were mentioned as contributing to this variability in student preparedness were: differences in geographic location of schools (rural, urban, etc.); availability of supplies and equipment (i.e. limited budgets); range of high school teacher competence; conservative nature of some communities limiting the teaching of certain topics like evolution; availability of AP classes and diverse secondary

education standards between states. Many also assume that their students will have taken biology early in high school and therefore probably not retained too much information.

The questionnaire also asked how strongly they agreed or disagreed with a series of statements about the transition between high school and college biology. For analysis purposes, the Likert scale responses were converted to scores from 0 to 4 (0= strongly disagree and 4= strongly agree). Table 9 below provides a summary of the mean and standard deviation for the responses to these statements. The results indicate that the average professor will probably disagree with the statement that “most students come to entry level biology courses with adequate basic biology knowledge” or remain neutral about it.

Table 9

Total mean scores for Question 3 of the professor questionnaire which asked: “How strongly do you agree with the following statements?” (0= strongly disagree, 1=disagree, 2= neutral, 3= agree, 4= strongly agree), N=33, the numbers in parenthesis represent standard deviation.

Statement	Total Mean
1. Most students come to entry level Biology courses with adequate basic Biology knowledge	1.64* [1.17]
2. Introductory biology courses in college re-teach basic concepts of high school Biology because students are lacking the background knowledge.	2.76*** [1.23]
3. Some high school biology is needed to prepare students for college-level Biology courses	2.61** [0.23]
4. In my introductory biology course, I focus on depth rather than breadth	1.70* [0.95]
5. High school biology should focus on depth rather than breadth	1.42*** [1.03]

N.B. * indicates significance at the .1 level, ** at the .05 level, *** at the .01 level

Twenty two of the professors (66%) agreed or strongly agreed with the statement “introductory biology courses in college re-teach basic concepts of high school Biology because students are lacking the background knowledge”, while only 6 (18%) disagreed or strongly disagreed. There was also a high agreement rate (66%) regarding the need for some biology in high school to prepare students for college biology, though I was surprised to find that as many as seven (21%) of the professors disagreed or strongly disagreed with this statement (Figure 6).

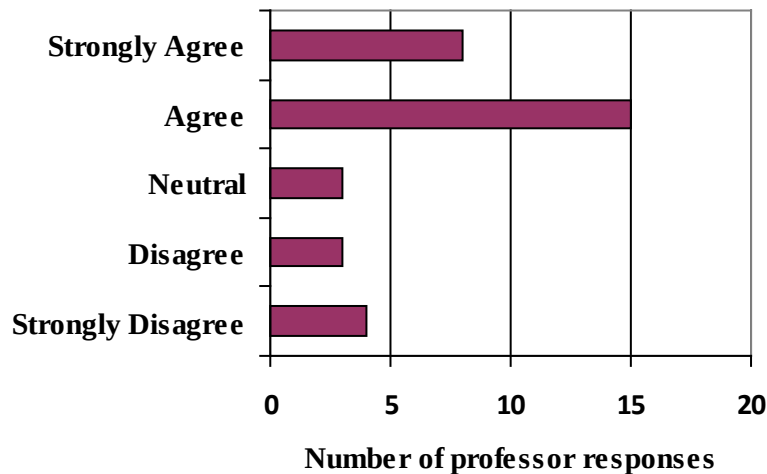


Figure 6. Responses to the statement: “Some high school biology is needed to prepare students for college level biology course,” (N= 33).

Regarding the nature of the high school biology course, as illustrated in Figure 7, only 18% agreed or strongly agreed with a focus on depth rather than breadth, while 63% disagreed or strongly disagreed.

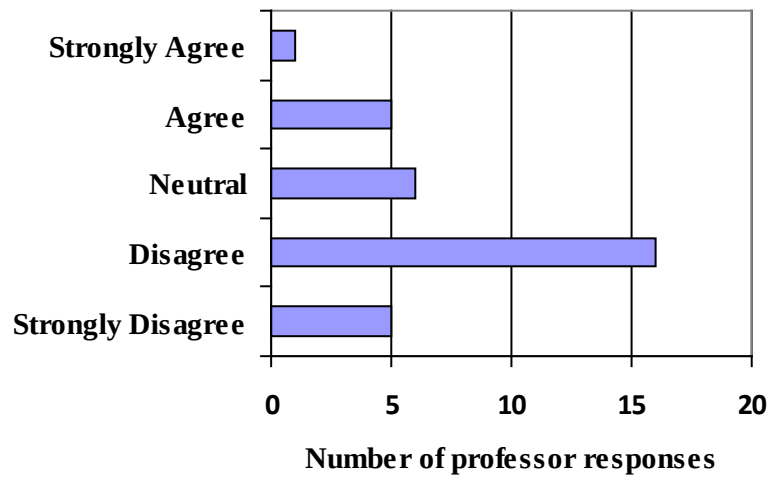


Figure 7. Responses to the statement: “High school biology should focus on depth rather than breadth” in the professor questionnaire, (N= 33).

This suggests that the majority of introductory biology professors believe a survey type course in high school would be better preparation than one which focuses on covering fewer, more in depth topics. This seems to match the focus of their own courses, as results suggest that almost half of all introductory biology courses are broad survey type courses. It is illustrated in the fact that 45% of professors disagreed to some degree with the statement that they focus mainly on depth over breadth, 15% agree that they focus mainly on depth and 39% remained neutral (which suggests that they probably focus equally on breadth and depth). Whether or not survey courses are more effective in a constructivist approach towards learning and student progression through the different levels of biology courses has been the subject of other studies (Schwartz et al, 2008) it is important to note that the data here speaks only to the professors’ perspective of how high school biology could prepare students better for their introductory course.

Interviews with College Biology Professors

Three biology professors were interviewed to gain a deeper understanding of their thoughts regarding the high school to college gap. Two of them felt that the degree to which students were prepared for their course varied greatly, while the other one felt that in general they were not well prepared at all. The better prepared students come fresh out of higher level courses such as AP Biology, they are self-motivated and ready to work hard. Others know they have an interest in biology, or are required to take the course because of their major but don't have a solid background. They may have taken one biology class a few years before as thus forgotten most of what they learned, or may have taken one recently but not put enough time into the subject and gotten by as Professor T (professors have been given a letter to maintain anonymity) put it, "with no skills except cramming". Many also come in with poor reading comprehension and unable to handle the level of the material presented, or they are unorganized and not ready for the rigor of college courses. Professor M felt these underprepared students "are not able to start off strong, they get overwhelmed within a few weeks and drop out of the course and major.

All three professors agreed that students' high school experience is a key factor on how successful they are in entry level science courses. Students who have not been challenged enough in high school, lack study skills or are not organized will have a hard time adjusting to the rigor of college science. Professor M also pointed out that "students who have been exposed to more scientific terminology in high school are the most successful as the words aren't quite as foreign to them when they get to university" as are those who are able to identify and apply key concepts. Other factors mentioned by the interviewees that affect student performance in introductory biology were attendance,

coming prepared to class, organization, how they manage their social growth and being away from home in general.

Two of the three professors interviewed (M and T) replied that although they do expect students to know basic biology vocabulary, they consider more important that students come to their course understanding science as a process rather than a body of knowledge, and that they have solid fundamental skills. As Professor M said, “we are losing students before we get into the biology aspect of the course, we’re losing them in the chemistry and math, things like that”. It is important that they are able to analyze a basic set of data, know how to create and interpret graphs, understand what the roots of key biology terms mean, and have a grasp of scale and the metric system when they start their course. Professor R identified concepts such as purpose and results of cell division, basic genetics, evolution by natural selection, food webs and biogeochemical cycles as the most important for students to understand coming into an introductory biology course. This professor expressed disbelief at the fact that many college students do not know what fossil fuels are, where they come from and how they produce energy; or that they do not know what a herbivore is. On the other hand this professor is not interested in students knowing things like the steps of mitosis or the names of the bones when they come in. It is important to note however, that none of the professors interviewed or their department gives their students a pre-test when they start their course to find out exactly what they know about biology or how strong their subject related skills are, they mainly go by assumptions given their prior experience with other groups of students.

Many universities have strategies in place to help freshmen transition into college science, such as providing student tutors (who have taken the given course and excelled,

thus being familiar with not only the material but also the professor's teaching style and expectations) and offering study skills courses (Beltzer et al. 2003; Wischusen & Wischusen, 2007). Professor R teaches in a department where classes are kept small and labs taught by the professors themselves, allowing them to interact and support students more directly. There are professors like T who dedicate time during lecture to go through study skills and exam taking strategies and others who require their students to keep a time management log including a study schedule to help them learn how to organize their time outside class more efficiently. Many universities, as mentioned in some of the literature I reviewed, are taking advantage of computer tools to help their students prepare for college courses (Beltzer et al. 2003; Wischusen & Wischusen, 2007; Marbach et al. 2006). Professor M is deeply involved in this area: "we are moving towards digital modules on key topics that students can work on before starting the introductory biology course, putting more of the burden on students to catch up what they should have learned in high school". Another way this professor mentioned for getting students up to speed on concepts they are expected to understand beforehand is to provide "10 minute virtual mini-lectures" before class for them to prepare.

To improve the transfer of content knowledge between high school and college, professors suggested universities keep classes small in order to be able to monitor student learning more closely and have a lab component, emphasizing the importance of solid study skills throughout the semester and providing more outreach programs for bringing high school teachers to campus for workshops (as well as getting them resources for use in their classrooms). Professor R emphasized that high schools should require more reading from students outside of class and "focus on the process of learning and on

overarching concepts”. Challenging students more by asking questions that require deeper thinking, providing them with the opportunity to become self-directed learners and teaching them study and subject specific skills like experimental design would also help improve the transition. They also suggest students can be more successful in introductory courses by going over material numerous times including with peers and professor, realizing that college courses require more work outside of class than high school ones did, attending all classes, closing the loop by listening to feedback from their professors and acting on it, and making use of the support system that is available to them.

CONCLUSIONS

The aim of this study was to highlight the disconnect that exists between the secondary and post-secondary education biology experience, adding to existing longitudinal data for similar gaps in physics and chemistry education. Evidence gathered from my research suggests that the level of student preparation for introductory level college biology in terms of background knowledge is inadequate. This claim is based primarily on student performance on the content test I used and the comments of their biology professors. Overall students scored very poorly on the content test (the mean for the sixteen multiple choice questions is 33% and only 10% of students got the free response question right). However, what is particularly worrying is that there is no statistical difference in scores on the multiple choice questions between students who had taken only Biology 1 in high school (when it was taken during freshman, sophomore or junior year) and those who hadn’t taken any biology (see Tables 3 and 4). Even students

who took biology as seniors only scored marginally higher than those who did not take any (Table 4). This in turn suggests that Biology 1 may not be enough for producing students who will retain any significant amount of biology content by the time they get to college. Perhaps this is why as many as 21% of the professors interviewed disagreed or strongly disagreed with the statement that some high school biology is needed to prepare students for college biology (see Figure 6) However, although my data does not speak directly to student final grade on the introductory biology courses, past literature has shown that students' background knowledge and ability to apply concepts that were covered in high school courses had a strong impact on their success in freshman biology courses (Marbach-Ad, 2006; Beltzer et al 2003; Gibson & Gibson, 1993; Odom, 1995; Uno, 1988). High school biology has the potential to be an excellent primer for college life science courses and should be treated as such at both the secondary and post secondary levels, taking measures to ensure that students who are interested in the subject and considering higher education get the most adequate skills and a solid content knowledge to help them with the transition.

Findings from this project suggest that there are four main factors that may be contributing to the decline of high school biology as a potential foundation for college biology in terms of content taught and consequently retained by students:

1. *The year biology was taken in high school.* Having taken a biology class the last year of high school for example, has a strong positive impact on student scores on the pretest, while having taken only one class as freshmen had a strong, negative impact. The year biology was last taken contributes to student readiness for college biology content directly because they will retain more subject knowledge

the more recently they have used it, but also indirectly in that students who take biology later in high school will be more geared at that stage towards thinking about and preparing for college while in earlier grades the emphasis is on getting students to be interested in the natural world and learn about the scientific process. On the other hand, taking biology as freshmen allows for more time to take other biology courses including electives and higher level classes, which also had a strong effect on student performance in the pretest.

2. *Scope and depth of biology content covered.* The study did not provide clear evidence regarding which depth to breadth approach would be more effective for helping students transitioning into college biology. Although data from professor questionnaires and interviews suggest that more of them feel a broader approach in high school biology (more topics covered in less depth) would provide better preparation for their courses than a “depth over breadth” approach, many of their comments seemed to contradict this belief. In turn, teachers who are expected to teach many topics in one year due to state mandates or preparing students for standardized tests expressed frustration about it and say students learn little more than a list of disconnected facts that they will quickly forget. Those who have the choice, prefer teaching a few overarching ideas in depth, so that students really understand the principles behind them and learn how to apply the material.
3. *Lack of tracking in science classes.* Some of the high school teachers and professors agreed that the lack of tracking might be another reason why many students get to college science unprepared. Having a drastic range in abilities within one group makes it challenging to prepare all students for college when

many in the class have low reading levels for example and teachers are forced to teach to the lowest denominator. Moving away from the idea that “one class fits all” (call it tracking or something else) is an issue that needs to be re-addressed and re-evaluated by the education system as soon as possible, because as it stands, many children are indeed being left either because they are not getting the support they need or not being given the opportunity to excel and achieve their full potential.

4. *Misalignment of student expectations.* The results showed that perceptions of secondary and post-secondary biology educators of how well prepared their students are for college biology are misaligned, as are their expectations of students. While more than the majority of professors said that students introductory biology are not adequately prepared to tackle the course, about the same percentage of high school teachers believe their students are. While high school teachers are more concerned with students leaving their course with critical thinking skills and appreciation for science, professors are divided between those who have high expectations including these skills and a solid content knowledge, and those who have no expectations whatsoever of their incoming students. A lack of communication between secondary and post-secondary educators is the main reason why expectations of students are misaligned.

The purpose of this study was not to assign blame to the problem of students being underprepared for college biology, but to raise awareness of the extent to which this gap between secondary and post-secondary biology exists across the country and of

some of the contributing factors. Better understanding of this issue will help to decrease this gap and make transfer of subject knowledge and skills more effective. Perhaps the most significant measure that could be taken to help students transition into college biology would be to increase vertical communication between high school and college faculty, who agreed about this. It is an unfortunate reality that most often, high school teachers are limited by the year in which biology is taught, the mixed abilities in their class and a dictated common curriculum. Therefore even if a true partnership with a local higher education institution is developed, they will still not have complete say in what they teach and how, but it is a step forward and would at least provide them with a better understanding of what is expected of students in freshman level biology courses. They could learn for example which are the topics students struggle with the most in when they get to college and try to focus more on them to create a more solid foundation for students (this study identified evolution, metabolism, molecular biology and ecology as being the topics students were weakest in, but further research might identify more and specific concepts they have difficulty understanding). Professors might also suggest more emphasis on skills (such as scientific process skills, math, chemistry, reading and writing skills as applied to scientific context) and could offer ideas for how to teach these more effectively. While there don't seem to be enough university outreach programs for connecting high school and university biology educators, high school teachers should seek out and take advantage of those in their local colleges or propose some form of collaboration, even virtual for example, if there is not already a program in place. On the other hand university faculty would become more aware of the K-12 standards. This is not to suggest they should adjust their instruction to the K-12 standards, but rather that it

would help them determine the level and amount of background knowledge they can hold the students accountable for. This could serve as a reference point to formulate pre-tests at the start of the semester in order to find out how much that specific group of students have retained from high school and misconceptions they carried out rather than base their teaching on assumptions. Consequently, pretests would help determine which students would benefit from tutoring services, digital review modules or other programs that would put more of the responsibility of catching up on students rather than professors. This type of support would decrease the variability among the class resulting from very different high school experiences.

To conclude, increased communication and collaboration between all parties involved (high school teachers, college professors and their students) would mean teachers could incorporate more clear goals regarding college preparation into their syllabus and professors would be able to build on student knowledge and teach higher level applications rather than re-teaching basic high school biology concepts. This might lead not only to a higher retention of biology majors, but also a greater number of students going into specialized fields or graduate programs and to increasing biology literacy overall.

OPPORTUNITIES FOR FURTHER RESEARCH

Instruments for further research in the topic of transition between high school and college biology could be improved by adding more content questions to the student pre-course survey, including additional open-ended ones as well as some designed to test subject specific skill. In addition, it would be interesting to determine what percentage of

the variance in final lecture grade could be attributed to variation in student performance on the pretest I designed by collecting pass/ fail data. Student interviews at the end of introductory biology courses could provide greater insight into what topics they felt least prepared in and whether they took advantage of any support systems available to them. They would also serve to gather additional information about other aspects of their high school biology experience that may have affected their performance.

The implementation of the new content standards will provide a great opportunity to examine whether any improvement can be made in terms of college preparation when the focus of high school biology shifts from factual knowledge to overarching core ideas and there is more emphasis on effective content progression K-12. It would also be interesting and potentially inspiring to contrast the mechanics of this transition from high school to college biology in other countries, particularly those with the highest proportions of biological science graduates and highest levels in math and science.

Although there are a number of studies that look at the effects of university transition programs (e.g. biology “boot camps”, online seminars, digital review material, skills workshops) on student performance in introductory biology, it would be of great value to do a longitudinal study comparing and contrasting their effectiveness. Similarly, more research needs to be done on the types of university outreach programs available to high school biology teachers and their students and how they relate to college preparedness. It would be interesting to look into the make-up of teachers taking advantage of these programs, what percentage of the local teaching community they serve and factors that may affect participation such as funding, advertising and time restraints.

As I mentioned earlier, there is significantly less literature on the transition between high school and college biology than there is regarding chemistry and physics education. I merely skimmed the surface of the issue, there is much more work to be done to understand and address this gap, hopefully preventing comments like “Proteins carry genetic information just as nucleic acids. Truthfully I have no idea. That’s why I want to be a Chemist!!!” from introductory biology students.

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APPENDICES

APPENDIX A

PRE-COURSE STUDENT SURVEY

63
Appendix A:
Pre-Course Student Survey

Pre-course Student Survey

You must be 18 or over to participate in this study, if you are not, please exit the survey by closing the window.

This questionnaire consists of **22 questions** and should only take between 5 and 15 minutes to complete.

This research study is being carried out by a graduate student at Montana State University and not linked to your professor or university in any way. Your decision to participate or not will not affect your current or future relations with the institution you are enrolled in.

Participation is strictly voluntary; you can leave the survey at any point by simply closing the window. Please be as honest as possible when answering the questions and if you don't know an answer give it your best guess. Your answers will not be recorded anywhere until you press the "Submit" button at the end of the survey, in which case they will only be accessed by members of the research team at Montana State University.

The results will be used to gain a clearer understanding of the transition between high school and college Biology. By participating in this study, you could be helping future students be better prepared for college biology courses. This study poses no additional risks to you other than those experienced in everyday life.

All answers are completely anonymous, there are no identifiers linking them to you.

If you have any questions at this point, please email me, the researcher: Marta Toran (martatoran@gmail.com). If you have any concerns and would like to reach someone other than the researcher, please contact Dr. Eric Brunsell (brunsele@uwosh.edu) or Dr. Mark Quinn (mquinn@montana.edu) Chairperson for MSU's Institutional Review Board, before proceeding with the survey.

By clicking the "Submit" button at the end of the survey, you are acknowledging that you are 18 years or older and have freely chosen to participate in this survey after reading these directions. You also agree to give the researcher permission to use and disclose the anonymous results. This will be in the form of a Master's project and potentially as an article in a peer-reviewed educational journal.

Thank you very much for your time!

Marta Toran
Montana State University

* Required

1. Have you taken any other Biology classes in college before the one you are taking now? (If so, please indicate the course title)

- ☐ No.
- ☐ Yes _____

2. What is the HIGHEST level of Biology you completed in high school? *

- ☐ Biology I/ Introductory Biology
- ☐ Biology II
- ☐ AP Biology/ Honors Biology
- ☐ IB Biology
- ☐ Other: _____
- ☐ I didn't take Biology in high school

3. When did you take your LAST Biology course in high school? *

- ☐ Freshman Year/ Gr.9
- ☐ Sophomore Year/ Gr. 10
- ☐ Junior Year/ Gr. 11
- ☐ Senior Year/ Gr. 12
- ☐ I didn't take Biology in high school

4. What was your last Biology class mainly focused on? *

- ☐ Mainly understanding
- ☐ Mainly memorization
- ☐ An more or less even combination of understanding and memorization

5. How confident are you about your Biology background? *

- ☐ Very confident, I feel well prepared for this college biology course
 - ☐ Fairly confident, I will probably be prepared for this college biology course
 - ☐ Not very confident, not sure how prepared I will be for this college biology course
 - ☐ Not confident at all, I think I might struggle with this college biology course
-

6. All matter is made of particles. Which of the following shows components of the human body, arranged from SMALLEST to LARGEST?

- A. Cells, atoms, molecules, organs
- B. Atoms, molecules, cells, organs
- C. Atoms, cells, molecules, organs
- D. Molecules, atoms, organs, cells
- E. None of the above, the human body does not contain atoms.

7. Which of these helps chloroplasts and mitochondria function more efficiently?

- A. enzymes
- B. hormones
- C. increased membrane surface area
- D. enzymes, increased membrane surface area
- E. enzymes, hormones, increased membrane surface area

8. Which of these is an organism made up of cells that do not have a nucleus? *

- A. Wheat
- B. Yeast
- C. *E. coli*
- D. Red blood cell
- E. Two of the above

9. In a grassland ecosystem, which of these populations would be LEAST affected by competition?

- A. mouse
- B. deer
- C. snail
- D. rabbit
- E. sheep

10. What process is responsible for obtaining the energy from food in humans? *

- A. absorption
- B. digestion
- C. photosynthesis
- D. respiration
- E. chemosynthesis

11. Which of these statements is TRUE?

Organisms need energy, cells don't; they just produce it.

A human can get more energy from a molecule of glucose than a mouse can, because humans are more efficient.

Humans, lizards and amoeba can all get energy from proteins.

The only molecules that humans get energy from are carbohydrates, the rest are needed for other functions like building muscles and providing insulation.

Two of the above statements are correct.

12. Which of these cells is the product of meiosis, in which the number of chromosomes gets halved? *

- A. white blood cell
- B. neuron
- C. muscle cell
- D. sperm cell
- E. they all are

13. A specific gene...

- A. can code for several proteins
- B. can code for a protein or a lipid
- C. codes for a specific amino acid
- D. codes for different proteins depending on what species it is found in
- E. codes for the same protein in any species

14. The process by which pieces of chromosomes break off and rejoin during cell division can lead to severe genetic disorders. Are there any benefits to chromosome breakage and rejoining?

- A. no, any chromosome breakage or rejoining will cause disorders
- B. although chromosome breakage and rejoining does not always lead to disorders, it is never beneficial
- C. chromosome breakage and rejoining can increase a species' chances of survival
- D. chromosome breakage and rejoining is needed for fertilization
- E. chromosome breakage and rejoining is needed to make egg and sperm cells

15. A couple has two children. The boy resembles the dad and the girl looks very much like the mom. What is the most likely explanation for this?

- A. Boys tend to get more genes from their dad and girls more from their mom.
- B. Boys usually express more strongly the genes received from their dad and girls usually express more strongly genes from their mom.
- C. Children always get more genes from one of the parents, which is why they look more like one than the other.
- D. Which child received specific dominant genes happened by chance.
- E. Two of the above are the correct explanations.

16. Could photosynthesis take place in the absence (without) of carbon dioxide? *

- A. Yes; carbon dioxide is not needed for photosynthesis, it is a waste product
- B. Yes; carbon dioxide is only needed in respiration.
- C. No; carbon dioxide is needed to make glucose.
- D. No; carbon dioxide is needed to provide the energy for photosynthesis to happen.
- E. It depends if there is light or not, because carbon dioxide is needed to absorb the sunlight energy.

17. Which of these reflects natural selection?

- A. Individuals pass along to their offspring beneficial adaptations they acquire during their lifetime.
- B. An individual of a rabbit species adapts to a new environment by shedding its fur when it is warm out.
- C. A population of cuckoos lays eggs that imitate other species' eggs
- D. A population of salamanders gets divided geographically and becomes two separate species
- E. All of the above

18. There are several chemicals in cigarette smoke that can cause mutations in lung cells and lead to lung cancer. If a woman with lung cancer has a baby, which of the following will be TRUE about the child?

- A. The child's lung cells will not be affected by the mother's lung cancer
- B. The child will not be born with lung cancer, but will be much more likely to develop it later in life than the average person
- C. The child's lung cells will show the same mutations at birth but will not necessarily develop lung cancer
- D. The child will only have lung cancer if the father also has the disease
- E. The child will also be born with early stages of lung cancer

19. A patient has swollen hands and feet. He seems to be retaining fluids and a blood test reveals high levels of amino acids and salts. Which organ is most likely failing, therefore resulting in these symptoms? *

- A. liver
- B. heart
- C. kidney
- D. pancreas
- E. spleen

20. Where do most food molecules enter the bloodstream? *

- A. through the stomach wall
- B. through the colon
- C. through the liver
- D. through the small intestine
- E. through the gall bladder

21. Which of these mechanisms are used by the nervous system to send signals around the body? *

- A. chemicals are sent from one nerve cell to the next
- B. electrical signals travel through nerve cells
- C. nerve cells are physically connected to each other and pass along signals in the form of electricity
- D. A, B
- E. A, B, C

22. Explain the connection between proteins and nucleic acids in three sentences or less (in your own words) *

APPENDIX B:

POST-COURSE STUDENT SURVEY (EXIT POLL)

Appendix B
Post-Course Student Survey (Exit Poll)

Post-course Student Survey

To answer this poll question you must be 18 or older and should be about to complete your FIRST biology course in college. If this was NOT the first biology class you've taken in college, please exit the survey by closing the window.

There is only 1 question to answer, it should just take you a few seconds.

This poll is part of a research study by a graduate student at Montana State University and not linked to your professor, university or high school in any way. Your decision to participate or not will not affect your current or future relations with the institution you are enrolled in or any others.

Participation is strictly voluntary; you can leave the survey at any point by simply closing the window. Please be as honest as possible when answering the question. Your answer will not be recorded anywhere until you press the "Submit" button at the end, and will only be accessed by members of the research team at Montana State University.

The results will be used to gain a clearer understanding of the transition between high school and college Biology. By participating in this study, you could be helping future students be better prepared for college biology courses. This study poses no additional risks to you other than those experienced in everyday life.

All answers are completely anonymous, there are no identifiers linking them to you.

If you have any questions at this point, please email me, the researcher: Marta Toran (martatoran@gmail.com). If you have any concerns and would like to reach someone other than the researcher, please contact Dr. Eric Brunsell (brunsele@uwosh.edu) or Dr. Mark Quinn (mquinn@montana.edu) Chairperson for MSU's Institutional Review Board, before proceeding with the survey.

By clicking the "Submit" button at the end of the survey, you are acknowledging that you are 18 years or older, taking your first biology class in college and have freely chosen to participate in this survey after reading these directions. You also agree to give the researcher permission to use and disclose the anonymous results. This will be in the form of a Master's project and potentially as an article in a peer-reviewed educational journal.

Thank you very much for your time!

Marta Toran
Montana State University

How well did your HIGH SCHOOL BIOLOGY course/s prepare you for the Biology course you took in college this semester?

- ☐ Very well, I felt confident with my background knowledge coming in and through out this college course
- ☐ Fairly well, but I felt that my high school teacher or curriculum we followed could have done a bit more to prepare me better.
- ☐ Not much, I felt that my background knowledge coming into this college course was poor and I was learning everything from scratch.
- ☐ Don't know/ or Can't determine to what extent my high school biology course was responsible for my preparation or lack thereof.
- ☐ I didn't take biology in high school

APPENDIX C:

INTERVIEW QUESTIONS FOR COLLEGE PROFESSORS

Appendix C:
Interview Questions for College Professors

Before the interview, participants will be read the statement that follows about what their participation and the research study entails:

“Thank you for agreeing to participate in this research study. You will be asked five questions about student preparation leaving high school biology and entering college biology courses. The purpose of the study is to gain a better understanding into this transition. Your participation is strictly voluntary and you are free to withdraw at any point of the interview or chose not to answer a question. All personal and identifying information will be kept confidential to only the researcher. This research study is in no way linked to your institution. By participating in this interview you are granting the researcher permission to use your answers and divulge the results for the sole purpose of this research study without using any identifiers. The interview should only take 10 or 15 minutes. If you have understood the information presented to you and still wish to participate, please say “Yes”.”

BIOLOGY PROFESSORS:

1. How well prepared do you think high school graduates are for tackling Biology courses in college?(In terms of content knowledge, understanding biology concepts and subject-related skills)
2. What factors have the greatest impact on student performance in entry -level college Biology courses?
3. Which topics/ concepts, do you think are the most important for students to understand coming into college Biology?
4. What strategies are in place in your classroom or university as a whole to help students transition into college Science courses?
5. What can the following parties do to improve the transfer of subject knowledge between high school and college biology...
 - ...High schools?
 - ...Students?
 - ...Colleges?

APPENDIX D:

INTERVIEW QUESTIONS FOR HIGH SCHOOL TEACHERS

Appendix D:
Interview Questions for High School Teachers

Before the interview, participants will be read the statement that follows about what their participation and the research study entails:

“Thank you for agreeing to participate in this research study. You will be asked five questions about student preparation leaving high school biology and entering college biology courses. The purpose of the study is to gain a better understanding into this transition. Your participation is strictly voluntary and you are free to withdraw at any point of the interview or chose not to answer a question. All personal and identifying information will be kept confidential to only the researcher. This research study is in no way linked to your institution. By participating in this interview you are granting the researcher permission to use your answers and divulge the results for the sole purpose of this research study without using any identifiers. The interview should only take 10 or 15 minutes. If you have understood the information presented to you and still wish to participate, please say “Yes”.”

1. How prepared do you think the average student will be upon leaving your course for introductory level biology courses in college?(In terms of content knowledge, understanding biological concepts and subject-related skills)
2. What factors have the greatest impact on student performance in your class?
3. How much emphasis do you put on preparing students for college Science courses in terms of topics, coverage, study skills, etc?
4. What biology topics/ concepts do you consider the most important; the ones you definitely want your students to take away from your class?
5. What can the following parties do to improve the transfer of subject knowledge between high school and college biology...
 - ...High schools?
 - ...Students?
 - ...Colleges?

APPENDIX E:

ONLINE QUESTIONNAIRE FOR COLLEGE BIOLOGY PROFESSORS

Appendix E:
Online Questionnaire for College Biology Professors

Questionnaire for Biology Professors Teaching Introductory Biology Courses

This questionnaire consists of 5 questions and should only take a few minutes to complete. It is part of a study by a graduate student at Montana State University and not affiliated in any way with any other institution. The results will be used to gain a better understanding of the transition between high school and college Biology.

Participation is strictly voluntary, you can chose to exit the survey at any point by simply closing the window. Your answers will not be recorded anywhere until you press the "Submit" button at the end of the survey.

All answers are completely anonymous; your answers will be received with those of other professors around the country and there will be no identifiers linking them to you. The names of those contacted as potential participants will be kept confidential to only the researcher. By clicking the "Submit" button at the end, you are acknowledging that you have freely chosen to participate in this survey after reading these directions and giving the researcher permission to use and disclose the anonymous results.

If you have any questions regarding this study, please contact Marta Toran at martatoran@gmail.com. Thank you for your time!

1. What expectations do you have of students coming into your course in terms of basic biology KNOWLEDGE?

2. What expectations do you have of students coming into your course in terms of subject-related SKILLS?

3. How strongly do you agree with the following statements?

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Most students come to entry level Biology courses with adequate basic Biology knowledge.	☐	☐	☐	☐	☐
Introductory biology	☐	☐	☐	☐	☐

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
courses in college re- teach the basics concepts of Biology because students are lacking the background knowledge.					
Some high school biology is needed to prepare students for college-level Biology courses	☐	☐	☐	☐	☐
In my introductory biology course, I focus on depth rather than breadth.	☐	☐	☐	☐	☐
High school biology should focus on depth rather than breadth.	☐	☐	☐	☐	☐

4. Do you feel that the majority of high school graduates are well prepared to tackle college-level biology?

- ☐ Yes
- ☐ No
- ☐ Neutral/ I don't know

5. In your opinion, what are the 3 most important topics/ concepts that you would like students to understand coming into your class?

Submit

APPENDIX F:

ONLINE QUESTIONNAIRE FOR HIGH SCHOOL BIOLOGY TEACHERS

Appendix F:

Online Questionnaire for High School Biology Teachers

Questionnaire for High School Biology Teachers

This questionnaire consists of 5 questions and should only take a few minutes to complete. It is part of a research study by a graduate student at Montana State University and not affiliated in any way with any other institution. The results will be used to gain a better understanding of the transition between high school and college Biology.

Participation is completely voluntary, you can chose to exit the survey at any point by simply closing the window. Your answers will not be recorded anywhere until you press the "Submit" button at the end of the survey.

All answers are anonymous; your answers will be received with those of other teachers around the country and there will be no identifiers linking them to you. The names of those contacted as potential participants will be kept confidential to only the researcher. By clicking the "Submit" button at the end, you are acknowledging that you have freely chosen to participate in this survey after reading these directions and giving the researcher permission to use and disclose the anonymous results.

If you have any questions regarding this study, please contact Marta Toran at martatoran@gmail.com. Thank you for your time!

1. When teaching General Biology, do you mainly focus on breadth or depth?

- ☐ Breadth
- ☐ Depth
- ☐ Both equally

2. How important are the following teaching goals to you when teaching General Biology:

	Very important	Important	Somewhat important	Of little importance	Not important at all
Preparing students to meet school/ state requirements	☐	☐	☐	☐	☐
Preparing students	☐	☐	☐	☐	☐

	Very important	Important	Somewhat important	Of little importance	Not important at all
for success in specific standardized stests such as SAT2, ACT, AP					
Providing students with skills for their everyday life	☐	☐	☐	☐	☐
Helping students gain a solid background knowledge/ content for college biology	☐	☐	☐	☐	☐
Helping students develop skills for Science college courses	☐	☐	☐	☐	☐

3. How well prepared do you think the average student leaving your course is for college-level biology?

- ☐ Very prepared
- ☐ Adequately prepared
- ☐ Poorly prepared

4. Do you or your students participate in any university-run outreach programs? (eg. such as teacher workshops, student lectures, etc)

5. What are the 3 most important biology topics/ concepts that you want your students to take away from your class?