

An Explorations Approach to Summer Bridge at a Selective Liberal Arts College: One Path Toward Equalizing Student Success

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Abstract

St. Olaf College recently restructured its Summer Bridge Program (SBP) course for incoming low-income (LI) and first-generation (FG) college students from a non-major biology course, "Issues in Biology," to an interdisciplinary "Explorations in Science" course. Two significant changes were made with the intention of giving students more agency as scholars: a) lab-based research projects vs. library projects and b) explicitly taught quantitative skills. Both courses used a coherent theme, outside readings and provided opportunities to practice study and exam taking skills. Here we describe the "Explorations" course in detail and compare the outcomes of its first two offerings to those of the original "Issues" class. Both SBP cohorts were compared to students who were neither LI nor FG. We learned that global outcomes such as average retention rate and major selection were not affected by the new format. However, students in "Explorations" mastered more quantitative skills, succeeded in their independent lab research and met higher cognitive skills on exams while tending toward higher grades. Students in the updated SBP course met our learning goals preparing them to apply critical thinking, writing and analytical reasoning skills as learning tools in subsequent classes.

Keywords: summer bridge program, low-income and first-generation students, quantitative skills, research skills, liberal arts college, discovery-based inquiry, non-science majors

Introduction

In a time of change, both in the population of students who attend college and in the educational goals of colleges, it is important that programs and curricula adapt in order to enhance the success of all students. Educational goals are moving away from mastering a particular body of knowledge and toward the development of life-long learning skills such as writing, critical thinking, and analytical and quantitative reasoning (Berrett, 2016). Simultaneously, colleges are successfully recruiting new groups of students, including low-income (LI) and first-generation (FG) college students, many of whom are less-prepared academically and socially for

the traditional college experience (e.g., reviews: Cabrera, Miner, & Milem, 2013; Douglas & Attewell, 2014; Sablan, 2014). Programs that generate academic momentum, strengthen resilience, and build social networks among students, faculty and support staff early in the college career help at-risk students stay in school e.g., (Allen & Bir, 2012; Bir & Myrick, 2015; Slade, Eatmon, Staley, & Dixon, 2015; Tomasko, Ridgway, Waller, & Olesik, 2016).

Summer bridge programs (SBP) are one means of improving retention and graduation rates of first-year LIFG students. Although the effect of SBPs on LIFG students at liberal arts colleges has not been studied extensively, a review of SBPs at community colleges and less-selective four-year colleges concluded that SBP attendance increased graduation rates by 10% (Douglas & Attewell, 2014) probably because these programs help students avoid remedial coursework while developing academic and college navigation skills (Sablan, 2014). Successful programs seem to be tailored to specific institutional needs and are well-integrated into other institutional support, such as financial aid, academic support offices and advising programs (Slade et al., 2015). However, despite a strong sense of their worth, it is difficult to pinpoint which components of the programs are most essential, due to the lack of uniformity, insufficient data collection, lack of reasonable control groups, the high dependence of college GPA on pre-college preparation and the additional support services frequently provided for SBP participants during their first year of college (Cabrera et al., 2013; Douglas & Attewell, 2014; Sablan, 2014; Slade et al., 2015; Strayhorn, 2011).

Here we describe the elements of our SBP, including the rationale behind having a natural science course at its core. Then, we describe our motivations for changing our long-standing biology course "Issues in Biology" ("Issues") to a new science course "Explorations in Science" ("Explorations") to incorporate a lab-based research project, quantitative approaches and other active learning to help students study a problem from multiple-disciplinary perspectives. We compare first-year retention rates, GPAs, and declared major distributions for students who participated in either version of the summer bridge course with those of students who were neither LI nor FG. Perfor-

mance in the two versions of the SBP is compared directly through grades and their exam structures. Finally, we assess whether our students met the specific goals of the "Explorations" course.

A Description of our Summer Bridge Program and its Natural Science Course

Our SBP began in 1991 and is embedded in a four-year TRiO Student Support Services (SSS) Program for LIFG students with academic and leadership promise despite significantly lower academic preparation compared to other students in their incoming class. Approximately 40 SSS-eligible students participate annually in our intensive four-week program. St. Olaf's SBP participants have a longstanding record of graduation success, averaging 85% vs. 88% for the college as a whole. However, in general, SBP students graduate with slightly lower GPAs and are less likely to major in Humanities or STEM fields than non LIFG students.

Our SBP has multiple components anchored by an introductory natural science course. The contact hours of this course are equivalent to a full semester course: it meets our lab science general education requirement and counts as a biology major elective. In addition, our SBP includes a synergistic writing class and an integrated math lab called "Doing the Math". Three or four faculty members take responsibility for the science, writing and math instruction. SBP students also attend events to familiarize themselves with the campus and its resources, while study skills and residence hall acculturation are emphasized. About a dozen peer-teaching assistants (TAs) provide essential program support through formal supplemental instruction (SI), tutoring in science and writing as well as organizing social activities under the supervision of professional SSS staff.

Why offer a science course?

We offer a science course in our SBP for several reasons. First, the science course is intended to prepare all students to meet our academic and social expectations by developing critical skills in a safe environment (Douglas & Attewell, 2014). For instance, science classes require all of the basic skills needed to succeed in college, including reading comprehension, writing (from clear sentences to

well-crafted essays and papers), oral expression, critical thinking, quantitative analysis and visual literacy. Science courses include different modes of learning, and students are assessed in multiple formats. Second, science classes often cause the most student anxiety, particularly in those students not interested in science. Introducing science in this relatively safe context addresses those concerns and gets students past one academic hurdle successfully while providing confidence and momentum (Douglas & Attewell, 2014). Third, college science classes require precision and evidence, academic habits that we hope transfer to other classes. Fourth, our SBP is intended to recruit new students to the STEM disciplines and retain those who were interested in STEM initially. This latter goal is an attempt to address the national, and our own, disparity between the numbers of LIFG and other students in STEM (Johnson & Okoro, 2016). Moreover, we are developing STEM literacy and discovery-based inquiry experiences for students who profess no interest in STEM, but who will, just by living in the 21st century, be asked to make decisions based on scientific data and technological advances (Ballen et al., 2017).

Why Modify the Core Course in a Successful Summer Bridge Program?

Although our former SBP successfully prepared incoming LIFG students for the entire college experience, we felt compelled to modernize our SBP science course to include more engaged learning and quantitative approaches since it is known that practicing these skills deliberately and early on helps students, especially underrepresented minority students, in future classes (Allen & Bir, 2012; Bangera & Brownell, 2014; Barlow & Villarego, 2004; Bir & Myrick, 2015; Cooper, Ashley, & Brownell, 2017; Eagan et al., 2013; Gregerman, Lerner, von Hippel, Jonides, & Nagda, 1998). One means of engaging and retaining students is active learning and inquiry, often through a research experience that engages them in a question related to their lives (Auchincloss et al., 2014; H, SL, & A-B, 2010; Johnson & Okoro, 2016; Lopatto & Tobias, 2010). Simultaneously, the value of integrating concepts across disciplines while developing quantitative and communication skills across the curriculum is widely recognized (Berrett, 2016; Elrod, 2014). This research led us to re-design our SBP core course to include a student-driven lab-based independent research project and a twice-weekly math lab. Specifically, our goals were to help students build confidence and ownership for their work, develop their understanding of the process of science and enhance their critical thinking, research, quantitative and communication skills. We also wanted to ensure that the course was appealing and useful to all SBP students since most do not intend to become science majors. Furthermore, we sought to model innovations in pedagogy emphasizing academic skill development, helping students to challenge assertions systematically, and to recognize

the types of evidence needed to support claims in daily life (Allen & Bir, 2012; Berrett, 2016; Cooper et al., 2017; Sirum & Humburg, 2011). These factors, along with national calls for educational change (Science, 2011) and our HHMI funding, made it possible for us to develop our new course, "Explorations," with these components:

- 1) a coherent research theme approached across disciplines;
- 2) lab activities supporting student-driven research to explore aspects of this theme;
- 3) explicit integration of quantitative approaches to explore ideas and support conclusions;
- 4) writing, visualization and speaking skills integrated into the course content, including poster and paper presentations of their research for a public audience;
- 5) linking the focus of study to issues of civic and personal concern through a variety of readings and writing assignments beyond the text.

The lab research and quantitative components (#2 and #3) were significant changes to the SBP course requirements whereas the other three criteria did apply to "Issues" but were given greater prominence in "Explorations". Meeting these expectations is a lot to accomplish in a four-week course, especially since we wanted to maintain systematic development of academic skills (e.g., note-taking, study, reading for meaning, exam strategies, writing, participating in discussion, and, very importantly, asking for help) that had been honed over the years.

Developing the Explorations Course

The former "Issues" course was a classic non-major biology offering that gave students a taste of relevant biological questions at multiple levels of organization from molecules, cells, and tissues, to ecosystems and evolution. The labs reinforced these topics including predator-prey exercises, a trip to explore diversity at a local pond, followed by bacterial diversity and a lab on foods and digestion. We used themes to build coherence (criterion #1) and relevance for the students (criterion #5): for example, in 2008 (an Olympic year) the theme was *Biological Issues Come to Play in the Olympics*, ideas we explicitly discussed in each class period. Our students worked in pairs to prepare an oral presentation and then wrote individual research papers based on topics such as "Bionic Legs" and "Gecko Feats".

In "Explorations", our theme became *Survival: How do Microbes do it?*, which was broad enough to bring in other science concepts, especially chemistry, as well as connect to multiple social issues. It also permeated deeply into every aspect of the course, including the independent research project and the additional two hours a week devoted to quantitative exercises.

How could a class of 40 incoming students complete a research project in just four weeks? From prior experience, we knew students thrive when given the chance to try out their own ideas when they are given the tools to successfully frame and carry out an experimentally-based research project. We planned the lecture and lab portions of the course to be mutually supportive, and we chose lab techniques that students could master quickly. In lecture,

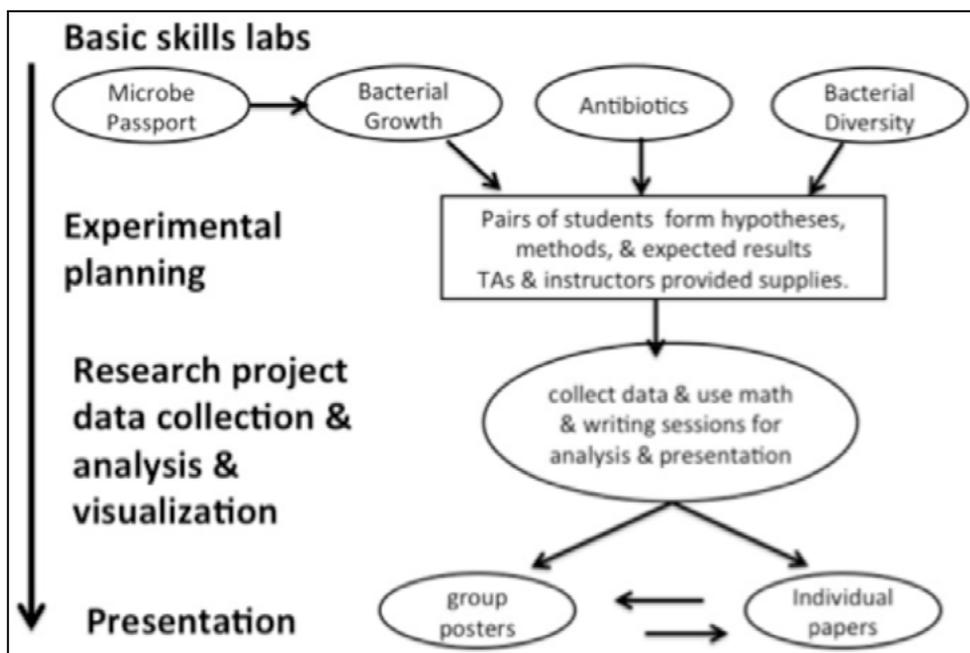


Figure 1. The laboratory plan for "Explorations in Biology" is designed to build the skills and conceptual understanding needed for students to design, complete, analyze and present their own research projects. In the first four lab periods all students do the same exercises in pairs. Research teams develop an independent research project that they complete over the next three lab periods. Writing and "doing the math" sessions focus on developing shared posters and individual papers describing the research with effective graphs and quantitative analysis.

Lab title	Lab skills	Conceptual skills	Quantitative skills
Microbe Passport	<ul style="list-style-type: none"> ● Microscopy ● Micropipets ● Spectrophotometer 	<ul style="list-style-type: none"> ● Bacterial size ● Serial dilutions ● Absorbance 	<ul style="list-style-type: none"> ● Linear units ● Beer-Lambert law ● Calculate slope ● Exponents ● Graphs
Watching Bacteria Grow and Divide: Population Dynamics Measured in Two Ways	<ul style="list-style-type: none"> ● Spectrophotometer ● Grow bacteria in flasks ● Sterile technique ● Micropipets ● Grow colonies on agar plates ● Plate counts 	<ul style="list-style-type: none"> ● Optical density ● Growth kinetics ● Serial dilutions 	<ul style="list-style-type: none"> ● Graphs ● Logistic growth ● Exponents ● Units ● Counting ● Calculate surface area, volume
Antibiotics: Bacterial Susceptibility & Resistance	<ul style="list-style-type: none"> ● Growing lawns of bacteria on agar plates ● Disc drug dispersal ● Measuring Zone of Inhibition 	<ul style="list-style-type: none"> ● Bacteria vary in susceptibility to drugs ● Drugs have different modes of action. 	<ul style="list-style-type: none"> ● Measure ● Calculate mean & standard deviation ● Draw conclusions from a “look up” table.
Bacterial Communities in Various Environments: how large? how diverse?	<ul style="list-style-type: none"> ● Collect bacterial samples from the environment ● Grow colonies on agar ● Visually distinguish growth characteristics 	<ul style="list-style-type: none"> ● Bacteria are ubiquitous but amounts vary by environment. ● Different species of bacteria in different environments 	<ul style="list-style-type: none"> ● Count ● Sort ● Bar graphs ● Comparisons

Table 1. Lab, conceptual and quantitative skills developed in each lab exercise.

we explored fundamental ideas of populations, metabolism, genetics, chemical communication, and community ecology. In lab, we studied growth rates, nutritional demands, effects of antibiotics and the biodiversity of microbial communities, matching these topics with appropriate experimental measurements and quantitative skills. Our students learned how to perform serial dilutions, plate counts, spectrophotometry, antibiotic testing, and bacterial sampling. We could then guide them in realistic experimental design, data analysis and presentation.

What did the students do in “Explorations”? Over four weeks, we had seven two-hour labs concluding with a public poster session. The first four lab sessions were devoted to exercises designed to build skills and the last three were devoted to student project data collection, analysis, and poster preparation for student-generated projects (Fig. 1). For the projects, the students were assigned one of three broad areas: bacterial population growth, bacterial death/growth inhibition or bacterial diversity. Each pair of students proposed their research proj-

ect in consultation with the TAs, and completed a detailed project planning form (Supplemental Materials) that included hypothesis, rationale, required materials, measurements to be made, data analysis plan and what potential outcomes might mean. Our students created a flowchart that showed their strategies and timelines. This flowchart ultimately became a figure in their poster presentation. TAs and faculty worked with each pair of students to constrain, expand or clarify their projects as needed. Typical examples of projects included comparing the amount and diversity of bacteria on washed vs. unwashed spinach, ability of different soaps to kill bacteria isolated from skin, and *E. coli* growth rates at three temperatures or in apple juice vs. growth media. Their project documentation was completed in multiple stepwise assignments worth 30% of the class grade, including the planning form, flow chart, paper drafts, poster and final paper.

“Doing the Math” Lab

“Doing the math” was a response to a call to inte-

grate quantitative reasoning across the curriculum, intended to develop college-level competency at applying mathematical and graphical skills to analyze real-world problems (Science, 2011). Greater quantitative skill development is needed in the US: for example, only 13% of US adults test as “proficient” in quantitative literacy and fewer than 30% are considered to be able to use scientific data to draw conclusions (Elrod, 2014; Kassae & Rowell, 2016).

Learning to apply quantitative tools outside of mathematics classes is difficult, and successful learning requires multiple thoughtful attempts throughout the college curriculum (Hester, Buxner, Elfring, & Nagy, 2014; Matthews, Belward, Coady, Rylands, & Simbag, 2016). Fortunately, deliberate efforts to integrate mathematical concepts into introductory biology courses or a SBP have proven successful in improving quantitative skills and understanding (Doerr, Arleback, & Staniec, 2014; Hester et al., 2014) thus justifying our attempt to do this in our SBP pre-matriculation course.

Students attended 2 hours of math lab per week. During “doing the math,” students practiced quantitative skills directly tied to the lab projects such as basic arithmetic, algebra, exponents, logarithms, unit conversions, some geometry, calculus concepts and summary statistics as well as visualization of relationships in graphs and flowcharts (Table 1). These skills were referred to in lecture, used by students to complete their lab work, covered during the “doing the math” sessions, tested on exams, and were required for the final poster and paper. For example, to complete the Microbe Passport lab (Table 1), students learned the Beer-Lambert Law directly relating absorbance (Abs) to concentration (C), ($Abs = \epsilon lC$), by sketching the graph they would expect. Then they plotted their actual data in terms of concentration, found the slope of the line, and calculated the molar absorption coefficient (ϵ) given the 1cm path length (l). As another example, students used colony plate counts to estimate bacterial concentrations, which required them to become comfortable with powers of ten, serial dilutions and linking the data to their experimental questions. They completed exercises in “doing the math” until students could estimate expected plate counts from known bacterial con-

centrations and calculate bacterial density in a flask from the number of colonies on a plate.

Writing, reading and oral presentations in the context of the course

Learning to write is best done when students have something to say and someone to say it to (Moskovitz & Kellogg, 2011a, 2011b). The lab projects gave them something to say and the public poster presentation and a written paper provided venues in which to say what they had learned. Articulating their work required understanding the background, how their question lead to their experimental design, and how they assessed their results quantitatively. In this respect, the students taking “Issues” and presenting their library research projects had a similar experience. The key difference was that “Explorations” students presented *their own* research data and conclusions, discoveries they had made directly in lab.

Each week, students spent 2 hours in a formal writing course to focus on both creative writing and writing fundamentals to help them prepare their research papers. Frequent reading and writing assignments from the sci-

ence faculty helped prepare students for their own papers by demonstrating how scientific ideas are shared among different audiences. The “non-text” reading was increased from two assignments in the “Issues” course to eight assignments beyond the textbook in the “Explorations” course (Table 2). Students prepared answers to questions designed to help them discern facts, link the reading to other class activities, articulate conclusions and formulate their own conclusions. These were turned in before class to ensure readiness for class discussions.

The bacterial pathogen assignment, “Bad Bacteria” (Supplemental Materials), introduced independent learning, teamwork and oral presentation skills while giving students ownership of a bacterial species. It was a low-stakes assignment (2% of the grade) done in groups of three to address: a) What are the human disease symptoms caused by the pathogen? b) What is the microbe’s ecology? c) What molecular attributes give rise to the virulence factors permitting this bacterium to cause disease? Presentations were five minutes or less with three-five slides. The grading rubric included scientific correctness and sophistication, quality of the slides, organization and overall level of engagement. Groups were encouraged to rehearse these talks and the TAs were enthusiastic about working with them. This presentation helped prepare them to share their research posters.

Midway through the course, students wrote drafts of the *Introduction and Materials and Methods* sections of their individual papers and obtained feedback from the science and writing faculty. Guidelines for papers and posters and grading rubrics were provided (Supplemental Materials). Posters were presented to a college-wide audience after the teams had rehearsed with the TAs. Final individual papers were due on the last day of class.

Methods

Research Design

These four offerings of SBP courses (two “Issues” and two “Explorations”) were chosen because there was overlap in the instructors with MCS and AW teaching all four sections and collaborating with EMCD for “Issues” and LB for the development and instruction of the first iteration of

Title	Type of source	Questions/Skills
Germ of Life	Nature Magazine (Orion Magazine)	What are bacteria? Why are they important? What is the value of biological communities? Why do humans need bacteria?
New Antibiotics/New Resistance	General Science (American Scientist)	Clearly explained basis of antibiotic action, resistance mechanisms and how these spread. Nice demo of how antibiotics are tested.
Inside Job	General Science (Science News: Magazine of the Society for Science & the Public Interest)	Microbiome bacteria are our “frenemies”. Roles of intestinal bacteria. Reason for probiotics.
Biological Nitrogen Fixation	Science Education (Nature Education: Knowledge Project)	Symbiosis of bacteria and plants – plant microbiome. Importance of nitrogen for growth.
Understanding Biofilms	General Science (Bacteriality—Exploring chronic disease)	Inter- and intra-species communication and cellular responses. Disease mechanisms
Bioluminescent Bacteria	General Audience Issues on Science & Society (Wired UK)	Inter- and intra-species communication. Circadian rhythms. Bacterial growth rates.
Superorganism Revolution	General Science (American Scientist)	Human ecosystem – microbiome. Function in an ecosystem .Evolution & community ecology: succession, mutualism, competition.
Some Like it Hot	General Science (Science – Perspectives)	Cyanobacteria species types depend on soil temperature. How will increased temperatures alter function, specifically nitrogen fixation?

Table 2. Non-text readings from Survival: how do microbes do it?. Each reading had a structured homework assignment to help students extract and organize information.

Cohort	n	ACT (mean ± SD)	First Year GPA (mean ± SD)	Sophomore Year retention
“ISSUES” years				
SBP	85	20.7±3.1	2.67±0.44	94%
Not SSS-eligible	1226	28.9±3.4	3.28±0.52	94%
“EXPLORATIONS” years				
SBP	76	22.8±2.6	2.88±0.44	92%
Not SSS eligible	1119	29.2±3.4	3.28±0.52	94%

Table 3. Academic and retention information for students in the summer bridge programs compared non-SSS eligible students.

“Explorations”: The tone, number of quizzes and exams, collaboration with TAs and interactions of faculty with students was almost identical. Moreover, the SSS Director along with the residential aspects including SI and study schedules, peer mentoring and tutoring were the same. The only logistical change was the removal of “student work” from the “Explorations” SBP in order to create time for “doing the math”.

Participants

Approximately 40 students were identified annually by Admissions and then selected for the SBP and SSS by the SSS Director based on the following criteria: all were LI, FG, or both but showed promise of success despite low ACT scores. All students meeting these criteria who are accepted at St. Olaf College must participate in the SBP.

Data collection

Disentangling the effect of our SBP and the changes we implemented in “Explorations” was extremely difficult at St. Olaf, as elsewhere, due to the plethora of additional support components provided. It is the ensemble that determines important measures of success such as retention and graduation rates (Slade et al., 2015; Strayhorn, 2011). Regardless, St. Olaf’s Office of Institutional Research collected data for us on the academic background (ACT scores), academic performance (GPA), retention and major choice at St. Olaf for both the “Issues” and “Explorations” students and students who were neither LI nor FG. The vast majority of our students take the ACT: any SAT scores were converted to an ACT equivalent using concordance tables provided by the College Board (2009).

Analysis

We compared the two courses by the grades students earned and by the nature of the exams we gave,

which in all cases represented 48% of the course grade. We evaluated the exams in three ways: comparing the format of the questions, the degree of cognitive difficulty using Bloom’s taxonomy and by the prevalence of quantitative or experimental-design focused questions. The types of questions were divided into “restricted response” (multiple choice, matching) and constructed response (short written answers, drawings, essays) (Wright et al., 2016), and since the number of points per question varied, we summed the points by category and calculated the percentage of total examination points for each type of question. Assigning a level of cognitive difficulty using Bloom’s taxonomy proved more difficult. Each of us assigned levels by question for all sixteen exams and then reconciled our rankings. We were guided by examples and descriptions of items fitting each of the six levels of Bloom’s Taxonomy (Crowe, Dirks, & Wenderoth, 2008; Momsen et al., 2013). To identify the extent of quantitative or graphical knowledge we were measuring, we counted the number of questions per exam that involved graph reading, graph creating, calculations (numerical, genetics problems) or understanding quantitative relationships and determined the fraction of these on the respective course exams. Finally, to assess the impact of the focused theme and research project and “doing the math”, we report data from quantitative surveys collected in 2014 and a semi-quantitative assessment of student gains in mathematical approaches.

Results

Comparisons of GPA, Retention, and Major between Summer Bridge Program and non LI or FG Students

To assess the overall impact of our SBP, we compared the GPA, sophomore-year retention, and major selection

of our SBP participants to students who were non LI or FG. Nearly all students at St. Olaf who are LIFG are SBP- and SSS-served, so there is no direct control group. The students who participated in our SBP were, by their ACT scores, a separate population from students who are not SSS-eligible (Table 3). The latter population (about 74% of the student body) had an average ACT score of 28.9 whereas the SBP population (5% of the incoming class) had an average ACT score of 20.7 in the “Issues” years or 22.8 in the “Explorations” years. The remaining 21% of students were LI or FG or a racialized minority with high ACT scores (not shown). Despite lower incoming ACT scores, the SBP cohorts earned respectable GPAs (2.67, 2.88, equivalent to a B- or nearly a B average) after the first year, although lower than the 3.28 (close to B+) average of those not SSS eligible. The retention rates of the SBP participants to sophomore year were also very high (94 and 92%), virtually identical to the 94% retention to sophomore year for non-eligible students (Table 3).

Factors other than ACT scores may predict success in college. It is noteworthy that SBP students generally graduate from underperforming high schools near the top of their classes; in this one regard, being among the best of their high school peers, they are similar to the rest of the students at St. Olaf.

Major choices

We wondered whether changes in the SBP course affected students’ choices of majors; specifically, did more SBP students in the “Explorations” course choose majors in STEM fields? Also, how did major choice compare to students who were neither LI nor FG? The percentages of students declaring (or completing) at least one major in a given academic division were calculated for the two groups of SBP participants and the paired larger groups of not SSS eligible students

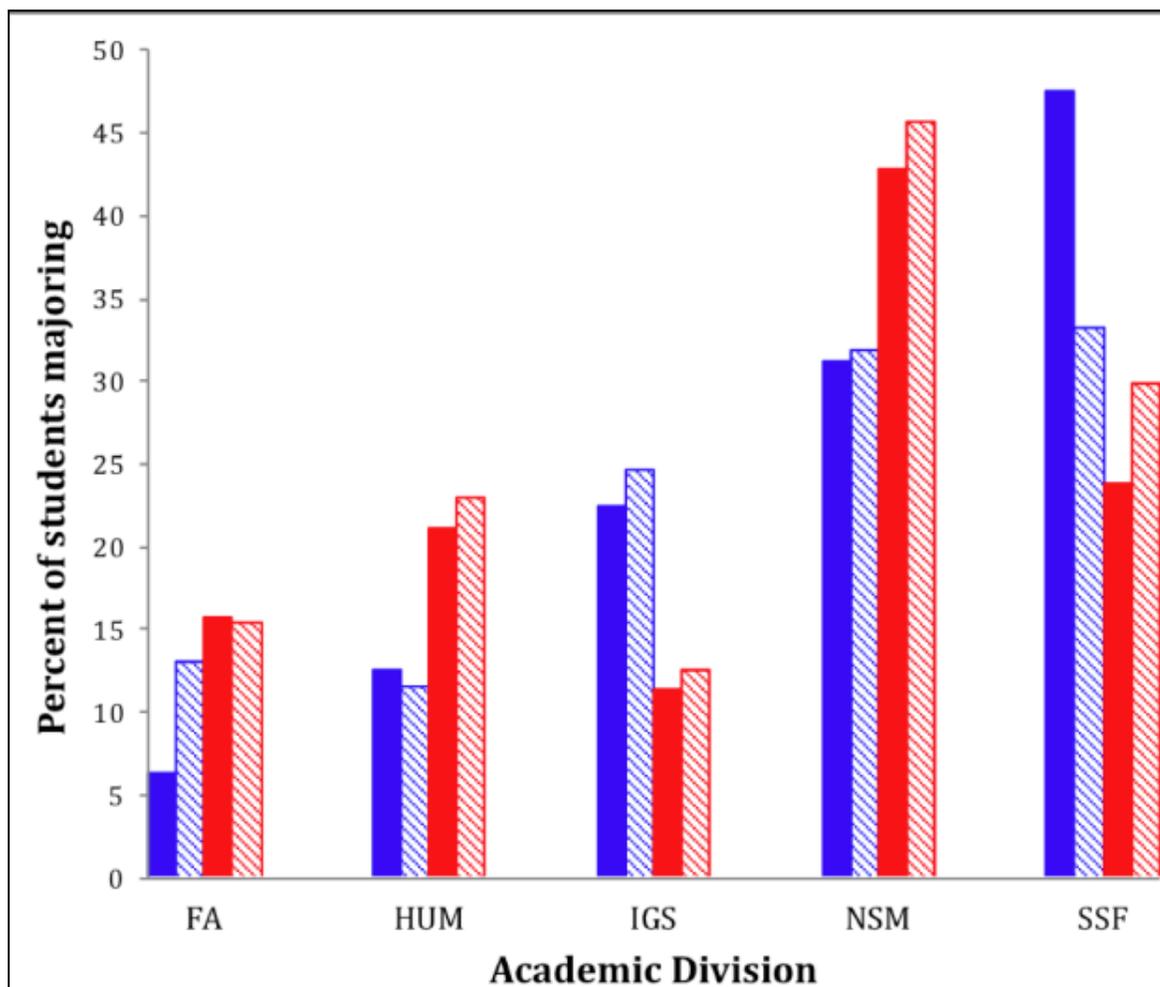


Figure 2. The distribution of majors by area of study for Summer Bridge Program students (blue bars) and students who are not SSS eligible (red bars) who entered in the “Issues” years (plain) and “Explorations” years (patterned). Majors: fine arts (FA), humanities (HUM), integrated studies (IGS), natural sciences and mathematics (NSM), and social and applied sciences (SSF).

	“Issues” (n = 86)	“Explorations” (n = 76)
SBP course grade (average ± SD) on a four-point scale (A=4.0)	2.8 ± 0.7	3.1 ± 0.6
% questions with restricted responses (multiple choice, matching)	33.7%	19.7%
% questions with quantitative content	9.3%	20%
Average Bloom’s Score on a 1-6 scale.	2.31	2.45

Table 4. Comparison of the examinations given in “Issues in Biology” and “Explorations in Science”. The course grade, restricted response and quantitative questions and Bloom’s Taxonomy scores are compared. The three mid-terms and a final exam represented 48% of the course grade in all four versions of the SBP course.

ed challenges, the course grades for the “Explorations” cohort were significantly higher than the grades for the “Issues” cohort (3.1 vs. 2.8 on a 4-point scale; paired t-test, $p < 0.05$) (Table 4). In both courses, exams made up 48% of the grade and the other components (lab, poster, research paper, quizzes, homework), although somewhat different in character for “Issues” vs. “Explorations”, made up the rest of the grade.

To see if there was a difference in the nature or difficulty of the exams, we compared them in terms of question format, the number of quantitative questions and the degree of cognitive difficulty based on Bloom’s taxonomy (Table 4). The number of questions and length of the exams were almost identical. However, “Issues” exams had 14% more points generated from “restricted response” questions due to “matching” questions that were replaced with short answer questions on the “Explorations” exams. Reflecting the quantitative focus in the “Explorations” course, 20% of the exam questions had graphical or quantitative content compared to 9.3% of the “Issues” exam questions. When we used Bloom’s taxonomy to analyze the questions, the “Explorations” exams scored slightly higher at 2.45 on a scale of 6 compared to 2.31 for “Issues.” In both cases, the majority of the points were “low” levels of cognition falling in the “knowledge” and “comprehension” category but about 25% of the questions were scored as synthesis and application.

Effects of the Laboratory Based Research Project

The rationale for adding a student-driven lab-based research project in the SBP was to help students build confidence and ownership for their work, develop their understanding of the process of science and become better at formulating critical questions about topics they read or hear about. To gauge the extent to which “Explorations” students felt they had learned to approach a topic scientifically, we asked them to self-report their sense of progress at the

(Fig. 2). The percentage with STEM majors (NSM) was virtually identical in the “Issues” and “Explorations” cohorts (31.3 vs. 31.9%) and lower than the percent of STEM majors for non-SSS eligible students (42.9 and 45.7%). We saw a greater disparity in the Humanities with 12.5% and 11.6% of SBP students compared to 21.1 and 22.9% of non-SSS eligible students majoring in these departments. Higher proportions of SBP students majored in social and

applied sciences, e.g., economics, social work, etc., and integrated studies majors such as women’s studies.

Comparison of grades and exam content among Summer Bridge Program Cohorts

The new “Explorations” course had the added challenges of an independent research project and greater attention to quantitative skills. However, despite these add-

Question: This course....	Mean score
increased my awareness of how we think about science	4.2
increased my awareness of how science is done	4.3
helped me become better at reading and critiquing scientific literature.	3.9
improved my ability to formulate research questions	3.9
helped me get better at communicating science in writing and orally.	3.9

Table 5. Student perceptions of the effect of the summer bridge course on their understanding of science as a discipline. The data were collected from one Explorations cohort immediately after the course. All items are on a scale of 1 (strongly disagree) to 5 (strongly agree). (n=39)

Question: This course....	Mean score
helped me to use calculations to answer questions	3.4
made me more comfortable processing and displaying data	3.7
made me more able to use computers to process and display data	3.5
Helped me get better at communicating quantitative ideas	3.9

Table 6. Student perceptions of the effect of the summer bridge course on their quantitative skills. The data were collected from one Explorations cohort immediately after the course. All items are on a scale of 1 (strongly disagree) to 5 (strongly agree). (n=39)

Skill or task	Improvement
Graph reading	+++
Making their own graphs	+++
Using units when solving problems	+++
Converting units	+++
Use simple geometry to calculate surface areas of volumes	+++
Solve a dilution problem	+++
Use logarithms and recognize an exponential curve	++
Iterative solutions e.g., population growth curve models	++
Find parameters from data (e.g., growth rate or carrying capacity)	+
Solve problems about things they cannot see	+
Use flow charts	+

Table 7. Quantitative skill mastery was assessed semi-quantitatively by performance on a “pre-test” and final exam questions and project papers for one cohort. The degree of improvement is indicated by the number of “+”.

end of the course (Table 5). They were most confident in their gains in awareness of how we think about and do science. They reported robust improvement in reading critically, formulating research questions and communicating, although a few (3-4) individuals strongly disagreed that they had made any progress in these areas.

Impact of Quantitative Work – “Doing the Math”

Implementing the quantitative part of the course was difficult because for both the instructors and TAs this was new material presented in a new context. Furthermore,

the quantitative skills of the TAs varied, so occasionally they added confusion rather than clarity to the assignments. Nonetheless, the students reported feeling somewhat more confident about their quantitative abilities (Table 6). Interestingly, 15 students felt neutral (neither agree nor disagree = 2.5) about their comfort level in processing and displaying data, and 6 students disagreed or strongly disagreed that the course had helped them communicate quantitative ideas in contrast to the 31 students who felt that it had. It is possible that these six students were surprised to use math skills in a biology class or, more

likely, they were disappointed not to be using higher math skills they had learned in a pre-calculus class.

Based on a pre-course assessment compared to final course outcomes (final exam questions, project presentations) the students did gain facility with the math and visualization skills that we taught (Table 7). They made particular gains in reading graphs, graphing their own data, using units and converting as needed. Almost everyone mastered dilution problems whereas few could do them before the course. They all learned to transfer their understanding of simple geometry to ask questions about bacterial surface area and volume and physical density in a flask. Using logarithms and feeling comfortable with translating an equation to an exponential curve showed significant progress, as did their use of growth rate models solved iteratively. Fewer mastered finding parameters and solving multistep problems from data they could not visualize. Interestingly, many students resisted making flow charts or found these more difficult than filling in the project planning forms, showing how difficult it is to translate words into images.

Research Projects Created Links to Students Lives

The importance of doing something linked to students’ lives appeared in their reasons for their choice of “most memorable labs”. One strategy for stimulating student engagement was to give them tools to investigate a question with which they are familiar or concerned about (Johnson & Okoro, 2016). Of the four pre-project lab exercises, two were the overwhelming favorites in the first year, “antibiotic resistance” (47%) and “bacterial diversity” (44%). The reasons fall into two categories: wonder or

Antibiotic Resistance	Bacterial Diversity
Examples of comments suggesting connections	
<ul style="list-style-type: none"> Physically saw what antibiotics do to bacteria. I enjoyed seeing antibiotic resistance practically after learning about it in class. I never realized what antibiotics actually did and seeing them in action was cool. It involved more than bacteria, more of a real life scenario. 	<ul style="list-style-type: none"> Finding diversity of bacteria in the spinach. Taking a swab from people and seeing how much bacteria on dishes. We studied armpits for our diversity because girl armpits had more bacteria than boy armpits. We saw different types of bacteria in different places.
Examples of comments suggesting pride in mastery or independence.	
<ul style="list-style-type: none"> Our poster presentation. I did a lot better than I thought. How hard it was but how accomplished I felt after. Being able to work with live samples. I have never done this before. How we used real scientific methods. 	<ul style="list-style-type: none"> The research I had to do to learn more about it. We got to sample the things we wanted. Being able to see bacteria from places of our choice. Getting results that contradicted our hypothesis. We got to be creative in testing.
Table 8. What students felt was memorable about the two most popular “assigned” labs, “antibiotic resistance” and “bacterial diversity”.	

interest in what they saw and feelings of accomplishment or ability to address this topic (Table 8). The favorite labs were less technically difficult, with the data easily collected “by eye” and simple measurements with a ruler or counting. The other two labs required learning to use a spectrophotometer, serial dilutions, graphing and calculations to get results. Mastering these resulted in huge amounts of pride but significant insecurity in the moment. Interestingly, measuring bacterial growth rate was more popular the second offering of “Explorations” perhaps because the TAs were familiar with the method and enthusiastically promoted it.

Discussion

Does the SBP Help with Retention, Grade Point Averages or affect Major Choice?

The gains by all students during four years of college are generally remarkable and anecdotally those of our SBP students are quite spectacular. These are students who had little expectation of being in college and who have many factors ranging from insecure home situations to academic and personal struggles that could trigger failure. They entered college with significantly lower ACT scores than the majority of students (Table 3) yet their first year GPAs hovered in the “B” range putting them on track for success. Over 90% of our SBP students return for their sophomore year, a rate no different than the rest of the college. The four-year graduation rate was 81%, very close to the 84.8% for the class as a whole. We do not have a direct comparison group of students who come with similar personal and academic challenges who are not SBP participants. However, compared to students in this academic demographic nationally, our retention and graduation rates are extremely high, suggesting that our SBP and subsequent SSS program activities are important for their success. For example, LIFG students who enroll

in four-year programs nationally graduate in six years at rates of 21% vs. 57% for non-LIFG students (Pell Institute, 2016). Not only are our graduation rates much higher, but our graduation gap is very small, only 3.8 points compared to 36 points nationally.

However, the significant difference in major choice is of concern. SSS students choose Humanities majors at approximately half the rate of non-LIFG students and STEM majors at about 70% of their non-LIFG classmates (Fig. 2), raising critical questions as to why this is so. For example, this disparity may be due to differences in interest, perceived job prospects, or academic access and success in these fields. This disparity is currently being addressed by the College.

Did Adding Student-Driven Research and a Quantitative Component Alter Retention, Grade Point Averages or affect Major Choice?

We made deliberate changes to an already strong SBP by adding a student-driven independent research project and an integrated math lab. On the surface, it appears that these changes had a minimal effect on the overall performance outcomes of the students. The higher SBP course grade and FY GPAs of the “Explorations” cohorts correlate, as expected, (Kassae & Rowell, 2016) to their higher incoming mean ACT scores compared to those of the students who took the “Issues” version of the SBP course. Retention rates were high and nearly identical for both groups suggesting that the changes in the “Explorations” version did not increase overall student ability or desire to stay in college. However, the “Explorations” cohorts mastered the more difficult material (Table 3) and our significantly more challenging expectations. Despite a greater emphasis on science and mathematics skills, the fraction majoring in natural sciences and mathematics is the same (31.6%) (Fig. 2). Understanding the extent of

STEM major choice is confounded by the fact that we opened new science and mathematics buildings in the fall at the same time as “Issues” was offered and many “Issues” students were selected as National Science Foundation STEM scholars providing them both financial and programmatic support to continue in science (Walczak, 2013). Indeed, the SSS students with NSM majors increased 25.5% with the opening of the new science building compared to the six years prior.

Although the “Explorations” students did not have a new building or STEM scholarships, they selected STEM majors at a similar rate suggesting either the new course

made a difference or a new sense that SSS students could succeed in STEM has become part of the ethos here.

Did our course revisions help us meet our goals?

SBP courses should prepare students to meet academic expectations at the college or university they are attending (Sablan, 2014). St. Olaf places significant emphasis on developing critical thinking, analysis and synthesis skills. Thus, it is interesting to note that both SBP cohorts were tested at a higher level of Bloom’s taxonomy than might be expected for a non-majors science course nationally. For example, an analysis of introductory biology exams at a large public university showed that 93% of the assessment items were considered “knowledge” and “comprehension” (Momsen et al., 2013), whereas only about 76% of our exam questions in both “Issues” and “Explorations” were at these levels, reflecting the skills our students need starting in their first year of college. Moreover, despite the fact that the “Explorations” exams required more student-generated answers and had more than twice as many quantitative problems than exams in the “Issues” course and a slightly higher Bloom’s score, “Explorations” students readily met these challenges scoring significantly better on these more difficult exams than their “Issues” counterparts making us conclude that we did meet this goal.

In “Explorations”, students also read more “non-text” material requiring more synthesis in their homework and class presentations than those in the “Issues” classes. Thus based on their exam grades, GPA, retention and major selection, we conclude that despite the adjustments to meet new expectations of engagement with research, synthesizing ideas and quantitative thinking, the students actually mastered the goals we set as well or better than the content and skills goals of the “Issues” course.

Our data suggest that we meet our new goals with the

“Explorations” version of the course. The students’ self-report that they have learned to think more like scientists (Table 5) and to use calculations and display data (Table 6) as we might expect from other studies implementing inquiry-based labs (Jeffery, Nomme, Deane, Pollock, & Birol, 2016) and explicit quantitative work (Hester et al., 2014). Although they are somewhat less confident in their own articulation of ideas or critiquing the literature, they have practiced doing so. Their self-assessments are bolstered by the measured improvements in graphing and problem solving using multiple quantitative skills (Table 7). Finally, we helped them make connections between the science they were learning and their own lives as well as bolstering their pride in doing college work (Table 8). In short, with this non-science-major class, we model opportunities to improve scientific literacy skills, apply social issues at the scientific interface, and use quantitative evidence for decision-making (Ballen et al., 2017).

Implications for Educators

Our project demonstrates that the efforts to increase active learning through lab research projects and to integrate quantitative work into SBPs are possible and worthwhile pedagogical goals. We were intentional about our learning goals and how each hour of this tight SBP course would contribute to student success. We learned that integrating formal disciplines (writing, math, lab science) around one topic and actively engaging students in all three simultaneously was possible. No harm was done and many of our indicators point, albeit weakly, to success. Introducing quantitative work outside of formal math classes allows students to use quantitative arguments more successfully (Tables 6, 7) but takes thought to do it seamlessly without depending on rote calculations. Raising the bar (e.g., the exam question profile) is feasible. The pride on students faces when they present their own experimental results is hard to measure (although Table 8 indicates it was real) suggesting that others contemplating such a change in a first year or SBP or non-majors’ science course, should be encouraged to do so with appropriate in-course scaffolding to increase the likelihood of success.

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mer developing the new lab program, drafting the new lab manual and testing some of the quantitative exercises: her work was key to implementing the new course. We thank Kathy Glampe, Brian Greening and Wendy Gonzales who have helped with data and comments and Emily Mohl helped us understand and apply Bloom’s Taxonomy to our exams. Two anonymous reviewers provided helpful comments on our manuscript.

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Anne Walter has taught biology for over 25 years in various courses in cell biology and animal physiology. She has explored access to learning for first generation, low income students by teaching in the Summer Bridge Program hosted by SSS TRiO at St. Olaf College multiple summers. She was the PI for an NSF Scholarships for STEM program to develop a cohort of students that would complete majors in biology and continue into biology careers or graduate programs. Her current pedagogical focus is integrating mathematical thinking, especially modeling, effectively into the undergraduate biology curriculum and experimental approaches into mathematics.



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Supplemental Materials
I. Project Planning Form
II. Paper Guidelines & Grading Rubric
III. Poster Guidelines and Evaluation Form
IV. "Bad Bacteria" Assignment and Rubric

Project Planning Form

Group Members: _____

TAs initials: _____

_____ Instructor's initials: _____

The following worksheet is designed to help you plan your experiment. You should work through each question with your lab partner in consultation with the instructors and TAs. Also, feel free to discuss your ideas with students in other groups.

When you have completed this worksheet, explain your answers to one of the instructors who will either approve your plan or suggest ways to improve. When your plan has finally been approved, which will be indicated by an Instructor's initials on this sheet, you should turn in one copy of this form and keep at least one copy for your group. This page will also go to Maria Kelly as the basis for your Introduction and Discussion sections of your paper. Note a copy of this form is on Moodle so that you can fill it out as a WORD document if you wish.

1. What is your experimental question? (You should consider the equipment and supplies available to you before finalizing this).
2. What do you think the answer is? That is, what is your hypothesis?
3. What lead you to this question? Example: journal article, textbook, previous experiment, etc.
4. Why is this question important to the scientific community or the public
5. Describe your experimental design.
 - A. What methods will you use?
 - B. What is the timeline (when will you do each step).
 - C. What will be your independent variable (what are you varying?)
 - D. What will be your dependent variable (what are you measuring?)
 - E. What are your controls?
 - F. How will you analyze and report your results? Will you use a graph, table?
6. Draw a "prototype" of the graphs and/or data tables you plan to use. Include a figure legend and labeled axes (in the case of a graph).
7. What do you need in order to carry out your experiment? Be specific.
 - A. Bacterial strains
 - B. Equipment
 - C. Media (plates or broth for growing bacteria)
 - D. Solutions (include concentration)
 - E. Special chemicals or reagents
 - F. Other

SCIENTIFIC PAPER GUIDELINES & EVALUATION FORM

TITLE

___ Does the title give an accurate preview of what the paper is about? (i.e. Is it informative, specific and precise?)

ABSTRACT

Your abstract is one of the most important parts of your paper. The abstract is a concise summary of your paper. It should include your hypothesis or question, describe the method(s) used, and emphasize results and conclusions. It should be a self-contained, single paragraph that accurately reflects the body of your paper. One rule of thumb in writing abstracts is to devote one or two sentences (no more!) to each section of the paper. An abstract is NOT an introduction!

___ Are the main points of the paper described clearly and succinctly?

INTRODUCTION --

Your introduction will introduce your reader to your subject, explain why you carried out your experiments, and provide the background information needed to understand the methods used and the importance of your findings. It should clearly introduce your question or hypothesis and the basis, based on previous observation by you or others and discuss methods available to address your question. Remember, your work is based on previous knowledge. You will include a review of relevant literature to introduce what is known to date about your problem.

A good way to organize the introduction is to begin with the general and proceed to the specific. Assume that the reader is moderately familiar with the general subject of the paper. This "hour-glass model" will help you focus your paper especially if the last paragraph of the introduction is "In our study we . . .". The "methods" and "results" sections are the narrow part of the hourglass and the "Discussion" will broaden out again covering the issues brought up in the "Introduction".

Hint—you should write the first draft of your introduction BEFORE doing your experiments but be ready to redo and edit this first draft as the data will prompt new insights and questions.

___ Does the Introduction have a logical organization? Does it move from the general to the specific?

___ Has sufficient background been provided to understand the paper? How does this work relate to other work in the scientific literature?

___ Has a reasonable explanation been given for why the research was done? Why is the work important? What is its relevance?

___ Is the final paragraph a brief description of the hypothesis/goals and findings of the paper?

MATERIALS AND METHODS

The materials and methods section provides detail about the experimental approaches used including organisms, media, solutions, key steps and analysis tools. Procedures that have been repeated should only be listed once. Variations to the procedure should be briefly summarized. The M&M should not read like a recipe), i.e., this section is written in a paragraph form in the past tense; do not use numbered, bulleted or dated steps in this section.

___ Could the study be repeated based on the information given here?

___ Is the material organized into logical categories?

RESULTS

The entire experimental findings of a paper should be apparent from reading the results section even without the other sections of the paper. The reader should understand the question the authors are asking, the experimental approach they use to answer the question, the results of those experiments, and basic analysis of the data. The data must be in figures or tables with legends and referred to in the text. Results are written in the past tense. Larger issues of what the research means, how it relates to other work, etc. should be included in the discussion.

___ Is the content appropriate for a results section?

- Simple introduction to the scientific question
- Brief description of the methods
- Clear description of the results for each experiment
- Analysis of those results

___ Are the results/data analyzed well?

- Given the data in each figure, is the interpretation accurate and logical?
- Is the analysis of the data thorough or are some aspects of the data ignored?

___ Figures

- Are the figures appropriate for the data being discussed?
- Are the figure legends and titles clear and concise?

DISCUSSION

The discussion should interpret and explain the meaning of your result and be an argument for a particular interpretation of your data. Discussions are written in the present: the results you observed are now discussed as though they are real and just as real as other people's results. A discussion usually proceeds from the specific to the general (remember the hourglass model of a paper). Begin with a one or two sentence summary of your results—just the important trends. Then relate your results to your own initial hypothesis or question: are they what you expected? What does that mean? Don't forget that "negative" results can be important too. It is also possible that your variable had "no effect" and that your data significantly show this. Sometimes the variability is high and this is an interesting fact. Relate your results to other published work. The discussion should point out the significance of your findings.

___ Does the author clearly state whether the results answer the question?

___ Does the author clearly articulate the basis for supporting or rejecting the hypothesis?

___ Were specific data cited from the results to support each interpretation?

___ Does the author make connections between data sets within the paper?

___ Does the author adequately relate the results of the current work to previous research?

REFERENCES

___ Are the references appropriate and of an adequate quantity?

___ Are the references cited properly (both within the text and at the end of the paper)?

WRITING QUALITY

___ Is the paper well organized? (Paragraphs are organized in a logical manner)

___ Is each paragraph well written? (Clear topic sentence, single major point)

___ Is the paper generally well written? (Good use of language, sentence structure)

Poster Guidelines and Evaluation Form

A poster is a visually informative way of explaining a research project that is enhanced when the authors are present but comprehensible when they are not. Typically a poster is a set of text and graphics put up in sections on a poster board. The sections are similar to a paper BUT a poster is NOT a paper. The text and figures must be visible from a distance of 6 feet away (large font, clear colors) so expect to use few sentences. Instead, information will be conveyed mostly in lists, diagrams and graphs using clear headings and a logical arrangement on the board.

What is needed?

Title—clear, informative and catchy in a large font.

Authors and their affiliation.

Very brief abstract of the entire project. This is a box of text in sentences and can be identical to the abstract in your paper.

Introduction or Background to your project – in a few words or diagram state the problem you are addressing and why.

Approach or Methods written in fairly general terms indicating the key variable and the range used, how data were collected (e.g., OD in spectrophotometer, plate counts etc.). A flow chart can often help here.

Results take center stage on a poster. Clearly present your findings in a graph or diagram as appropriate. Tables may be used if there are just a few numbers. The figure legend should contain key information about the particular experimental conditions and headings to each figure should clearly indicate what is being shown. Axes labels must be large enough to see. Bright colors and high contrast help convey results—use large symbols and thick enough lines to be seen far away.

Discussion will highlight the meaning of the results in the context of past knowledge and Future Experiments suggest what you would do next if you were to continue this project.

Finally, there should be an Acknowledgements section (were you grateful to your TA for advice?) and a short list of key References (cited in the poster).

SCIENTIFIC POSTER EVALUATION FORM

1. Does the poster have adequate background information allowing you to understand why the investigation was done?

Strongly disagree / disagree / agree / strongly agree

Explain:

2. Does the poster have a clearly stated hypothesis or question?

Strongly disagree / disagree / agree / strongly agree

If so, what is it? If not, explain:

3. Does the methods section adequately detail how the investigation was carried out?

Strongly disagree / disagree / agree / strongly agree

Explain:

4. Does the poster present the results in figures and tables that are easy to understand and appropriate for the data?

Strongly disagree / disagree / agree / strongly agree

Explain:

5. Did the presenter do a good job explaining the investigation?

Strongly disagree / disagree / agree / strongly agree

Explain:

6. Was the poster well laid out and aesthetically pleasing?

Strongly disagree / disagree / agree / strongly agree

Explain:

Bacterial Pathogen Oral Presentation Assignment

For this assignment, your group must create a 3-5 minute PowerPoint presentation on your assigned bacterial pathogen.

Use reliable written and electronic sources to investigate and answer the three questions below about your pathogen. Cite your references at the bottom of each slide.

On the title slide of your presentation, write the name of your bacterium and the names of your group members.

Maximize the visual appeal of your presentation by including pictures on each slide and minimizing the amount of text. (Don't forget to cite the source of your pictures).

Make sure to divide the work between all three partners – everyone must participate in both the research and the oral presentation.

Most of all, engage us and make us appreciate this topic and remember it!

Questions to be addressed during presentation:

Each group should address the following questions. To make this presentation easy to follow for your classmates, it is best that you clearly present the question (perhaps in the title of the PowerPoint slide) and then follow with what you learned in your research. These questions do not need to be addressed in this order. You may divide the work how you wish – different pathogens will require different levels of dedication to each question.

1. Focusing on the human: What are the symptoms of the disease caused by this microbial pathogen?
2. Focusing on the microbial ecology: Where does the bacterium normally live? Does it have a non-disease habitat? How is it spread?
3. Focusing on the bacterium at the sub-cellular scale: What virulence factors does this pathogen produce? In other words, what structures (like a flagellum or a capsule) or molecules (like a protein toxin) are necessary for the bacterium to cause disease?

Bacterial Pathogen Presentation Scoring Rubric

<p>The questions above were investigated and answered in a way that was:</p> <ol style="list-style-type: none"> 1. not clearly evident 2. evident, but undeveloped 3. appropriately developed and clearly portrayed 	Grade	Comments
<p>PPT slides or other visual aids were:</p> <ol style="list-style-type: none"> 1. not clear and/or not helpful 2. adequate 3. clear and efficient 		
<p>Quality of speaking (eye-contact, volume, clarity, organization) was:</p> <ol style="list-style-type: none"> 1. unacceptable 2. adequate 3. clear and articulate 		
<p>Overall level of engagement and enthusiasm was:</p> <ol style="list-style-type: none"> 1. Low 2. Adequate 3. Highly engaging – makes me deeply appreciate this topic and want to study it further! 		

Microbial pathogen:

Names of group members:

Bacterial Pathogen Presentation Sign-up Sheet

<i>Organism</i>	<i>Disease</i>	<i>(Name 1)</i>	<i>(Name 2)</i>	<i>(Name 3)</i>
<i>Bacillus anthracis</i>	Anthrax			
<i>Streptococcus pneumoniae</i>	Pneumococcal pneumonia			
<i>Enteropathogenic E. coli</i>	Food poisoning			
<i>Helicobacter pylori</i>	Ulcers			

<i>Neisseria gonorrhoeae</i>	Gonorrhea			
<i>Borrelia burgdorferi</i>	Lyme's Disease			
<i>Chlamydia trachomatis</i>	Chlamydia			
<i>Vibrio cholera</i>	Cholera			
<i>Mycobacterium tuberculosis</i>	Tuberculosis			
<i>Staphylococcus aureus</i>	Staph infection			
<i>Streptococcus pyogenes</i>	Necrotizing fasciitis			
<i>Clostridium tetani</i>	Tetanus			
<i>Clostridium botulinum</i>	Botulism			