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CUR Focus

Integrating Research Across Biology to Strengthen Senior Capstone Research

Abstract

Westminster College is a small liberal arts institution graduating about 35 biology and molecular biology majors annually. Ten years ago our department began requiring all seniors to complete individual capstone research experiences. During the initial years of this new research intensive requirement, preliminary assessment of student research proposals revealed that most capstone students were unprepared for utilizing scientific literature in an effective manner; were inexperienced at reading, interpreting and applying information from the literature; had difficulty identifying their own questions within their areas of interest; and failed to see the relevance of their work in real-world situations. Their lack of preparation in these areas diminished their enthusiasm and motivation for the capstone experience, which resulted in an unwillingness to take ownership of their capstone projects, leading to unsatisfactory student performance. Therefore, in 2011 we revised our introductory and intermediate biology courses in order to better prepare our students for the goals and objectives of our capstone course as well to provide students with the skills needed for a broad range of careers in the biological sciences. This article highlights the revisions made throughout our curriculum so that students could: (1) gain more experience with scientific literature; (2) develop better questions and testable hypotheses based on current knowledge; (3) improve experimental design as well as understanding of how to collect, analyze, and interpret data; and (4) report findings and conclusions in a more effective and professional manner. Following implementation of our curricular revisions, qualitative and quantitative as-

essment indicated that a number of our goals and objectives are being achieved. Student understanding and application of the scientific process has shown noticeable improvement, which has ultimately led to improvements in the quality of our students' research experience.

Introduction

Westminster College is a small liberal arts institution graduating about 35 biology and molecular biology majors annually. Ten years ago we began requiring senior capstone research in our biology curriculum, and beginning in 2011 we revised our introductory coursework to include more authentic research experiences. These changes to our courses (see Table 1 for the general curriculum outline) were developed to better prepare our students for the capstone and to better provide students with the skills needed for careers in which they must apply and communicate science (AAAS 2010).

Our overall aim for both the introductory and capstone courses was to help students to: (1) gain experience with scientific literature; (2) develop good questions and testable hypotheses based on current knowledge; (3) design experiments and collect, analyze and interpret data; and (4) report findings and conclusions in an appropriate professional style (laboratory notebooks, primary research papers modeled on undergraduate research journals, NIH-style grant proposals or conference-style posters).

We emphasized literature to help students develop an understanding of current knowledge pertaining to a topic, and to understand how science is communicated. Scientific literacy involves higher-level cognitive activities (Bloom 1956), has

Table 1. Westminster Biology Core Curriculum

Course Number and Title	Student Population	Linked lab	Sections (10-24 students)	Instructors
BIO 201 Cell Biology and Genetics	Freshmen	Yes	5 or 6 fall semester	1 per section
BIO 202 Evolution, Form and Function	Freshmen	Yes	3 or 4 spring semester	1 per section
BIO 203 Biodiversity and Ecology	Sophomores	Yes	2 fall semester	1 per section
BIO 206 Biostatistics and Experimental Design	Freshmen/Sophomores	No	1 every semester	1 per section
BIO 601 Biology Capstone	Juniors	No	2 spring semester	2 per section
BIO 602 Biology Capstone	Seniors	No	2 fall semester	2 per section
Bio 300 - 400 Advanced Electives (5 required)	Sophomores-Seniors	Yes	Varies by semester	1 per section

been shown to greatly enhance research skills (Carey and Colicelli 2005), and is an essential skill for success in graduate school or in technical careers (Alberts 2009). The ability to interpret literature in turn prepares students to develop better questions and design experiments, allowing for the use of inquiry-based methods, which cultivates students who view science as solving problems rather than merely involving performance of tasks (Gormally et al. 2011). Finally, we focused on helping students learn to analyze and report the outcomes of their research, as these were areas where growth was needed. Studies have found that students' skills in quantitative thinking, in particular, are deficient across the biological curriculum (Bialek and Botstein 2004), but such skills are essential to preparing students for the growing need for quantitative approaches to biology (National Research Council 2003). Furthermore, assessments that require students to write in a format suitable for publication in a specific setting have traditionally not been used in undergraduate teaching, but reports of the benefits of such assessments are on the rise (Gliddon and Rosengren 2012).

A Research-intensive Capstone

Requiring an individual research project is a straightforward mechanism for providing all students with an authentic scientific experience (Lewis et al. 2003) and, given the small class sizes at Westminster (15 to 40 per cohort), it was an easily achieved goal. In the spring semester of their junior year, biology majors enroll in a capstone course (see Appendix A for the Bio 601 syllabus). Each student is matched with a faculty advisor to draft a research project of the student's own design, within the advisor's area of expertise. In order to achieve our programmatic goals, the design phase includes an extensive literature review and the writing of a research proposal. During the fall semester of their senior year (see Appendix B for the Bio 602 syllabus) biology majors complete their research and subsequently present their results to faculty and peers during a juried poster session. Throughout both semesters, students attend capstone classes in which their progress is monitored and assessed by capstone instructors using various assignments (Table 2).

Table 2. Research Activities, Assessment in Westminster Biology Capstones

Course	Assignment	Outcome Assessed
Bio 601	Journal Club Presentation	1) Gain experience with scientific literature
	Journal Club Review	4) Report findings and conclusions in a professionally appropriate style
	Annotated Bibliography	1) Gain experience with scientific literature 2) Develop good questions and testable hypotheses based on current knowledge
	Question Summary	2) Develop good questions and testable hypotheses based on current knowledge
	Proposal Presentation	2) Develop good questions and testable hypotheses based on current knowledge 3) Design experiments; collect, analyze, and interpret data 4) Report findings and conclusions in a professionally appropriate style
	Pilot Study Summary	3) Design experiments; collect, analyze, and interpret data 4) Report findings and conclusions in a professionally appropriate style
	Proposal Drafts	1) Gain experience with scientific literature 2) Develop good questions and testable hypotheses based on current knowledge
	Final Proposal	3) Design experiments; collect, analyze, and interpret data 4) Report findings and conclusions in a professionally appropriate style
	Qualifying Exam	2) Develop good questions and testable hypotheses based on current knowledge 4) Report findings and conclusions in a professionally appropriate style
Bio 602	Project Update Presentation	2) Develop good questions and testable hypotheses based on current knowledge
	Poster Progress Presentation	3) Design experiments; collect, analyze, and interpret data
	Poster Draft	4) Report findings and conclusions in a professionally appropriate style
	Poster Session Presentation	

Over the first few years of implementing the capstone experience it became clear that our expected outcomes were not being met. Assessment of students' research proposals during the first semester of the capstone revealed that students were inexperienced at utilizing appropriate databases to find relevant literature; were inexperienced at reading, interpreting and applying information in the literature to formulate good questions of their own; and failed to see the relevance of what they were doing to real-world situations. Their lack of preparedness in these areas diminished their motivation to see their academic activities as meaningful and to try to attain benefits from them (Brophy 2004; Glynn et al. 2009). Lack of preparation and motivation resulted in unwillingness to take ownership of their capstone projects, which was likely a major contributing factor in poor performance since lack of motivation correlates significantly with underachievement (Balduf 2009).

Moreover, students' familiarity with their faculty members' research interests was surprisingly limited and, being unaware of the range of methodologies available to them, students frequently based their questions on preconceived ideas of what they thought could be achieved, rather than formulating good questions and then utilizing appropriate methods to answer them. Some students even expected faculty to provide them with defined projects, which circumvented the need for independent inquiry and an extensive review of the literature.

Such issues persisted through the development of their research projects in the first capstone course (Bio 601) and into the conduction of their research in the second capstone (Bio 602). Posters displayed deficiencies in students' ability to analyze and communicate results; students struggled with the application and interpretation of statistical tests necessary for proper analysis of biological data. For example, about 75 percent of the total of 225 students in our cohorts from 2005 to 2013 who performed statistical analysis used only ANOVA (Analysis of Variance), with over half of them using ANOVA inappropriately.

Further, the majority of capstone students were uncomfortable or unfamiliar with the oral and written communication styles of scientific information, leading them to perceive the goals and objectives of assignments that integrated literature and research to be unrealistic and difficult (Waters 2015). Moreover, there was a disconnect between faculty expectations and student performance in the proposal and presentation assignments. Our faculty was disappointed with the caliber of capstone work, with an average of 6 percent of students (one to three students, depending on class size) each year failing to adequately meet faculty expectations

Westminster Senior Meredith Mishler presents her capstone research to first-year students at the course poster session.

for capstone work, and thus not receiving a passing grade in the course.

To address the writing and motivational issues, we made the experience more realistic and relevant to science-related careers by replacing faculty-written guidelines with the NIH grant-writing guidelines (NIH 2010). Additionally, a written qualifying exam was added at the end of Bio 601, directly addressing the students' comprehension of both the scientific process and their own specific project. Since making these changes the students seem more engaged, and the quality of their proposals has improved. When surveyed, 60 percent of our eight biology faculty members agreed that capstone students now formulate more-sophisticated questions than previously, and these questions are the core of their research proposals.

Further, as seen in other models (Kember et al. 2008), making the capstone course as realistic an experience as possible has improved the course dramatically. Our course design could be translated to other small institutions with manageable student-to-faculty ratios for individualized research, but it also could be modified to work at larger institutions as well. Expansion could be achieved either through a selection and requirement process to identify specific students for advanced research or through an approach that has all students complete the literature search and project design assigned in Bio 601 without performing the bench work required in our Bio 602 course, an approach that has been successful at other institutions (Valter and Akerlind 2010). However, we also propose that the most successful research capstones are built upon early introduction of all the skills required to develop students into well-rounded scientists.

Table 3. Introductory Biology Laboratory Module

	Content	Assignments	Outcome Assessed
Session 1	Learn relevant background information	Reading comprehension quiz	1) Gain experience with scientific literature
	Learn appropriate methodology		
	Perform controlled experiment	Lab notebook	4) Report findings and conclusions in a professionally appropriate style
Session 2	Data analysis of controlled experiment	Lab notebook	3) Design experiments; collect, analyze, and interpret data 4) Report findings and conclusions in a professionally appropriate style
	Literature search of relevant topics	Literature search worksheet	1) Gain experience with scientific literature
	Develop new question and hypotheses based on controlled experiment and literature search	Experimental design worksheet, lab notebook	2) Develop good questions and testable hypotheses based on current knowledge 3) Design experiments; collect, analyze, and interpret data 4) Report findings and conclusions in a professionally appropriate style
Session 3	Carry out independently designed experiment and analyze data	Lab notebook	3) Design experiments; collect, analyze, and interpret data 4) Report findings and conclusions in a professionally appropriate style
	Write research paper	BIOS-style research paper	

Introducing Research into Introductory Courses

The changes introduced at the senior-year level improved the ability of our students to meet our program objectives; however, the synthesis and execution of an independent research project also required changes designed to develop students' baseline skills across all of our objectives earlier in the curriculum. Our introductory biology courses (Table 1) are composed of linked laboratory and lecture sections taught by the same instructor. Until 2011, the required lab component of each course included a series of stand-alone labs, each assessed with a short report that focused on results and conclusions. These labs introduced students to a variety of skills and concepts, but emphasized breadth of coverage over depth and inquiry. Most of the lab exercises were narrowly focused, addressing a specific skill or concept that neither connected to topics that engaged the students nor required a comprehensive literature review for the stu-

dents to formulate testable hypotheses. Information-literacy assignments were generally stand-alone exercises that were not linked to a lab exercise, which is thought to reduce their efficacy (Carey 2005).

Further, students were unmotivated in conducting the exercises and writing their lab reports because we failed to help them understand the relevance of the activities to professional research and because students were confused by different expectations among professors regarding the style of the lab reports. Some faculty members expected more formal lab reports than others. In order to better achieve our desired student outcomes, we altered the curriculum so that students developed the needed skills, and we intertwined them logically to better reflect how scientific research occurs. The introductory series of labs was transformed into a combination of skills workshops and several multi-week research modules in each course, a successful trend in inquiry experiences (Colabroy 2011; Gliddon and Rosengren 2012). Skills workshops introduce methodology or concepts (microscopy, spectroscopy, information literacy, etc.), whereas modules aim to meet all of our desired outcomes for students' research experiences (see Table 3 for the general overview of a research module).

One of the hardest transitions for first-year students into this style of learning is finding appropriate literature, being able to understand and incorporate the

content into their own experiments, and writing in a clear, succinct scientific style. Previous studies indicate the importance of trying to introduce these skills early in order to develop long-term benefits (Sato et al. 2014). We took multiple approaches to improve our students' expertise in these areas. First, the initial skills workshop in Bio 201 is a computer laboratory session in which we instruct students about finding literature using the most appropriate databases and resources for the field of study (which varies by course content), and we introduce EndNote as a tool for managing citations.

Throughout subsequent research modules, guided homework or in-class assignments are used to ensure that students not only find literature, but also assess the relevance and usefulness of sources for experimental design and the content of research papers. These exercises have students describe their search process and use of key words, classify

sources as primary or secondary, summarize article contents, and indicate how content will be used in their research papers.

Students are first introduced to the module system in Bio 201 with a series of exercises that focus on the scientific method, incorporating an experiment tied to the summer reading assignment from the Westminster College “Next Chapter” First-Year Program, which is intended to connect a common summer reading to several curricular experiences in the freshman year. Such modules have included exploring the anti-bacterial properties of tea in conjunction with *The Ghost Map* by Stephen Johnson and examining the effect of cellular stresses on protein expression in HeLa cells to complement *The Immortal Life of Henrietta Lacks* by Rebecca Skloot (described in detail in Resendes 2015).

Further modules were developed by transitioning existing lab activities into modules. For example, before curricular revision, Bio 201 students performed a common exercise using spectrophotometry to measure peroxidase enzyme activity, submitting their results as a short lab report. The transformation of this exercise into a research module exemplifies the template (Table 3) used for all of our modules. The first session of the module involves a “canned” experiment on the effect of an “unknown substance” on peroxidase activity that introduces the required methodology, as well as data collection and analysis for subsequent experiments. The second session involves no wet work; rather, students use graphs to determine that the unknown substance in their experiment was an inhibitor. Then they work in teams to find relevant primary and secondary literature to help them formulate questions and hypotheses about variables that might affect enzyme activity. Using the literature, they design experiments to test their hypotheses, and develop the introduction and discussion sections of their research papers. During the final week of the module, students conduct their experiments and analyze data. The final product is a primary research paper in the style of the journal *BIOS*, an undergraduate research publication from the TriBeta National Biology Honor Society.

We propose that it is the style of these modules that provide the strength to our curriculum; 75 percent of our faculty agreed that students in capstone cohorts who were trained using the introductory module system use more relevant sources than previous cohorts, and 50 percent agreed that students are better at incorporating these sources into their capstone proposals. Additionally, as noted above, before the incorporation of modules into our introductory curriculum, on average 6 percent of students did not receive a passing grade in capstone courses. Our first cohort at Westminster taught with the module-style introductory courses began the capstone process in 2014, and every student in both this cohort and the next met course expectations and received a passing grade in Bio 601.

Dr. Kathy Robertson evaluates Westminster Senior Caitlin Stiffler's senior capstone poster presentation.

These outcomes suggest that the consistency in format and expectations for both the laboratory sessions and linked assignments prepared students for realistic research experiences in capstones and beyond. Previous studies demonstrate that when introductory courses are transitioned to discovery-based, multi-week modules, students go on to engage in intermediate and advanced courses with increased confidence and enthusiasm (Gormally et al. 2009; Ronsheim et al. 2009).

The module format can easily be fashioned to fit existing curricula and works well for different content areas in biology. For example, this mixture of skills workshops and modules is used in Bio 202 (Evolution Form and Function), which is taken in the spring of the first year. Students are exposed to new methodologies, while skills in the identification and use of literature resources and the writing of research papers are reinforced. Modules in this course include experiments in molecular phylogenetics and in cardiac physiology using *Daphnia*. In Bio 203 (Biodiversity and Ecology), half of the course focuses on ecological principles and is well-suited to reinforcing the scientific method. The modules in this course transition students into new areas, introducing students to ecological studies in which hypotheses are tested without manipulating a system and to independent projects with fewer constraints on methodology and systems.

Incorporating Experimental Design, Statistical Analysis

The scaffolded introduction to experimental design, analysis of research literature, and scientific communication offered in Bio 201, 202, and 203 did not fully address the students' lack of experience with data interpretation and statistical analysis. Students still struggled to understand how the choice of statistical test could serve as a framework for study design, and they admitted to being uncertain about what statistical test was appropriate for their data. Therefore, in 2008 we added a required course, Bio 206: Biostatistics and Experimental Design to the curriculum as a prerequisite for capstone courses (see Appendix C for course syllabus). This course builds on the concepts of hypothesis-testing and ex-

perimental design and exposes students to more advanced graphing and data-analysis techniques. These objectives are achieved by emphasizing the importance of making a research plan by introducing elements of good experimental design such as replication, controls, randomization, and blocking. In doing so, students are taught that they must consider statistical issues early to avoid flaws in study design. These concepts are introduced using real biological questions, and the students go on to design experiments using these principles.

To develop student skills in data analysis and eliminate the tendency to use raw data, this course also teaches students how to summarize and visualize their data with tables and figures. Specifically, we use graphing assignments that include creating proper table titles or figure legends, and written descriptions of patterns in the data. Then, to help students interpret their data, they are introduced to a tool kit of both categorical and numerical statistical tests, and how to execute them with computer software (for example, IBM SPSS Statistics for Windows; Minitab Statistical Software). As each test is introduced, students build a flow chart based on the type of biological question and the type of variables that were measured. This assignment helps them to systematically work through problems and serves as an important reference for lab experiments. In addition, problem sets require students to use probability-based outcomes of statistical tests to interpret biological questions.

Finally, we continually emphasize that statistical tests are a very useful tool, but that students must remember to also think critically as biologists because statistical significance is not the same as biological importance. As a result, we have seen an increase in the ability of students to read and critique results in the literature, and an increase in the rigor of their analyses in capstone research. As indicated in Table 4, once Bio 206 was introduced into the curriculum we saw both an increase in the number of different statistical tests used by students in their capstone posters and a decrease in students relying solely on an ANOVA, the main test they were aware of previously. These trends began with students who opted to take Bio206 voluntarily before it became a required prerequisite for the capstone (Table 4), and the trend continued moving forward.

This successful incorporation of experimental design and statistical analysis can be introduced into a curriculum in

various ways at other institutions. While the development and incorporation of a new course as we have done is one option, these skills can be woven into existing courses by purposely developing modules in which emphasis is placed on experimental design and the introduction of statistical tests relevant to the particular type of data that would be generated in a specific module.

Reinforcing Outcomes in Advanced Courses

In addition to the introductory 200-level sequence and the capstone experience, our curriculum requires five elective courses, with nearly all electives including a required laboratory section. Reinforcement of all of our desired student outcomes is now more intentionally continued in these upper-level electives so that students are able to identify practices common to different disciplines, for a more holistic, inquiry-driven approach to their education. Students continue to read, analyze, and interpret primary articles pertinent to the course-specific discipline; their skills are typically assessed through journal-club workshop presentations.

At the advanced level, when primary articles are more specialized and intimidating to students, further training is provided. For example, in several courses a three-week journal-club workshop is included in the syllabus; we teach students to read primary articles using a systematic method, which focuses on interpreting figures using a process-oriented, guided-inquiry learning (POGIL) model (Moog and Spencer 2008). Students create their own rubrics to guide their presentations (Robertson 2012). Students who have taken the workshops subsequently get better grades than students who have not, earning more A's and B's and fewer grades of C or lower (Robertson 2012). Students' perceptions of the workshop also indicate they feel that they gained greater confidence in their abilities. In a survey, 85 percent of students reported that they felt better prepared to present a paper after doing the workshop, and 97 percent said it helped them to better understand and feel more confident about reading primary literature for other classes (Robertson 2012).

In addition to advanced training in literature interpretation, approximately 50 percent of the lab sessions in our upper-level courses are discovery-style, and several include a semester-long project. Projects are often centered on the instructor's own research area, which fosters interest by students in potential capstone projects. In many of these

Table 4. Students' Improved Statistical Analysis in Capstone Posters

Outcome	Student Cohorts before Introduction of Bio 206 (Biostatistics and Experimental Design)	Mixed Cohorts (Only Some Students with Bio 206 Experience)	Cohorts after Bio 206 Was Required for Capstone
Average number of different statistical tests used per cohort	7.5	7	10.3
Average percent of students relying solely on ANOVA (Analysis of Variance) for statistical analysis per cohort	43%	14.30%	15.20%

projects, we encourage students to utilize primary literature and other sources of information to support their questions and hypotheses. For example, in the course titled *Animal Behavior* students observe a species of their choice in the field for several weeks and develop an ethogram. Their ethogram, supplemented with primary sources, becomes the basis for their question. In *Developmental Biology*, students use data and observations collected during lab experiments as the basis for formulating “next-step” questions (Moog and Spencer 2008) and writing mini research proposals. The reports for such projects are written in the style of a journal relevant to the course discipline.

For example, students in *Cell and Molecular Biology* use the style of *Cell*, and *Animal Behavior* students write in the style of *Animal Behaviour*, and are referred to the “instructions for authors” on the *Animal Behaviour* website to develop their own style guidelines. These types of modifications are a great first step at broadening the use of literature and research in the curriculum and also allow instructors the freedom to incorporate skills that are specific to their particular subfield. These experiences prepare students for advanced independent research both at the undergraduate level and beyond.

Outcomes

Through the modification of our introductory courses and the capstone experience itself we have achieved success, to varying degrees, in achieving each of our desired student outcomes. Regarding the goal of increasing our students’ experience with scientific literature, the use of primary sources has increased and student searches are more targeted, so the papers they find are more relevant to their experiments. Before the use of modules, although students were encouraged to seek primary sources for their lab report discussions, the average number varied from none to two to five per course by motivated students. Now, students are expected to use at least three primary sources per module, making their minimum use nine sources per course, with motivated students finding and using up to 15 sources per course. In addition, the use of EndNote for collecting, organizing, and citing articles occurs uniformly among all capstone students.

Regarding experimental design, our faculty members have reported both an improvement in the quality of research questions asked and increased sophistication in experimental design. Additionally, the overall use of statistical analysis has increased, with students selecting methodologies that are more appropriate for their data (Table 4). Finally, the overall quality of the capstone projects and presentations has improved dramatically, with 60 percent of faculty reporting increases in students’ confidence and articulation at their poster presentations. Most importantly, there has been a decline in students failing to meet course expectations, and we have seen a rapid increase in students with research projects of high enough caliber for external presentation.

Specifically, capstone cohorts before the Bio206 requirement sent on average 26 percent of seniors (three to six students, depending on class size) to present their work externally, whether at regional Tri-Beta honors society meetings, NCUR (National Conferences on Undergraduate Research), or discipline-specific national meetings. Beginning with the 2011 capstone cohort, at least 50 percent of seniors (15 to 20 students depending on class size) presented their research at external meetings. This change reflects the opinions of our faculty on the quality of capstone projects, as it is the responsibility of the research mentor to decide whether a student’s work is of sufficient depth and merit for external presentation.

As a whole, we have experienced success in improving the quality of our students’ capstone research on multiple levels, and have provided them with an enhanced skill set in applying and communicating science through the incorporation of research and analysis throughout our curriculum.

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Kerri Cornell Duerr is an assistant professor in the Biology and Environmental Science Programs at Westminster College. She teaches courses in biodiversity and conservation, ornithology, and biostatistics. Her research interests focus on the effects of multi-scale habitat patterns on the demography of bird populations. Duerr received her MS from Villanova University and her PhD from the University of Vermont. She is a member of The Wildlife Society and the American Ornithologists' Union and serves on the Council for the Wilson Ornithological Society.

Katherine Robertson is an associate professor of biology at Westminster College. Her research interests focus on learning and memory in social insects and the development and plasticity of connections in the brain. In pedagogical research, Robertson is interested in how students perceive and assimilate different scientific methodologies. Her work has been published in *Developmental Biology, Development, and the Journal of College Science Teaching*, among other venues. She received her PhD in developmental biology from the University of London, UK, and has done postdoctoral research at Carnegie Mellon University. She also has taught at Duquesne University in Pittsburgh.

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Appendix A: Bio 601 Syllabus

Biology Capstone

BIO 601 (01)

Spring 2016

INSTRUCTORS

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LECTURE

M, W, 8:10 - 9:10 AM

Place: 150 Hoyt Science Center

Attendance in class is mandatory. Because part of your grade in the course will be based on participation and because it is essential for you to be engaged with what is going on in this course, your success depends on being in class. Absences will only be excused for documented personal emergencies or health-related problems. If you miss a class, it is your responsibility to contact us and make yourself aware of any information or assignments that you missed. Any missed group work must be made up on an individual basis and will be graded on an individual basis.

REQUIRED: a three-ringed binder, in which you will keep assignments and course materials. This will become your portfolio (see below) and will be handed in at the end of the semester for a grade

COURSE OBJECTIVES

1. During BIO 601, each student will:
 - a) Initiate discussions with potential faculty research advisors in order to develop a research project;
 - b) Identify questions, using appropriate literature and resources, that are of potential importance to our understanding of the natural world, and are within an area of interest of Westminster faculty;
 - c) Select a faculty advisor and work in collaboration with them to develop a proposal for a project (to be carried out in BIO 602): formulate a good specific question, select appropriate experimental methodology and identify a suitable model system with which to study your question;
 - d) Complete a pilot project to assess the feasibility of your research;
 - e) Present your ideas to other students and learn how to incorporate constructive criticism and suggestions into the experimental design and final proposal;
 - f) Write a comprehensive research proposal in the style of a NIH grant application, as outlined in the provided guidelines
2. Evaluate and assess current concepts, theories and ideas in the field of biology through active review of primary literature and active engagement in current scientific methodologies
3. Continue to develop the qualitative and quantitative reasoning skills required for scientific inquiry and data analysis;
4. Enhance your information literacy, including facility in locating, reading, and interpreting scientific articles;
5. Strengthen your written and oral communication skills and problem-solving skills

COURSE CONTENT

Participation: You will be expected to participate in all class discussions by asking questions or offering insights and suggestions to your peers. Attendance alone is not enough to gain participation points. Unexcused absence from class will negatively impact your participation grade.

Identification of a research advisor: Following a faculty fair (date TBA) you must talk to several faculty members whose research interests you, and identify 2-3 whom you would like to work with on your project. You will be asked to submit a short application to each of those people with an explanation of why you want to work with them. The faculty will select students to work with them based on your applications. All effort will be made to match you to your first or second choice, keeping in mind that students will be divided evenly among the faculty.

Annotated bibliography: You will be expected to obtain and read at least 10-12, relevant primary articles and at least 6 relevant secondary articles from suitable sources; this is necessary for you to adequately identify a good question and discuss the background to your proposed project. You are strongly encouraged to ask your research advisor for an article or two to start you off and get you on the right track. You will be expected to submit a summary of the information you have gained from each article, highlighting relevance to your project in an annotated bibliography. Each entry should include (1) proper citation of the source (in the style of a journal within your field and approved by your advisor), (2) an explanation of why this source is relevant for your proposal, (3) a copy of the first two pages of each source that includes identification of the source as primary or secondary.

Question summary: You will refine your questions and ideas through reading and discussion with your research advisor and identify a specific question that you wish to investigate through your fall research project. Your final question should be novel, and should have potential importance to our understanding of the natural world. You must write summary of the question and a statement describing how the question is relevant to biology, approved and signed by your research advisor.

Journal club presentation: You will be expected to present the data from the primary research paper that is most relevant to your proposal ideas to the rest of the class in a clear, informative, and critical style, focusing on 1 or 2 key figures. You will develop your own guidelines for your presentation during a primary paper reading workshop

Journal club review: Students who are not presenting a paper on a given day will review a paper being presented by another student. Reviewers will write a 1 page summary of the paper being presented and a brief critique of the paper as well as the presentation. The reviewers will also decide whether they would accept the paper for publication in a hypothetical journal, or reject it, and explain their decision in writing.

Proposal first draft: Having identified your question, you will write a first draft of your research proposal using the NIH research grant application guidelines. These will be provided in a separate document. This draft will be written and submitted in parts. Specific Aims and Significance will be due first; Approach (Methods), Concluding Remarks, Citations, and Abstract will be due at a later date. Incomplete versions will not be accepted. A 5% reduction in possible points will be applied for each day the selected portions are late. Any portion of the proposal that is more than 1 week late will receive a grade of zero (0).

Proposal presentation 1: You will make an informal presentation of your ideas for your proposal to your peers and instructors, and a description of your intended pilot study. You will not be given basic guidelines for the contents of this presentation – but part of your grade will be based on your own, effective presentation design.

Pilot study: You will perform one or two pilot experiments in order to determine whether your chosen methodology is manageable, reliable and reproducible. Grant-awarding bodies will usually not fund a research proposal without some preliminary data that shows the chosen methods are reasonable and appropriate. You will be asked to write a report of what you did, what you found, and how you intend to continue.

Proposal presentation 2: You will make a formal, PowerPoint presentation of your research proposal to your peers and instructors, which you will have modified from presentation 1, based on feedback and your pilot study. You should include a description of and data from your pilot study. You will not be given guidelines for this presentation – part of your grade will be based on your own, effective presentation design.

Final proposal: Feedback from your initial version along with results of the pilot study should be used to write the final draft of your proposal. A 5% reduction in possible points will be applied for each day the proposal is late. Any proposal that is more than a week late will receive a grade of zero (0).

Portfolio: You will be expected to keep your question summaries, annotated bibliography, the first two pages for all papers used for the proposal (in an organized manner that matches the bibliography), final proposal, graded versions of the initial proposal in a neat, professional portfolio. Your portfolio will be graded at the end of the semester.

URAC: You will be expected to attend the Westminster Undergraduate Research and Arts Celebration (URAC) on April 20th and write summaries of 2 presentations. The presenters must have done their research in Biology, Molecular Biology, Neuroscience, Chemistry, Biochemistry, Physics or Environmental Science. You will write a 1 page, critical summary of one oral presentation and one poster.

Final - Capstone Qualifying Exam: Assessment of your proposal presentation will be used to customize final exams that test comprehension and recall of important concepts specific to your project. The qualifying exam will consist of 2-4 questions that are specific to your project, followed by a more general short essay question that every student will be required to answer.

GRADING

Assignment	Points
Participation	60
Annotated Bibliography	100
Journal club presentation	50
Journal club review	20
Question summary	25
Proposal draft 1 (Submitted in two parts)	200
Pilot study summary	65
Proposal presentation 1	50
Proposal presentation 2	50
Proposal final draft	200
Research URAC summaries (2 @ 15 points)	30
Portfolio	50
Capstone Qualifying Exam	100
Total	1000

Above 93%: A	87% - 89.9%: B+	77% - 79.9%: C+	67% - 69.9%: D+	below 60%: F
90% - 92.9%: A-	83% - 86.9%: B	73% - 76.9%: C	63% - 66.9%: D	
	80% - 82.9%: B-	70% - 72.9%: C-	60% - 62.9%: D-	

BIO 601(01) – Capstone – Spring 2016 - Course Schedule (subject to revision).

Date	Topic	Assignments
W, 20-Jan	Introduction to Capstone	
M, 25-Jan	5:30 PM – Faculty Research Fair	Location HSC 150
W, 27-Jan	Finding scientific literature and endnote	<i>Application for top 3 research advisors due F, 29th Jan</i>
M, 1-Feb	Journal club workshop	
W, 3-Feb	Research advisors assigned & Journal club workshop	
M, 8-Feb	Review of literature & journal club worksheet	
W, 10-Feb	Review of literature & journal club worksheet	
M, 15-Feb	Journal club presentations	
W, 17-Feb	Journal club presentations	
M, 22-Feb	Journal club presentations	
W, 24-Feb	Writing Specific Aims & Significance	<i>Journal club reviews due, W</i>
M, 29-Feb	Proposal presentation 1 <i>(feedback for proposal)</i>	<i>Question Summary and Annotated Bibliography due, W</i>
W, 2-Mar	Proposal presentation 1 <i>(feedback for proposal)</i>	
M, 7-Mar		
W, 9-Mar	<i>No class, Spring break</i>	
M, 14-Mar	TBA	<i>Specific Aims & Significance due, M</i>
W, 16-Mar	TBA	
M, 21-Mar	Writing Approach & Concluding Remarks	
W, 23-Mar	Writing an Abstract	
T, 29-Mar	Peer editing	
W, 30-Mar	TBA or peer editing	<i>Approach, Concluding Remarks, Citations & Abstract due, W</i>
M, 4-Apr	Proposal presentation 2 <i>(feedback for proposal)</i>	
W, 6-Apr	Proposal presentation 2 <i>(feedback for proposal)</i>	
M, 11-Apr	Trouble shooting/writing questions	
W, 13-Apr	Trouble shooting/writing questions	<i>Pilot study report due, W</i>
M, 18-Apr	TBA	
W, 20-Apr	<i>No class, URAC</i>	
M, 25-Apr	TBA	<i>URAC Summaries due, M</i>
W, 27-Apr	TBA	<i>Portfolio & Final Proposal due, M</i>
M, 2-May	Preview of possible questions for final	
W, 4-May	TBA	

**R, 12-May
11:30 –
2:00 PM**

FINAL EXAM

Academic integrity: The issue of academic integrity is taken very seriously at Westminster. Students are expected to abide by the College Policy on Academic Integrity. The policy can be found in the college catalog, available online at: http://www.westminster.edu/acad/undergraduate_catalog.cfm

Academic integrity is particularly important when dealing with scientific writing. We encourage students to work together, and discuss their assignments. But written assignments must be the original work of each student. Quotes, data or ideas taken from another source must cite that source fully and correctly. Work that is not the students own (*i.e.*, copied from an external source, a classmate, or class material) is considered to be plagiarized, and will receive a score of zero for the assignment. Note: plagiarism includes extensive, unnecessary quoting from another source, even if it is cited. More than one incident of plagiarism will result in a grade of "F" for the course. If in doubt, ask.

In the case of your research project, if your question, ideas, experiments or data are not your own and have been previously published by someone else, or if you fabricate, falsify or modify your data, you will earn an "F" for the course. These violations of integrity amount to scientific fraud; persons attempting to publish fraudulent work are liable to prosecution.

"Accessibility Statement"

Westminster College actively strives for the full inclusion of all our students. Students with disabilities who require access solutions for environmental or curricular barriers should contact Faith Craig, Director of Disability Resources, located in 209 Thompson-Clark Hall. Phone: 724-946-7192 e-mail: craigfa@westminster.edu

Appendix B: Bio 602 Syllabus***Biology Capstone II******Bio 602 (01)******Fall, 2015***

BIO 602: Biology Capstone II is the continuation and culmination of the capstone experience that you began in the spring with BIO 601. This semester, you will primarily work independently on your original, individual research project. You will ultimately synthesize the results of all of your work in BIO 601 and BIO 602 to produce a poster that effectively represents your research efforts, results, and conclusions. You will present that poster in a public research symposium on December 4th.

We will meet as a class only occasionally. Those class meetings will help you develop your project, make progress and stay on track, and will give you the opportunity to present summaries and receive critiques of your ongoing work. We expect that you will work closely with your capstone advisor throughout the semester. We recommend that you schedule regular meetings with your research advisor to discuss your project's progress, establish and assess specific research goals and the project timeline, and talk about any difficulties or issues that arise in your work. It is imperative that you work closely and effectively with your research advisor. Not only will this collaboration benefit you and your project, but 50% of the grade in BIO 602 derives from your research advisor's evaluation of your performance.

On Friday, December 4th, you will present your research poster at a professional symposium. Students, faculty, staff, and administrators from across campus will be invited to attend that event. You will be given the opportunity to showcase what you have accomplished, to discuss your research and answer questions. Students from a number of courses will attend that poster session, so you should expect to be kept busy presenting your work to a large and diverse audience. This symposium is a great opportunity for you and the Department of Biology to showcase your research and celebrate what you have accomplished in your capstone experience.

INSTRUCTORS

Dr. Ann Throckmorton

Dr. Kathy Robertson

Office: 311 Hoyt Science Center
Phone: 724-946-7209217 Hoyt Science Center
724-946-7213e-mail: athrock@westminster.edurobertkl@westminster.eduOffice hours: Monday 9:20 - 10:20
Wednesday 12:50 - 1:50
Thursday 12:40 - 2:00Tuesday 9:30 - 10:30
Thursday 8:30 - 9:30**LECTURE**

Monday, Wednesday 8:10 - 9:10

150 Hoyt Science Center

Attendance in class is expected. Because part of your grade in the course will be based on participation and because it is essential for you to be engaged with what is going on in this course, your success depends on your presence in class. Absence may be excused for personal emergencies or health-related problems. If you miss class, it is your responsibility to contact us to obtain information and make arrangements to make up the work you missed.

COURSE GRADING

Grades in BIO602 will be based on the quality of your research work and on your poster presentation. Grades will primarily be determined by three things:

1. Your research advisor's assessment of your capstone performance. Your grade will not be determined by the outcome of your results but you will need results in order to earn a grade.
2. An evaluation of your poster and poster presentation by two to three biology department faculty members (other than your research advisor), and
3. Performance on in-class presentations and written assignments.

Advisor evaluation: 500 points

Your research advisor will assign a grade based on your capstone performance. He or she will consider the difficulty of your project, your effort, your ability to work independently, your problem-solving abilities, your capacity to work through difficulties and issues, how effectively you present your work in your poster, and other research-related areas in evaluating your performance. To do well, you must work closely with your research advisor throughout the semester.

Poster presentation: 300 points

Your poster and your presentation of the poster will be evaluated by several biology faculty members. The scores they assign will be based on a grading rubric developed by the biology department specifically for poster presentation evaluation; you will be provided with that rubric in advance of the poster presentation session.

Class activities and assignments: 200 points

Class presentation: project update [50 points]

Class presentation: poster update [50 points]

Poster – 1st draft [50 points]

Abstract [20 points]

Attendance and participation in class [30 points]

Assignments are due as indicated in the course schedule. You will be penalized for late assignments. If you do not submit your final poster by 5:00 on November 17th you will be responsible for printing and paying for your own poster and bringing it to the poster session. In addition, failure to meet the indicated final poster deadline will decrease your letter grade for BIO 602 by one full letter grade.

Total 1000 points

Your final grade in the course will be based on the following scale:

Above 93%: A	87% - 90%: B+	77% - 80%: C+	67% - 70%: D+	below 60%: F
90% - 93%: A-	83% - 87%: B	73% - 77%: C	63% - 67%: D	
	80% - 83%: B-	70% - 73%: C-	60% - 63%: D-	

ETS MAJOR FIELD TEST IN BIOLOGY

During the final exam period, you will take the ETS (Educational Testing Service) standardized exam in biology. The test will be graded by ETS and your score will be provided to you in the spring of 2016. The ETS exam provides feedback on your understanding of a wide range of important concepts in biology and allows you to compare your performance with that of other students nationally. ETS scores can be helpful to include in your resume. Results of the ETS exam are also used by the Department of Biology for curriculum assessment. The ETS exam is mandatory for completion of BIO 602, but no course grade points are associated with the exam. If you do not take the ETS exam, you will receive a grade of "I" for BIO 602 and will not be able to complete the course in time to graduate in May, 2016.

COURSE POLICIES

Assignments: Most assignments will be turned in electronically. They must be uploaded to D2L. Your assignments may be checked for plagiarism via Turnitin.com or D2L. Unless the guidelines for a specific assignment specify otherwise, a 5% reduction in possible points will be applied for each day an assignment is late. Any assignment that is more than seven days late will not be accepted and no points will be earned.

Academic integrity: The issue of academic integrity is taken very seriously at Westminster. Students are expected to abide by the College Policy on Academic Integrity. The policy can be found in the College catalog, available online at <http://www.westminster.edu/academics/catalog.cfm>.

Academic integrity is particularly important when dealing with scientific writing. We encourage students to work together and discuss their assignments. But written assignments must be the original work of each student. Quotes, data, or ideas taken from another source must cite that source fully and correctly. Work that is not the student's own (*i.e.*, copied from an external source, a classmate, or class material) is considered to be plagiarized, and will receive a score of zero for the assignment. Plagiarism includes extensive quoting from another source, even if it is slightly modified and/or cited. More than one incident of plagiarism will result in a grade of "F" for the course.

In the case of your research project, if your question, ideas, experiments or data are not your own and have been previously published by someone else, or if you fabricate, falsify, or modify your data, you will earn an "F" for the course. These violations of integrity amount to scientific fraud.

BIO 602 (01) COURSE SCHEDULE (subject to revision)

Date	Day	Topic	Assignments
August 31	Monday	Introduction to Capstone	Upload research proposal by 5:00 p.m.
September 2	Wednesday	Independent research	
September 7	Monday	Independent research	
September 9	Wednesday	Independent research	
September 14	Monday	Independent research	
September 16	Wednesday	Independent research	
September 21	Monday	Independent research	
September 23	Wednesday	Poster design and construction	
September 28	Monday	Presentations: Project summary/work in progress	
September 30	Wednesday	Presentations: Project summary/work in progress	
October 5	Monday	Presentations: Project summary/work in progress	
October 7	Wednesday	Presentations: Project summary/work in progress	
October 12	Monday	Independent research	
October 14	Wednesday	Independent research	
October 16	Friday		Poster draft due by 5:00 p.m.

Date	Day	Topic	Assignments
October 19	Monday	Independent research	
October 21	Wednesday	Writing a scientific abstract	
October 26	Monday	Fall break	
October 28	Wednesday	Independent research	
October 30	Friday		Abstract due by 5:00 p.m.
November 2	Monday	Presentations: Poster	
November 4	Wednesday	Presentations: Poster	
November 9	Monday	Presentations: Poster	
November 11	Wednesday	Presentations: Poster	
November 16	Monday	Individual work	
November 17	Tuesday		Final poster due by 5:00 p.m.
November 18	Wednesday	Presenting scientific posters	
November 23	Monday	Individual work	
November 25	Wednesday	Thanksgiving break	
November 30	Monday	Individual work	
December 02	Wednesday	Individual work	
December 04	Friday	Capstone research symposium 2:00 – 4:00 p.m. Witherspoon Room	
December 07	Monday	Lab cleanup	
December 09	Wednesday	Lab cleanup	
December 14	Monday 11:30 a.m. – 2:00 p.m.	Final day: ETS Biology Exam	

Appendix C: Bio 602 Syllabus

Instructor: Dr. Kerri Cornell Duerr
Office: 313 Hoyt Science Center
Office Hours: Mon 10:30- 11:30 am, Wed 1:00-2:00 pm

TIME AND LOCATION:
Tuesday & Thursday 11:00 AM – 12:30 PM
Patterson Hall Computer Lab: 1st

Course Overview: Statistics is the science of collecting, classifying, summarizing, organizing, analyzing and interpreting numerical information. As such, you won't be learning new math, but new ways to apply math you already know. This course will emphasize the application of statistical ideas and methods to the design and interpretation of biological experiments and comparative data. **Statistical methods allow scientists and others to make intelligent decisions in the face of uncertainty.**

Student Outcomes: The student will be able to assess a situation involving data analysis, state the nature of the biological question and the null and alternative hypotheses proposed, decide on the correct statistical procedure to test the null hypothesis and the assumptions of the test used, calculate the statistic, assess its statistical significance, and interpret the data in light of the calculated result. Assessment of a student's performance will be done through the use of problem-oriented, in-class tests and successful completion of assigned homework problems. Students completing this course should:

Experimental design:

1. develop an understanding of the role of experimentation, hypothesis testing, and data analysis in biology;
2. demonstrate ability to design experiments and studies incorporating treatments, controls, replication, randomization, and blocking;
3. develop awareness of pitfalls in experimental design including lack of power, poor controls, confounded effects, and pseudoreplication;
4. demonstrate understanding of why research design must include statistical planning.

Analysis:

1. demonstrate knowledge of probability and probability distributions
2. develop ability to select appropriate methods of statistical analysis commonly used in biology, including parametric and nonparametric tests
3. demonstrate ability to assess the statistical and biological significance of their results in light of the calculated statistics
4. demonstrate proficiency in common statistical computer software to enter data, graph and analyze, test hypotheses, and interpret results
5. develop an ability to critique data analyses conducted by others and assess the validity of statistical analyses in the scientific literature

Presentation:

Dr. K. Cornell Duerr

BIO 206: Biostatistics Fall 2015

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1. demonstrate how scientific data are summarized graphically and in tables
2. demonstrate proficiency in common graphing computer programs to generate effective graphs
3. develop the ability to interpret and evaluate scientific graphs

Required Materials: You should ALWAYS bring BOTH of the following to class each day:

- (1) *The Analysis of Biological Data*, 2nd edition, by Michael Whitlock and Dolph Schluter. © 2015. Roberts and Company Publishers.
- (2) Calculator

Statistical Software: Excel and SPSS. You will use both programs in class to demonstrate statistical concepts and calculations, and you will be required to finish the homework assignments with these programs. You will find SPSS installed on PCs in computing labs on campus.

Course format:

Lecture and discussion: Lectures will generally follow the schedule that appears below. I expect you to attend class, pay attention, and participate actively in class by asking and answering questions, and making comments. You should ALWAYS bring your textbook and a calculator to class.

Reading: The textbook provides a nice overview of experimental design and data analysis for biologists. Although we will only cover parts of chapters 1-17 in class, chapters 19-21 provide an excellent overview of some modern statistical techniques. As such, this text should serve as a nice "shelf reference" for you throughout your career. You are responsible for reading the material before class so that lecture time can be spent covering essential information that warrants closer study and repetition.

Problem solving assignments: After conceptual material is presented in lecture, you will engage in problem-solving sessions involving analysis and presentation of data. Some of these will be in-class exercises and some of them will be assigned for homework.

Evaluation and Grading: Students are evaluated on homework assignments, quizzes, examinations, and on participation in class. Grades will be updated on My Westminster periodically throughout the semester. However, you are responsible for keeping track of your own grade! Grade point distribution will be as follows:

Evaluation	Points
Exams (n=3; 100 pts. each)	300
Final comprehensive exam	200
Quizzes (n=5; ~ 25 pts each)	125
Assignments (n=10; ~20 pts each)	200
Participation	25
Total Points	850

A	>93%
A-	90-92.9%
B+	87-89.9%
B	83-86.9%
B-	80-82.9%
C+	77-79.9%
C	73-76.9%
C-	70-72.9%
D+	67-69.9%
D	63-66.9%
D-	60-62.9%
F	<60%

Graded Assignments:

- (1) **Exams:** Students are evaluated by two lecture exams and one cumulative final exam. The exams will include a mixture of multiple choice, true or false, short-answer or essay questions, as well as practical exercises in which you will demonstrate your ability to analyze, graph, and interpret data.
- (2) **Quizzes.** Quizzes are designed to help you evaluate your reading comprehension skills, understanding of material that we have recently covered, and your ability to use techniques that have been introduced. Quizzes will occur about once a week, or every two weeks. Most quizzes will be announced, but some may be unannounced. Material on quizzes may include any topics that we have covered in class, or on reading assignments.
- (3) **Assignments.** Each lecture topic will be accompanied by an assignment designed to give you experience in gathering, analyzing, presenting, and/or interpreting data. Many of these assignments will help you learn to apply ideas from lecture and use statistical software to graph and perform statistical tests.
- (4) **Participation:** I expect students to take active roles in their education. This means arriving to class on time and prepared, asking questions, and making comments. Students who are sleeping, texting, emailing, or “surfing” during class will be asked to leave the computer lab and will receive a zero for the day.

COURSE POLICIES:

Attendance: Attendance is expected. Multiple absences will result in a loss of participation points. Attendance is also evaluated indirectly through your grades on exams, quizzes, and assignments. ***Students are required to attend all in-class quizzes and exams.***

Assignment policy: Assignments are due ***at the time and date, and in the manner specified in the assignment.*** A 10% per-day penalty will be applied to all late assignments. Homework assignments that are more than 2 days late will not be accepted!

Academic Standards and Integrity: No form of academic dishonesty will be tolerated. Students enrolled in *BIO206* are expected to abide to the “Academic Integrity Undergraduate Pledge”. The definitions and penalties for violations of academic integrity apply to this course (see *Westminster College Undergraduate Catalog*). No form of academic dishonesty will be tolerated; practice of plagiarism or any other form of academic dishonesty will result in a grade of zero for the assignment and formal notification of the offense to the Dean of the College. Repeat violations of the integrity policy will result in a grade of F for the course and potentially, suspension and expulsion from the College.

I encourage you to work together and discuss your assignments with other students, **but all material you turn in must be your own work and written in your own words.** Don't just copy someone else's work and turn it in

Accessibility Statement: Westminster College actively strives for the full inclusion of all our students. Students with disabilities who require access solutions for environmental or curricular barriers should contact Faith Craig, Director of Disability Resources, located in 209 Thompson-Clark Hall. phone: 724-946-7192 e-mail: craigf@westminster.edu.